SEERC CIGRE HISTORY

Early electrification and empowerment of region where current electricity was born

2020



Cigre National Committees: Austria, Bosnia and Herzegovina, Czech Republic, Slovakia, Croatia, Georgia, Greece, Italy, Israel, Kosovo, North Macedonia, Montenegro, Romania, Serbia, Slovenia, Turkey, Ukraine.

SEERC CIGRE HISTORY

Early electrification and empowerment of region where current electricity was born

SEERC CIGRE HISTORY

Early electrification and empowerment of region where current electricity was born

Editor:
Kresimir Bakic

June 2020

Copyright © 2020 by Slovenian Association of Electric Power Engineers CIGRE&CIRED

Published by Slovenian Association of Electric Power Engineers CIGRE&-CIRED, Tehnološki park 20, 1000 Ljubljana, Slovenia

Editor: Kresimir Bakic

Authors: Kresimir Bakic, Massimo Pompili, Klemens Reich, Kerstin Weindl, Herbert Lugschitz, Sabina Dacic-Lepara, Zijad Bajramovic, Zdenek Muller, Goran Slipac, Giorgi Amuzashvili, Giorgi Arziani, Archil Kokhtashvili, Teona Elizarashvili, Markos Champakis, Georgios Georgantzis, Michael Papadopoulos, Massimo Rebolini, Marcel Ellenbogen, Alex Levinzon, Pranvera Dobruna Kryeziu, Aleksandra Krkoleva, Predrag Mijajlovic, Ciprian Diaconu, Ioan Hategan, Constantin Moldoveanu, Mihai Marcolt, Nebojsa Petrovic, Kazim Senocak, Hayriye Gurbuz, Yuriy Bondarenko, Prystupchuk Olena, Bondarenko Yaroslav, Trukhachova Anastasiia.

Book Design: Medium Žirovnica, Slovenia
Print: Medium Žirovnica, Slovenia
Number of copies: 800

Ljubljana, Slovenia, 2020

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

621.31(4-12)(091)

SEERC CIGRE history : early electrification and empowerment of region where current electricity was born / editor Kresimir Bakic ; [authors Kresimir Bakic .. et al.]. - Ljubljana : Slovenian Association of Electric Power Engineers CIGRE&CIRED, 2020

ISBN 978-961-6265-36-2
1. Bakič, Krešimir
COBISS.SI-ID 38466563

Authors of book by chapter

1. Introduction – The first 100 years of cigre ▸ Kresimir Bakic

2. Cigre global regions ▸ Kresimir Bakic

3. History of SEERC ▸ Kresimir Bakic

4. Results from questionnaire ▸ Massimo Pompili

5. NC Cigre Austria ▸ Klemens Reich, Kerstin Weindl, Herbert Lugschitz

6.NC Cigre Bosna-Herzegovina ▸ Sabina Dacic-Lepara, Zijad Bajramovic

7. NC Cigre Czech & Slovak ▸ Zdenek Muller

8. NC Cigre Croatia ▸ Goran Slipac

9. NC Cigre Georgia ▸ Giorgi Amuzashvili, Giorgi Arziani, Archil Kokhtashvili, Teona Elizarashvili

10. NC Cigre Greece ▸ Markos Champakis, Georgios Georgantzis, Michael Papadopoulos

11. NC Cigre Italy ▸ Massimo Rebolini

12. NC Cigre Israel ▸ Marcel Ellenbogen, Alex Levinzon

13. NC Cigre Kosovo ▸ Pranvera Dobruna Kryeziu

14. NC Cigre North Macedonia ▸ Aleksandra Krkoleva

15. NC Cigre Montenegro ▸ Predrag Mijajlovic

16. NC Cigre Romania ▸ Ciprian Diaconu, Ioan Hategan, Constantin Moldoveanu, Mihai Marcolt

17. NC Cigre Serbia ▸ Nebojsa Petrovic

18. NC Cigre Slovenia ▸ Kresimir Bakic

19. NC Cigre Turkey ▸ Kazim Senocak, Hayriye Gurbuz

20. NC Cigre Ukraine ▸ Yuriy Bondarenko, Prystupchuk Olena, Bondarenko Yaroslav, Trukhachova Anastasiia

QUOTE OF CIGRE SPIRIT

"Cigrians are seekers after fundamental truth, who are happy to exchange information with their fellow members in those areas of specialized technology which are common interest. Each man in effect, represent himself. His country of origin, for all practical purpose is interesting but not significant."

Andrew R. Cooper, president of CIGRE (1966–1972)
In Electra Special, 1972 – ***CIGRE Past and Future***

Table of contents

FOREWORD xiii

OPENING REMARKS xvii

REVIEWERS NOTE xviii

1. INTRODUCTION – The first 100 years of CIGRE 1
1.1 Beginning of electricity and knowledge dissemination before CIGRE 1
1.2 Short history of CIGRE 13
1.3 History of CIGRE Leaders 23
1.4 CIGRE present organizational flow chart 26

2. CIGRE GLOBAL REGIONS 27
2.1 AORC – Asia and Oceania Regional Council of CIGRE 28
2.2 RIAC – Regional Ibero-American of CIGRE 29
2.3 NRCC – Nordic Regional Council of CIGRE 30
2.4 SEERC – South-East European Region of CIGRE 31

3. HISTORY OF SEERC 2005–2020 33
3.1 The early years 33
3.2 Founding conference of SEERC CIGRE Region 34
3.3 SEERC Memorandum of Understanding 37
3.4 First meeting of SEERC Council in Rome 2014 40
3.5 Tracing the way to working program 43
3.6 Chronology of the SEERC events in period from 2015 to 2020 49
3.7 Unofficial SEERC meetings 89
3.8 Regional working groups meetings and Workshops 91
3.10 References for chapters 1, 2, 3 95

4. RESULTS FROM QUESTIONNAIRE 97
4.1 General on European Regional Cooperation 97
4.2 Questionnaire 100
4.3 Results of 2019 Questionnaire in CIGRE - SEERC member countries 102
4.4 References 110

5. NC CIGRE AUSTRIA 111
5.1 History of the electric power sector 111
5.2 History of the Austrian Cigre National Committee 130
5.4 References 134

6. NC CIGRE BOSNIA-HERZEGOVINA **137**
6.1 History of electric power sector 137
6.2 History of CIGRE in BH 148
6.3 Activities of BHK of CIGRE and achievements 152
6.4 Country electric power profile and RES vision 156
6.5 References 157

7. NC CIGRE CZECH & SLOVAK REPUBLICS **159**
7.1 History of the electric power sector 159
7.2 The electricity system of the Czech Republic - 2019 198
7.3 History of NC CIGRE Czech Republic and the Slovak Republic 207

8. NC CIGRE CROATIA **213**
8.1 History of the power system 213
8.2 History of CIGRE in Croatia 225
8.3 History of the Croatian National Committee of CIGRE 229
8.4 Activities and achievements of the Croatian National Committee CIGRE 231
8.5 CIGRE Awards 236
8.7 References 239

9. NC CIGRE GEORGIA **241**
9.1 History of the electric power sector of Georgia 241
9.2 CIGRE National Committee of Georgia 255
9.3 Current Situation in Georgian power system 257
9.4 References 261

10. NC CIGRE GREECE **263**
10.1 History of electric power sector 263
10.2 History of CIGRE in Greece 272
10.3 Activities of NC CIGRE Greece 277
10.4 Country electric power profile for 2019 284
10.5 References 285

11. NC CIGRE ITALY **287**
11.1 History of the Electric Power sector in Italy 287
11.2 History of Italian contribution in development of CIGRE 292
11.3 Achievements of the Italian NC CIGRE 341
12.4 References 343

12. NC CIGRE ISRAEL **345**
12.1 History of the Electric Power System in the Land of Israel 345
12.2 CIGRE in Israel 353
12.3 Israeli electricity systems characteristics today 356
12.4 References 356

13. NC KOSOVO **357**
13.1 History of electric power sector 357
13.2 History of CIGRE in Kosovo 362
13.3 Activities and achievements of NC CIGRE Kosovo 363
13.4 Country electric power profile / RES vision 364
13.5 References 365

14. NC CIGRE N. MACEDONIA **367**
14.1 History of the electricity sector 367
14.2 History of CIGRE in North Macedonia 373
14.3 Past and present activities 376
14.4 Country power electric profile/ RES vision 379
14.5 References 381

15. NC CIGRE MONTENEGRO **383**
15.1 History of electric power sector 383
15.2 The Montenegrin NC of CIGRE 392
15.3 Country electric power profile / RES vision 395
15.4 References 396

16. NC CIGRE ROMANIA **397**
16.1 History of the Romanian Electric Power System 397
16.2 History of the Romanian National Committee of CIGRE 398
16.3 Activity and achievements of the Romanian NC CIGRE 401
16.5 References 408
16.4 Romanian Electric Power System 408

17. NC CIGRE SERBIA **409**
17.1 History of Electric Power sector 409
17.2 History of CIGRE 430
17.3 Activities and achievements of NC CIGRE in Serbia 438
17.4 Country electric power profile / RES vision 443
17.5 References 446

18. NC CIGRE SLOVENIA **447**
18.1 History of electric power sector 447
18.2 History of CIGRE 453
18.3 Activities and achievements of NC CIGRE in Slovenia 459
18.4 Country electric power profile / RES vision 466
18.5 References 467

19. NC CIGRE TURKEY **469**
19.1 History of Electric Power Sector 469
19.2 CIGRE Turkish National Committee 477
19.3 Electric Power Profile 481
19.4 References 483

20. NC CIGRE UKRAINE **485**
20.1 History of electric power sector 485
21.2 History of NC CIGRE 505
20.3 Activities and achievements of NC CIGRE 508
20.4 Country electric power profile / RES vision 511
20.5 References 514

FOREWORD

WORDS OF DR. ROB STEPHEN, PRESIDENT OF CIGRE



Rob Stephen, President of CIGRE (2016–2020)

CIGRE is an organization that provides solutions to members on any aspects of the power delivery system from the output of the generator to beyond the meter. It achieves this by forming working groups with international experts supplied by their companies to solve problems of mutual interest. The problems are identified and analyzed by Study Committees covering all aspects of power delivery. CIGRE has 16 such study committees with around 230 working groups active at any one time. There are over 3000 experts who are members of the working groups busy solving the problems for the benefit of the industry. CIGRE then produces technical brochures describing the solutions for all stakeholder to employ in their area.

Members of CIGRE come from over 90 countries. The Board of CIGRE, the Administrative Council, consists of heads of National committees representing different countries. There are 60 National committees (at time of writing). The National committees ensure that information from the Study Committees is disseminated to members in their country. They also arrange conferences and invite working groups and Study Committees to meet in their countries to expose the international experts to their local engineers.

In some cases, it was found beneficial to group a number of countries together either due to language or geographical area to form a Region. Within a Region a sub structure of CIGRE is formed and topics pertinent to the Region are discussed and resolved. Such a Region is the South East European Region of CIGRE or SEERC. It was formed in 2013 and consists of 17 countries in the Region which are geographically close.

This book covers the history of electricity within each country as well as the history of CIGRE and the activities of CIGRE in their country. It is important to have such a record to ensure future generations are aware of the progress made and continue to make in the setting up of the Region and the events benefitting members and the industry.

The importance of CIGRE in the changing power generation and delivery environment cannot be underestimated. In the era of competition and evolving technologies, technical information and solutions to problems are not readily available or published. CIGRE forms a critical role in enabling information sharing and problem solving across competitor and country lines. This benefits all stakeholders including the end customer who can be assured that the methods and technology implemented is of the highest standard. Engineers also have a platform in which to network and share ideas which otherwise would have been impossible to achieve.

With the 4th industrial revolution underway and new challenges being experienced daily by utilities and energy providers; it is almost impossible to envisage resolving problems faced today without CIGRE. I have often stated that at a Study Committee meeting with international experts present, there is not a problem that you may think of that has not already been solved or can be solved with the expertise in the room.

I would like to thank the organizers and authors of this book that has made it possible to reflect on the history of this important Region and provide a better understanding of the countries that participate in the SEERC Region.

28th February 2020

WORDS OF PROF. DR. KLAUS FRÖHLICH, PRESIDENT OF CIGRE (2012 – 2016) AND ONE OF THE FOUNDING FATHERS OF SEERC



Klaus Fröhlich, President of CIGRE (2012–2016)

When CIGRE was founded in Paris in November 1921 it was intended to be a conference for sharing knowledge and discussion of problems concerning the electric power system. Not too many countries were contributing. Probably nobody at this time would envision an organisation which in the future would spread all over the globe becoming the number one platform for elaboration, dissemination and share of expertise in the field. Nowadays, almost one hundred years later history tells us an extraordinary success story. CIGRE quickly developed into an organisation with the bi-annual conference in Paris and successive installation of

work bodies. Mission and basic set up of the organisation did not change during the almost 100 years of existence. However, what has changed significantly is the size in terms of contributing countries, membership numbers and the work volume created by around 250 international working groups. Today CIGRE has members in more than 90 countries and more than 60 National Committees spread all over the globe. CIGRE by definition being an unpolitical institution crosses all political barriers which fact enables the organisation to operate with global significance. This way CIGRE's contribution has been most instrumental for the development of the electrical power system as we know it today.

Normally CIGRE deals with topics on an international worldwide basis. However, in places it seemed beneficial to cluster National Committees having a common ground in terms of geographical situation, language and/or economical interest. Therefore, in accordance with the CIGRE Administrative Council the so-called Regional CIGRE organisations were established – Asia-Australia (AORC) in 2000, Northern Europe (NRCC) in 2001 and South America including Spain and Portugal (RIAC) in 2006. Finally, in 2013 the South-East European Region of CIGRE was added (SEERC). The foundation of the SEERC clearly reflects the needs of this area for intensified cooperation. At the constituent meeting of the SEERC in Montenegro in 2013 it was a pleasure for me to see how CIGRE can provide a neutral platform for engineers and scientists smoothing discrepancies in interest and political opinion of the various participants.

After foundation of the SEERC the participating National Committees started with amazing efforts and speed. They have convincingly demonstrated by numerous meetings and a number of successful conferences that regional problems are dealt with in a most fruitful way. These events have been providing not only technical/scientific gain, but they also enhance visibility for the benefit of CIGRE in the various countries. Being president of CIGRE at this time I offer my respect and compliments to SEERC's efficient performance. The "SEERC book" as presented here is a perfect opportunity to learn more about the region. Historical facts concerning the origins of electricity show that the region was a sort of a cradle for the electric power system. Information about the work of SEERC and their achievements provided as well. History and profile of the power system in the various participating countries provide information of common interest. The book is an expression of joint efforts of the SEERC National Committees. In view of CIGRE's one hundred anniversary next year it is a most welcomed contribution of the SEERC. Congratulations on this excellent work to the authors of this book.

26th June 2020

WORDS OF PHILIPPE ADAM, SECRETARY GENERAL OF CIGRE



Philippe Adam, Secretary General (Since 2014)

At the time this book is published, 44 CIGRE National Committees (72%) are members of one of the four CIGRE regions. CIGRE SEERC is the largest, with 17 National Committees and 18 countries.

These numbers show the great interest that National Committees have for this organization between the global and national levels.

CIGRE Regions are essential and instrumental to develop events and activities around the planet on behalf of the global association.

This is because it is much easier for a Region than for a National Committee to reach the critical mass to convene a large conference, in terms of scientific and technical support and expected attendance.

Among the about 100 events organized by CIGRE every year, if we exclude the Paris Session and two symposia which are supported logistically by the Central Office, the largest are organized by the Regions, in addition to the many other events organized by National Committees individually.

They allow to address subjects that may not be seen with the same interest from a global perspective, but which are very important at regional level.

In addition to convening conferences, Regions are free to create specific Working Groups provided that they inform the Technical Council of their proposals so that eventually a global response could be considered.

Regions are also the adequate solution to disseminate the findings and news from the Paris Session that cannot be attended by all CIGRE members, if we consider our statistics which show that less than 25% of CIGRE members register to the Session.

Created in 2013 SEERC is the most recent Region of CIGRE, and has the dynamism of its youth. Since its creation seven new members have joined its founding members, and the third biennial conference was ready to be held in June 2020 when the pandemic due to the SARS CoV2 led the organizing committee to postpone it to 2021.

The preparation of this book is another proof of that dynamism, and it is a great honor for me to have been invited to write a few words to celebrate its publication.

On behalf of our Association I am happy to congratulate all the contributors to this milestone book, and notably its editor my Slovenian friend Kresimir BAKIC who is so passionate and knowledgeable with the History in general, and in particular the history of electricity.

OPENING REMARKS



Kresimir Bakic

This book tells us the story of the history and activities in the life of electrical systems in the countries of Central, Southern and Eastern Europe, which represent one of the world's regions of CIGRE. Representatives of these countries are their national committees CIGRE, which are part of the history of the development of these electrical power systems. All these national electrical power systems are interconnected to each other and create part of the global interconnection that is the greatest engineering achievement of mankind in the twentieth century. Global electrical interconnection is a great machine without which modern life would almost be impossible, as Neil Armstrong, first man on the Moon, stated in his speech in February 2000. In the creation of this machine, CIGRE has played an important unifying role in the last century. After 2000, Association CIGRE has expanded so wide around the world that it has demonstrated the need to establish regions. Their purpose was to further expand expert knowledge through additional activities. Region SEERC is representing early history of electrification in each member country and present activities of National Committees as well future plans.

The story really started in 1800 with the discovery of an electric battery and thus current electricity (or galvanic electricity), by the outstanding genius of physics, Professor Alessandro Volta, at Pavia University in Northern Italy. Eighty years later the focus of electricity inventions was on multiphase AC systems as system which enables wide electrification with economical advantages, where we met two extraordinary inventors from SEERC region (Tesla, Ferraris) as well AC pioneer company Ganz. For those reasons experts from SEERC region are

responsible to participate as much as possible in creation of the future power system.

Why is history of electricity so important? Having knowledge of our history allows us to understand where we are coming from, which in turn allows us to understand our present. It not only reveals the past, but it also helps us create a better future. An understanding of the successes and failures of the past is important to make progress going forward. And today electric systems faces major challenges of future design to decarbonization of power system. For this reason we discuss near future changes with penetration of Renewable sources in the system. History of each system was prepared by experts coming exclusively from each SEERC member state. It is the value of this book.

CIGRE is a truly great technical organization, growing like family with selfless mutual support of each member and the desire to share knowledge and experiences. This is what young engineers need more than pure theoretical conferences. CIGRE is like post-academic education in electric power development and operation. Those exact words were used my old CIGRE friend Jack Casazza some thirty years ago, when we discussed the value of CIGRE.

The concept of the book was to present the life of the SEERC region by the third conference in June 2020 and the development of electrification by country that make up this region of CIGRE. Therefore, the historical boundary is defined in June 2020.

Kresimir Bakic
Editor & co-author

REVIEWERS NOTE



Georgios Georgantzis

We are in a position to hold in our hands a very attractive, colorful and interesting history book referring to

a. a brief and comprehensive history of CIGRE organization,
b. the synergies towards the creation, development and running of SEERC CIGRE and finally
c. the development milestones and the today's profile of the electric power systems in SEERC countries.

The creation of a regional working group defined the frame and facilitated the procedures for this project to be successfully completed, with coordination of the editor Kresimir Bakic.
It was a great honor and pleasure for me to read the book, as reviewer. The value of history is unquestionable and in this sense this book has its own priceless value. It consists of 20 chapters, written by 32 authors coming from 16 NC's, and presents valuable historical information and detailed descriptions of several past events. The enormous efforts of these NC's, to create, set in operation and successfully run SEERC organization are also described. Finally, I believe that this book will serve as a fundamental recourse to all those interested in both history of electric power systems and CIGRE evolution in SEERC countries.

Dr. Georgios Georgantzis
Reviewer and co-author
Former chairman of CIGRE Greece



Massimo Rebolini

This book allows us, reading the past of the National Committees adhering to SEERC, to have a vision for the future despite the pandemic that characterized 2020. This dramatic event has spurred us to work on the text with greater passion. SEERC will also have challenging goals to achieve in the new century: a greater integration between electricity grids that will allow a progressive decarbonisation of electrical systems and a greater environmental sustainability compatible with social sustainability.
As a reviewer, it was not only a pleasure but also instructive to read the contribution of SEERC countries have made to CIGRE since its origins.
This book will allow the young engineers to study how in the past, the sometimes sudden and dramatic problems, that were presented on electrical power systems, have been addressed and solved.
From reading the book the hope is to involve other countries in the future of SEERC to cover the entire Mediterranean basin.

Massimo Rebolini
Reviewer and co-author
Former chairman of CIGRE Italy

1. INTRODUCTION – The first 100 years of CIGRE

1.1 Beginning of electricity and knowledge dissemination before CIGRE

Mankind needed almost 200 years (17th and 18th century) from first hypotheses about new natural phenomenon, with name "electricity", coined from Greek name of amber (W. Gilbert, T. Browne), to a recognition of static electricity and invention of second form of electricity also called **current** (or galvanic) **electricity** (by A. Volta, in year 1800), which significantly accelerated and changed the world.

The first awareness of the importance of electricity for wider use in society began in the year 1831, after the ingenious discovery of the phenomenon of electro-magnetic induction by Michael Faraday. It was possible to produce current electricity using mechanically powered generators converting mechanical energy. Next year, Hyppolite Pixii used steel magnets to build the first generator exploiting the induction effect. As generators improved over the years, they were used to operate arc lights and other uses. The dynamo-electric principle, discovered almost simultaneously and independently by Werner Siemens, Charles Wheatstone, and Alfred Varley, giving a strong boost to the development of use of electricity. In 1860, Antonio Pacinotti, invented an improved form of direct-current electrical generator, which he described in a paper published in Il Nuovo Cimento of 1865. It used a ring armature around which was wrapped a coil of wire, to produce a smoother current, than that available from previous types of dynamo. He found that the device could also be used as an electric motor. Next year in 1866, Werner Siemens, after his company invented dynamo generator (DC) and believed that "self-excitement" or dynamo-electric principle would play a major role in generating electric energy in the future. He supposedly coined the word *"electro-technique"*, meaning the complete application of electricity with generating, distributing, and using electrical devices. In that early years of applicable electricity, all progress, and dissemination of technical news were presented at different exhibitions all over the Europe and world.

The only well-known institution with reputation of transactions was the Royal Society (UK) and after 1800 the Royal Institution, where M. Faraday was employed. This institution played a particularly important role in dissemination

of electricity knowledge in the 19th century. National Technical Societies dealing exclusively with electricity progress, began with active work in second part of the 19th century, i.e. well-known as the IEE (British Institute for Electrical Engineers), that was founded in 1871, as the Society of Telegraph Engineers, which changed its name in 1880 to the Society of Telegraph Engineers and Electricians and in 1889 changed name again to the Institution of Electrical Engineers (IEE) or similar society American Institute of Electrical Engineers (AIEE), which was established in 1884 and later merged with the Institute of Radio Engineers and in 1963 renamed to today well-known IEEE, etc. In those years have been established national societies for Electrical Engineering in many countries worldwide.

At the end of the nineteenth century, the knowledge of Electrotechnical novelties was transferred mainly at the World Fairs or special International Expositions of electricity. The first, so called International Exposition of Electricity took place in Paris, in 1881. This event was associated with International Congress organized by French Government, led by Minister of Posts and Telecommunications, Mr. Adolphe Cochery and ordered by the president Jules Grévy. In opening speech, he expressed the great interest to clarify the state of electrical science and its applications, and to draw together and compare the results of research. It was first ever comprehensive international gathering of electrical technologies to take place (called *"Congres International des Électriciens"*), discussing on topics of springing up electricity science /R.8/. Congress was highly attended, with more than 250 experts and the most advanced world's scientists from 27 countries, e.g. Werner Siemens, H. Helmholtz, G. R. Kirchhoff, Z. Gramme, Jablochoff, H. Fontaine, M. Deprez, Lord Kelvin, G. Ferraris, etc. World population at that time was 1.5 billion.

Marcel Deprez presented new principles of electrical circuit operation – parallel scheme, which was contrary to previous series operation due to needs of constant current for arc lights. New principle opened the door to commercial use of electricity with different customers. At congress scientists for the first time discussed many interesting subjects and had international discussions on electricity units. They recommended the ampere, volt and ohm as practical units for current, voltage and resistance, which were generally adopted by electrical engineers. It was clear that the International Exhibition and Congress in Paris in 1881 showed very advanced stage of study of the development of the DC machines.

It is very interesting, and not by chance that exactly 40 years later in Paris was CIGRE established, which continued international congress for supporting electricity technology development, standardization of new equipment for electrical systems and exchange of technical information on electric power systems in a spirit of cooperation, impartiality and service.

Next year in 1882, on September 4th, in New York, Pearl Street Power Station began working, the first commercial electric power plant, operating with six dynamos (600 kW) fired by coal, and serving 82 customers with about 400 light bulbs (DC – direct current). Thus, electricity became a business.
In the same year, on September 16th, in Munich, Second International Exposition of Electricity was organized, where they demonstrated the transmission of electric power with direct current (DC) on long-distance of 57 km, from Miesbach to Munich. The project was designed by French electrician Marcel Deprez and German pioneer of electricity Oscar von Müller, who in 1903 established, the largest technical museum in the world, located in Munich ("Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik"). The project used voltage level of 2 kV, with power transmitted 2.5 kW, with which an artificial waterfall ran. They used a simple iron telegraph wire, which failed a few days later. Efficiency of the transmission was extremely low and confirmed that DC transmission on longer distances is not economical.
However, in the same year 1882, a new idea was born to approach an operation of current electrical systems, using polyphase AC systems. Many historians of electrical technologies used to say, that the period from 1882 to 1892 was the most innovatory period in history, which enabled later the development of massive electricity use. First attempt of this approach belongs to famous inventor Nikola Tesla. After the rumors runs by generations of people coming from Nikola Tesla homeland (Smiljan, region of Lika, Croatia), there is also explanation of where and how Nikola Tesla got this wonderful idea of multiphase AC system. During Tesla's work in Budapest, in 1882, Tesla took a rest one afternoon in the Budim Fisherman's Bastion, watching Donau River bathing in the sun. The waves on water were flowing synchronously with sunshine glitters atop of each wave. Twenty-six years old Tesla suddenly got an idea about similarities of transmitting power of Donau water with power in electrical machines by electro-magnetic waves. After that, he was obsessed with the idea of multi-wave systems and the thought of making it. Later, he developed model in his mind. This story was passing by generations from people close to him. The fact is that many scientists drew their ideas from nature. During

Tesla's work for Edison in Paris, just before he moved to USA in 1884, he made a presentation in Strasbourg on the model of 2-phase synchronous generator and motor connected with 4 conductors. However, invention of polyphase systems was not simple and passed vivid history, which somebody called "first technological war" or "war of currents" between DC and polyphase AC.

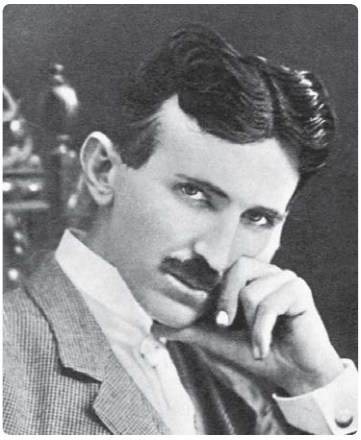


Fig. 1.1 Nikola Tesla (1856–1943)



Fig. 1.2 Prof. Galileo Ferraris (1847–1897)

In 1883, in Vienna, was the Third International Exposition of Electricity. On September 17th work started parallel to the exhibition of the scientific Commission having its purpose in taking of electrical measurements and conducting scientific research at the Exhibition. The elected president of the Commission was Professor Josef Stefan (Vienna) and as vice-presidents Professor Galileo Ferraris (Turin), Professor Hauffe (Vienna), Professor Kittler (Darmstadt), Sir William Siemens (London), etc. Commission was subdivided in eight sections according to the matters it concerned, i.e. scientific instruments, dynamo electric machines, electric lighting, transmission of power, telegraphy, telephony, etc. The public attendance on Universal Exhibition was exceptionally large, in average 15,000 visitors daily. The interest and impact of this event in Vienna to the whole region was enormous. Many countries in region started with first electric projects just after Vienna International Exposition.

Next important event in history of electricity was the Exposition of Electricity in 1884, in Turin (Italy). Based on the ideas of Galileo Ferraris, they made a single-phase AC transmission of 20 kW, 2000 V on 40 km distance, but without a motor. The efficiency of this long-distance transmission was 89%. The

results of this attempt shown that AC transmission of electric power is relatively simple and with high efficiency. The open question was the AC motor, which could have at least similar performances as the DC motor. This great challenge has been tackled by many researchers like *Tesla, Bradley, Haselwander, Ferraris, Dolivo-Dobrovolsky, Wenstrom, etc.* Due to historically very important inventions for later electrification of world following section try to describe little be more details about this amazing decade 1882 –1892.

Table 1.1a Chronology of the inventions of polyphase AC systems

Date	Researcher	Inventions, Patents
Feb 1882	Tesla	First idea and concept of polyphase system power transmission.
Mar 1884	Tesla	Model of 2-phase synchronous generator and motor presented in Strasbourg.
1885	Ferraris	Construction and tests with 2-phase induction motor.
6th Mar 1885	Blathy, Deri, Zipernowski	Granted patent, DRP 40414, via parallel connection of generators, transformers and consumers; **first use of the word transformer.** (Presentation at Budapest Exhibition).
8th May 1887	Bradley	First patent filed in USA (390439) of 2-phase synchronous machine with/without exciter.
12th Oct 1887	Haselwander	First public operation of 3-phase model generator with self-excitation (2,8kW, 32 Hz).
12th Oct 1887	Tesla	Applies US Patents 381 968 (el. mag. motor) & 382 280 (transmission of power).
30th Nov 1887	Tesla	Applies US Patent Office for 3 new patents: polyphase motors with short-circuited rotor.
23rd Dec 1887	Tesla	Applies US Patent Office for 2 new patents: application in distribution.
18th Mar 1888	Ferraris	Lecture in Turin on his tests with 2-phase induction motor.
1st May 1888	Tesla	Granted with all 7 patents applied in 1887.
16th May 1888	Tesla	Invited lecture at Columbus University, NYC: "A new system of AC motors and transformers", before the AIEE (American Institute of Electrical Engineers).

This Tesla's lecture was for him as somebody mentioned mistake as usually makes inventors. Just 2 weeks after patents were granted he presented all details of the patents, before he constructed these machines and made tests. Two months after the lecture (in July), comprehension reports about Tesla's inventions were published in German ETZ. After that, an avalanche of applied patents on polyphase systems happened all over the world.

Table 1.1b Chronology of the inventions of polyphase AC systems after Tesla's patents

Date	Researcher	Inventions, Patents
21st July 1888	Haselwander	Filed patents on polyphase motors.
Autumn 1888	Dobrowolski	Beginning of construction of the first inductive motor with rotating magnetic field.
5th Oct 1888	Bradly	Filed patent 404 465; 2-phase induction motor with caged armature.
20th Oct 1888	Bradly	Filed patent 409 450; 3-phase synchronous generator and motor.
Feb 1889	Dobrowolski	Testing AC 3-phase motor with rotating field.
8th Mar 1889	Dobrowolski	Filed patent (DRP 51083) for squirrel-cage induction motors.
9th Apr 1889	Wenström	Filed UK patent 5423 on rotating field systems
29th Aug 1889	Dobrowolski	Filed patent DRP56359 on arrangement of the cores and yoke of 3-phase transformers
5th Dec 1889	Dobrowolski	Filed UK patent 19554 on 3-phase connection, star/wye, delta for windings
8th Jan 1890	C.L. Brown	First patent on three-phase transformer is filed in Switzerland.
24th Jan 1891	C.L. Brown	HV tests in Oerlikon Fabrik for 20 kV & 30 kV transmission with bare conductors.
28th Aug 1891	Dobrowolski, Brown, Miller	First operation of 3-phase transmission system Lauffen-Frankfurt on distance 176 km, 15 kV; 42 Hz with generator 300 KM and at exhibition side was motor 100 KM; η= 75%.

Sometimes someone try to reveal historic truth, asking themselves who is the real inventor of inventions. In /R.11/, remarkably interesting statement on that subject was: "There is a different long journey between discovery and realization of invention. If an invention was created in the time when the elements for realization are not yet known, the authors of the realization and invention are both - inventor and creator of product. However, if the invention was created in the time when the elements of realization are known, the author of the invention is only an inventor". After 1884 many worldwide scientists were dealing with polyphase systems and motors. Many of them deserve to be remembered because the world would be different without these researchers and great geniuses.

Good analysis and chronology of invention of polyphase system and basic elements was investigated by German VDE (Verband Deutscher Elektrotechniker) in 1957–1959 /R.12, Hillebrand/.

The first published attempts with rotating magnetic fields were presented in 1883 by Marcel Deprez, but unfortunately this famous electrician stopped too

early with research on that topic. First attempts of the model for 2-phase inductive motor construction was made by G. Ferraris in 1885 /R 12,16/, but he unfortunately believed incorrectly that such motors can never exceed an efficiency of 50%, so he lost interest in continuing to develop this kind of machine. Anyhow, he offered his work freely to the service of mankind and for many other researchers it was a great challenge (i.e. Dolivo-Dobrovolski, as he stated in an interview). Table 1.1a and 1.1b present chronology of the inventions and patents of polyphase systems by different authors in period 1882–1892.

In conclusion of report /R.12/ author approved that Tesla was first who intensively dealt with electric power transmission using polyphase alternating current (AC) system and he was the first who described fundamentals of such transmission and the first who patented principle of polyphase induction motor. Report also states that in this period 1882–1892 the solution of the problem was almost in the air, so it is not surprising that similar paths of thought were formed in many minds, almost simultaneously with similar solutions. However, both initiators of invention, Tesla and Ferraris, were very generous and freely opened great ideas to all mankind, which caused dissemination of technical novelty and acceleration of development polyphase systems as well as competition. **Nikola Tesla** was not only a great scientist, but also a great humanist, namely a Human. Professor Milan Vidmar ("father" of the Slovenian electric power system) after met him in New York in 1936 was very happy to meet titan of the electrical profession, and described him with following words *"as an artist, a poet, who suffer when he creates, who is moving away from the world, who despises money, does not care for foolish titles and awards, who lives for his ideas and does not need comfort or luxury; he is exactly that".*
Unfortunately, **Professor Galileo Ferraris** died too early (February 7, 1897), only 50 years old, in time of his most powerful research capability. He left the first theoretical explanation of the operation of rotating magnetic fields to mankind *(Un metodo per la trattazione del vettori rotanti od alternativi ed una applicazione di esso motori elettrici a correnti alternate, Torino, March 1888).* For that reason, many historians defined him as a main researcher for rotating AC fields since he first constructed a two-phase motor and explained the invention in March 1888 during academic lecture in Turin.
In history of electricity there are well-known inventions, which were patented, but not publicized enough in professional community and for this reason remained unknown. For example, a Canadian invention *"Method and apparatus for controlling electric current"* from 1925 patented by Julius Edgar Lilienfeld, a

physicist born in the Austro-Hungarian Empire in Lemberg (known today as Lvov, Ukraine), who invented the actual version of primitive transistor (Lilienfeld proposed three-electrode structure, using copper-sulphide semiconductor material). More than 15 years later transistor was invented name coined and patented by three American inventors (Bardeen, Shockley, and Brattain). They received a Nobel Prize for that in 1956. From this example we can see the important role Ferraris and Tesla played, giving openly their own ideas and disseminated these ideas of polyphase electrical system to the world. This has hastened important discoveries.

On the other hand, it is true, that German engineer Dolivo-Dobrovolsky, was the first one, who constructed and applied the three-phase system, connected in a star or delta, which requires just three power lines instead of four, and thus is less expensive than a two-phase system. In August 1891, during International Exposition of Electricity in Frankfurt AC three-phase system was demonstrated for the first time in history as a long-distance transmission (175 km) between Lauffen and exhibition place in Frankfurt. This project was designed by Mikhail Dolivo-Dobrovolsky (1862–1919), Oskar von Miller (1855–1934) and Charles Lancelot Brown (1863–1924). Last one was from Machine Fabrik Oerlikon (MFO), Switzerland. After this project in 1891, Brown with his friend Walter Boveri, founded the company Brown-Boveri & Cie (BBC) in Baden, Switzerland, which became a global industry and took Swiss industry an enormous step forward. In 1978, BBC was merged with Swedish company ASEA to presently well-known company ABB. The project presented in Frankfurt involved **synchronous 3-phase generator** located in Lauffen (output power 230 kVA, speed 150 rpm, 42 Hz and voltage 95 V, with windings in a star connection), which was designed and constructed by C. Brown from MFO, with a step up transformer to 15 kV (prismatic magnetic core filled with oil). Overhead line contained with wooden telegraph poles with a span of 60 m, pin-type porcelain insulators filled with oil, copper conductors with diameter 4 mm. In the location at exhibition in Frankfurt, was a step-down transformer from 15 kV to 65 V and asynchronous 3-phase machine 100 HP, which operated a small waterfall. The overhead line and motor were designed and constructed by Dolivo-Dobrovolsky. International commission selected to evaluate project reported on transmission of power with following results:

- Efficiency of transmission was between 68.5% and 75.2%.
- Voltage of OHL was tested from 15 kV to 25 kV and maximum efficiency was 78.9%.

Thus, the first 3-phase transmission of electric power approved victory of polyphase AC against overcame a DC transmission. This demonstration of 3-phase

transmission project in 1891 announced the beginning of electrification of world.

Next polyphase project was made in 1895, and was proclaimed in the international press more than any other electricity project. It was a construction of Niagara Falls AC Power Plants with power transmission to Buffalo in USA, on the distance of 30 km. Westinghouse Company won the contract to build power plant and General Electric Company won the contract for power transmission to Buffalo. Power plant (called Adams plant) at Niagara Falls was designed as a 2-phase system with frequency 25 Hz. In substation it was converted to a 3-phase transmission system of 11 kV directed to Buffalo. Transmission project started with operation one year later (1896). It is interesting that selecting commission leading by Lord Kelvin discussed of five different options for transmission of power from Niagara Falls to Buffalo. One of the options was transmission power using compressed air. Many historic files approved that success of the 3-phase transmission project in Germany in 1891, was one of the main reasons for decision of AC polyphase system for Adams power plant and transmission power to Buffalo. Great popularity of this project was probably due to an exceptionally large power plant of 37 MW (50000 HP) at that time.

Thus, at the beginning of 20th century it was clear that future of electrification will run on a three-phase system. Electric energy definitely obtained an important part in the further development of humankind. In the technological duel between the direct current and alternating current, the form of alternating polyphase current was winning, since it proved to be the most appropriate form for broad use and economically more efficient. All inventors and creators of a three-phase power system deserve a credit for world's electrification and enormous fast development of our civilization.

Beside exhibitions, electricity was disseminated also through books. In that time particularly the "Julius Springer Publishing House" was specialized in literature from the natural sciences and engineering. Springer's publishing activities promoted the rise of these disciplines, paving the way for the modern knowledge-based society. In 1880s, they took over several scientific journals that quickly became staples in the professional world, e.g. VDI (in 1882). In a known inventive decade from 1882–1892, they published many books explaining fundamentals of DC and AC electricity world.

Elements such as generators, transformers, conductors, insulators, and systemic questions on the performance of electrical current became the focus of attention of the newly formed profession.
In addition, faculties for electrical engineering began to emerge. First university in the world to set up a chair in electrical engineering was in Darmstadt (Germany) in 1882, and in the next year, they founded the first faculty of electrical engineering and introduced the world's first-degree course in electrical engineering. Thus, at the turn of the 19th to 20th century rose interest for commercialization of the newest energy type – electric energy. For this reason, needs for standardization become crucial.

In 1904, in St. Louis (USA), was an important International Electrical Exhibition with a first meeting of scientists with goal to establish an International Electrotechnical Commission (IEC). In 2006, two years later, IEC was founded to meet growing need to standardize the electricity machinery and emerging home devices across the world. First president of IEC was Lord Kelvin (William Thomson). Soon, in 1907–1908, domestic devices as electric vacuum cleaner, washing machine were invented. Same year, vertical suspension string insulator was invented in electricity transmission sector, which enabled construction of OHLs over 60 kV, as well as first ACSR conductors (1907).
Next very important innovation was Ludwig Roebel's generator bars, in 1912, reducing loses in copper stator windings of AC generators. Roebel's bars enabled construction of much larger generators. All these innovations decreased cost of electricity production and increased number of customers.

IEC started working in 1910 with technical committee (TC) 1 – *Terminology*, and before first CIGRE conference in 1921, with another 7 technical committees (TC 2 – *Rotating machinery*, TC 3 – *Information structures*, and graphical symbols, TC 4&5 – *Hydraulic and Steam turbines*, TC 6 – *Lamp sockets and caps*, TC 7 *Overhead electrical bare conductors*, and TC 8 – *System aspects for electrical energy supply*).
However, at beginning it was obvious, that further development and operation of growing electric systems and market of elements and services requires more international discussion on specific technical issues, harmonization of certain approaches, solutions for frequency issues, sharing experiences, research works, etc. All these issues led to emerging of new international electro-technical conference.

Who invented the transmission of electrical power?

Frenchman Hippolyte Fontaine (1833–1910) was famous pioneer of electricity. He used to work with Gramme Society (Zenobe Gramme was famous Belgian electricity inventor). Dynamo invented by Z. Gramme in 1871, has been improved Siemens's dynamo from 1866 and the first in the world to provide a higher voltage and more stable direct current. At the World's Fair of 1873 in Vienna, H. Fontaine wanted to show visitors how a water pump could operate powered by an electromagnetic machine using DC electricity produced by new invented Dynamo. In the beginning water pump did not work properly. He found out that resistivity of link had to be increase. From neighboring exhibitors than he borrowed missing copper wire (it was approx. 1000 m), connected dynamo with DC motor nearby to the water pump. And finally, the pump was working properly. "After this experiment", said H. Fontaine, "I got an idea how mechanical power could be transmitted to distance by electricity". He wrote an article about it in a French newspaper. Fontaine's idea was first used by the French sugar factory-owners Felix and Chretien in 1878, at its factory in Sermaises. Since the processing of sugar beet is seasonal work and except for one month in the rest of the year their steam machines usually stay unproductive. So, they decided to use its steam engines for useful work, for transfer of electrical power from factory halls to plowing fields. At a steam machine they installed dynamo to produce DC electricity and used flexible cable at a distance of 800 m (from the factory to the ground fields) to transmit power to the DC motor, which was specially developed for the plow plowing. This was the transmission of electrical power into the electric plowing in France, in 1878. That example found many imitators in France and elsewhere, in particular because of the economic efficiency. Fontaine also played important role at the First World Electrotechnical Congress and Exhibition in Paris in 1881, and this story was discussed at the second session for public on October 4, 1881 (see Reference 8, page 371).

As a pioneer of electrical science, France awarded Hippolyte Fontaine the Legion of Honor, a high recognition.

Summary of milestones of growing electric power system before CIGRE was established:

- **1800,** Alessandro Volta was credited as the inventor of the electric battery, first source of **current (galvanic) electricity.** Today, we can say that this invention completely changed mankind.
- **1831,** Michael Faraday, invented the principles of **electromagnetic induction,** enabling many applications in electricity such as transformers, electric motors, and generators.
- **1865,** James Clerk Maxwell publication *"A Dynamical Theory of the Electromagnetic Field"*, which summarized knowledge of electromagnetism with 20 fundamental equations. Around 1882, Oliver Heaviside uses vector calculus and reduces it to 4 equations with 4 variables. Those equations fully **describe the theory of electrical engineering.**

- **1866,** Werner Siemens develops the dynamo-electric machine based on the double-T armature. This invention makes the current electricity useful and the story begins. Siemens coined a new word "electro-technique". Later Zenobe Gramme (1871) and Friedrich von Hefner-Alteneck (1873) improved a dynamo machine to produce a smooth DC voltage. In 1879 incandescent light bulb (Edison, Swan) was invented and opened a new application for wide use of electricity.
- **1881,** First International Electrotechnical Congress and Exhibition in Paris has made a big progress in electricity thinking, in electrical circuit principles and experts agreed on the first units, etc.
- **1882,** Beginning of commercialization of electricity (Edison's Plant "Pearl Street" in New York).
- **1882–1892,** Historical decade of innovations. **Nikola Tesla, Galileo Ferraris, Charles Bradley, Fredrich August Haselwander, Michael Dolivo-Dobrovolsky, Charles L. Brown** created polyphase AC system, which widely opened door to global electrification.
- **1891,** First demonstration of long-distance 3-phase electric system between Lauffen and Frankfurt in Germany.
- **1900–1920,** plenty of innovations in insulation, suspension insulators (1907), ACSR conductors (1907), electrical generators (bar windings by Ludwig Roebel, 1912), beginning of standardization (terminology, rotating machinery, graphical symbols, overhead electrical conductors, etc.), needs for international collaboration of technology development open the door for a permanent international conference for sharing knowledge of power system expertise.
- **In 1921 CIGRE in Paris, France was born.**

1.2 Short history of CIGRE

The IEC was responsible for the standardisation of equipment as an International Electrotechnical Committee for Standards, as well as the nomenclature of electrical quantities and units and the definitions of terms. Its work required the research support of international experts. Conferences were possible solution. With the help of another organisation, *Union des Syndicats de l'Électricité* (USE) from Paris, which had offered its staff and facilities, the idea of establishing an international conference was close to its realisation. The USE represented French experts from electrical profession. Thus, in the year 1921, the international organisation of CIGRE was founded as the result of the needs for an international cooperation of experts, who would solve common problems in creation of growing interconnected electrical system.

First acronym CIGRÉ stood from French *"Conférence Internationale des Grands Réseaux Électriques"*, while after the year 2000 changed to *"Conseil International des Grands Réseaux Électriques"* and after 2016, CIGRE means just a brand of global organization dealing with a whole electricity sector.

Europe was quite demolished after the First World War and needed fast renovation. Additionally, in the year 1920, severe drought had affected Europe. Great investments had to be made into the new infrastructure were linked with the beginnings of electrification. New views on connecting the small isolated electrical systems of that time and mutual support of hydro and thermo-systems, between Switzerland, France and Italy had emerged. Discussions on interconnected electrical networks began. This called for new equipment standards. At the same time, an international market for equipment was opening. This was an opportunity to convene an International Conference. On 21st March 1921 in Paris, the Secretary General of the French Association of the Electrical Profession (USE), Jean Tribot Laspiere, concluded an agreement with the President of the IEC, Dr. Cyprien O'Dillon Mailloux, and the Secretary General of the IEC, Mr. Charles Delacour Le Maistre in order to convene an International Conference for large electrical networks.

Dr. Cyprien O'Dillon Mailloux **(1860–1932) was the IEC president in between 1919–1923, and the director of the secretariat on nomenclature. He was president of AIEE in the period 1913–1914. He had served as president for the American National Committee of the IEC during 1914–1924, as chairman of the advisors on nomenclature, as representative of the National Research Council on the division of foreign relations and honorary president.**

Charles Delacour Le Maistre **(1874–1953) was first Secretary General of IEC, from 1906 until 1953. He was awarded as Knight Commander of the Order of Vasa from UK and Chevalier of the Legion of Honour from France. His contribution to the IEC was as critical to the creation of the modern world as the work of the famous scientists or innovators and entrepreneurs. For more than forty years, he attended every meeting, managed its activities, and travelled the world as the ambassador of international standardization.**

Jean Tribot-Laspière **(21 June 1882–10 May 1963) was Secretary General of USE (Union des Syndicats de l'Electricité) and from 1921 until his death Vice-president and Delegate General of CIGRE.**

Upon recommendation by the IEC, the Conference was to address the issue of transmission with high voltage and have a scientifically, technical, and usable character. At that time, the highest voltage in the world was 120 kV, with some experiments on 220 kV. After a six-month period of preparations, the first Conference was convened and held in Paris **from 21st to 26th November 1921,** at the USE headquarters. As this was an important Conference for the IEC, several countries that were members of IEC participated. To the first conference 231 delegates from 12 countries had attended. The defeated countries of the First World War were not invited and not allowed to participate in the Conference, although Germany was highly developed in terms of electrical engineering that time. For this reason, some historians considered CIGRE to be the "baby" of the Entente, the winning alliance of the First World War. A Frenchman, René Legouez, was elected as the first President of CIGRE (he remained in this position up to the year 1928), who up to that time, was the President of the USE, while Mr. Mailloux, the President of the IEC, was elected as the Honorary President. Altogether, there were 64 reports submitted to the first Conference and were discussed in three sections. At the First Conference there was no discussion on permanence of this organisation.



Fig. 1.3 Delegates at the first CIGRE Conference in Paris, November 21, 1921

The establishment of CIGRE must be considered in the context of searching for new economic and technological directions on a wider international basis. The difference between CIGRE and the IEC was, and still is, in the fact that CIGRE presents individual opinions on a certain technical issue and not (as is the case with IEC) nationally agreed standpoints. This gives the participants at CIGRE the necessary freedom of thinking in professional debates and the results of discussions on certain issues an added value. Advantage of CIGRE is also cooperation of all sides dealing with electricity sector as Electricity Supply Industry experts, Academia and Researching side and experts from Manufacturing Industry as well.

The **2nd CIGRE Session was held in 1923** (26th November to 1st December) at the same place as the first conference. Three important decisions were accepted:

- That Conferences should be convened biannually,
- That National Committees for the collection of Reports would be established in each country (the first National Committees were British, Dutch, and Italian), and
- That a Study Committee for the study of the ***"Rational Use of Energy would be established".***

From the Study Committee for the Rational Use of Energy emerged an idea for the establishment of a wider international organisation of energy. In fact, as early as 1924, World Energy Conference emerged from this CIGRE Study Committee, known today as the *World Energy Council* – WEC.
Initially, it was called the *World Power Conference* and was founded in London in 1924. The convener was Mr. Daniel Nicol Dunlop, who was later announced to be the Founder. In the year 1968, at the Conference in Moscow, its name was changed into *World Energy Conference,* and later on in the year 1992, at the time of the Congress in Madrid, into its present name: *The World Energy Council* (WEC). In the thirties, this organisation had an important role in directing the development of global energetics.
Second CIGRE Session 375 delegates from 19 countries had attended. From SEERC region came delegates from Italy (48), Turkey (2), Czechoslovakia (6) and Hungary (1).

The **3rd CIGRE Session was in 1925,** held on a new location in Paris. New venue was at the Foundation Rothchild building. Number of participating countries increased to 27 with 530 delegates. Important decision was made to establish second Study Committee (SC) named *"Statistics Generation Transmission".* This

SC was functioning for a short time and was transferred into that time created UNIPEDE association, which merged to EURELECTRIC in December 1999.

UNIPEDE - Union internationale des producteurs et distributeurs d'énergie électrique, was International Union of Producers and Distributors of Electrical Energy, founded in 1925 in Paris. In 1999, this organization was merged with European Grouping of the Electricity Supply Industry (EURELECTRIC).

The **4th CIGRE Session was in 1927,** which was particularly important in the history of CIGRE, because it established several Study Committees, which became later the focus of activities.
SC1 – Isolating oils and insulating materials,
SC2 – HV Cables
SC3 – Interrupters (or later named Circuit breakers),
SC x – Improvement of the Power factor (Reactive power compensation), and
SC xx – Parallel Operation.
Last two SCs were without numbers.
From fourth Session 1927 until the ninth Session in 1939, CIGRE events were held in the Salle Hoche (Avenue Hoche). In 1928 second president of CIGRE was selected. It was Marcel Ulrich from France.

5th CIGRE Session in 1929 continued with the rising of the participants. In the following table 1.1, increasing number of countries and delegates are shown in the first 5 Sessions.

Table 1.1 Increasing attendance at first 5 CIGRE Sessions

	Year	Countries	Delegates	Delegates from SEERC area
1st	1921	12	231	n. a.
2nd	1923	19	375	57
3rd	1925	27	530	75
4th	1927	28	545	78
5th	1929	29	703	84

6th Session in 1931, was important due to the first registration of CIGRE as a non-governmental organization in accordance with the French law. The first *Statutes of CIGRE* was approved on 18th June 1931. It was published in an old Electra issue no. 3 in November 1931.

First Statute of CIGRE defined international association as permanent with a name *"Conférence Internationale des Grands Réseaux Électriques"* based on French law from 1st July 1901. The head office was in Paris, at address Marceau 54.
Following paragraph defined a field of activities at biannual conferences under the aegis of IEC. International cooperation between conferences was stated in Statutes as follows:

- Construction and operation of central power stations and substations,
- Design, construction, insulation, and operation of the OHLs,
- Operation, protection, and integration of power systems.

Important stipulation in the Statute was the following statement *"organization and support of friendly technical cooperation between associations, administrations, engineers, scientists, and manufacturers of all countries".* Cooperation with other international organizations was highlighted in the first Statute.
In Paragraph 11 the basis for creation of National Committees of CIGRE was stated, administrative role of communication between individual and collective members and central control bodies of CIGRE. It is safe to say, that main framework of CIGRE as independent organization was established in 1931.
CIGRE became autonomous, that the administrative organization of the conferences was no longer supported by the USE as was the case since 1921. In 1931, SC 6 for Overhead lines was also established.

In 1933 a Frenchman, E. Mercier, who was an exceptionally gifted engineer, a builder of numerous power facilities, an innovator and a leading protagonist within the World Energy Conference (WEC) and the World Trade Organisation (WTO), became the President of the Paris CIGRE. He provided the organisation with a new momentum in this crucial period. His Presidential mandate was the longest thus far, comprising of 15 years. He was also known for his renowned statement that CIGRE was the spirit of the development of electric power systems, which still is true today. His successors – Presidents of CIGRE, were always very esteemed and reputable experts in the world's energetics. This is still the case today.

Thus, CIGRE is not only a state of mind. It also represents a type of spirit, a spirit which has often been called the CIGRE spirit.

– E. Mercier, president of CIGRE (1933–1948)

Table 1.2 presents the growth of CIGRE after establishment of the independent organization in 1931 until 1939 when CIGRE stopped with activities due to World War II (in continuing WWII).

Table 1.2 Attendance from establishing organization until 1939

	Year	Countries	Delegates	Delegates from SEERC area
6th	1931	36	731	95
7th	1933	31	751	101
8th	1935	46	834	120
9th	1937	41	870	144
10th	1939	41	814	n. a.

The number of participants grew with time, from 231 to 870, while the number of participating countries grew from 12 to 46. In the year 1937 at the 9th Session, it was the highest number of delegates counting up to 870; from SEERC region area came 9 countries and today 17, with 144 delegates or 17%.

The 10th Session was held just 3 months before the beginning of WWII, which had a great impact on reduced number of delegates (see Table 1.2).
The CIGRE organisation has reinforced its position in the period up to 1939 as the leading technical organisation for the field of electrical supply industry (ESI) in the world.
The first three National Committees were established in 1923 (UK, NL, IT) and nine more NC's after establishing the independent organization: Belgium, France, Denmark, Japan, USA, Norway, Spain, Sweden, and Switzerland. In 1932, Germany NC CIGRE was established, which attended the Session for the first time in 1933. In 1935, German NC was included, but in 1939 excluded again, and in 1952 approved again. Today, German NC CIGRE is one of the most active committee with the largest number of honorary members.

After the Second World War, CIGRE organised the **11th Conference** in Paris already as early as June of 1946. It was the first technical organisation in the world that activated its membership after the Second World War. Europe was in ruins, so all levels of the profession had to be activated quickly to set up a new era of electrification. Despite huge problems with transport across Europe, 877 delegates from 30 countries attended the first post-war CIGRE Conference.

Next decade was marked with constantly increasing interest for participation at CIGRE Sessions.

12th Session in Paris in 1948 attended 1144 delegates from 40 countries – over 1000 delegates for the first time at CIGRE Sessions. That was the time, when for the first time in history, a 400 kV cable was presented and was later put into operation in Sweden (in 1952). Figure 1.4 presents the development of the OHL's voltages growth, much like interconnection networks. Nominal voltage 400 kV (380 kV) was designed as early as in the 1930's, as the basic voltage of the pan-European network, but realized later in 1950's.

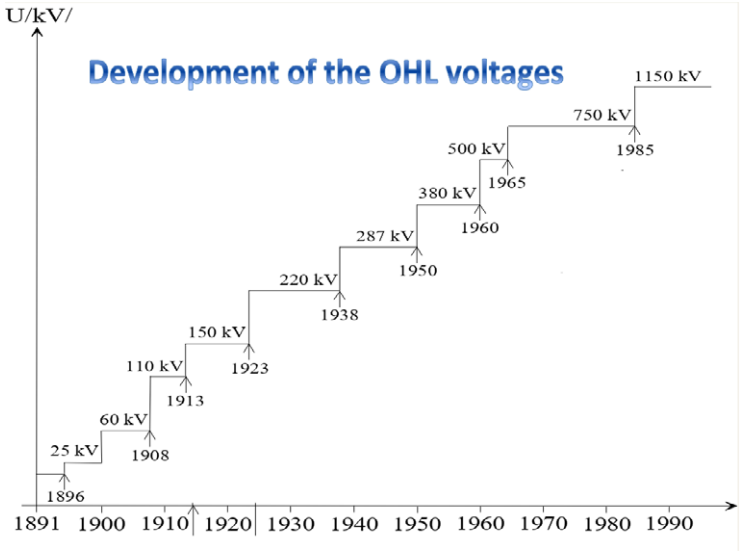


Fig. 1.4 Development of voltage levels from 15 kV to 1150 kV (1891–1985)

At the time, a number of new Study Committees were organised, namely SC7 – for poles, foundations and engineering of overhead power lines, SC9 – for AC Transmissions of very high voltages, SC10 – for DC Transmissions of very high voltages, SC11 – for telephone and radio interferences, and SC12 – for stability and regulation of frequency. From the names of the new Study Committees it is evident, that the electric power system began to expand quickly and that new problems began to accumulate, which required solutions. Due to the vast interest of experts, who wished to participate in the international Study Committees,

this was the first time that the number of regular members of Study Committees had to be limited to 12 members. Today's limit is 30 regular members.

The period 1946–1950 could be marked as the third milestone (see sub-chapter 1.3) in history of CIGRE.
Interestingly, CIGRE membership fee at that time depended on the production of electricity by a country member. Payment method was later changed.
Thus, over a decade after WWII, the number of participating countries jumped to 50 and the number of delegates exceeded 1500. (Table 1.3).

Table 1.3 Attendance from 1946 to 1954

	Year	Countries	Delegates
11th	1946	30	877
12th	1948	40	1144
13th	1950	42	1252
14th	1952	45	1351
15th	1954	50	1525

CIGRE also started publishing CIGRE journal called Electra. First version of Electra was issued in 1931 (15th June), several days before legendary 6th Session. This version was also used for SC minutes and other administrative information. During second milestone of CIGRE in 1967, when second reform of organization started, ELECTRA magazine also changed the design. President of CIGRE at that time was Andrew R. Cooper from UK, and Vice-President and Delegate General, Professor Francois Cahen. In 1967, the first issue of new Electra was published. During that period, magazine changed a lot, but always tried to stay closer to members.

Jean Tribot Laspiere was the Secretary General or so called Delegate General at that time, and "*spiritus agens*" of the organisation, ever since its foundation and up to the year 1963. Posthumously, he was proclaimed as the **Founder of the CIGRE.** Over 40 years, **Jean Tribot Laspiere** organised all CIGRE events from 1921 up to 1963.
Later, Professor Francois Cahen took on the role of Delegate General or Secretary General and the main CIGRE organizer, who at this critical time carried out extremely successful reforms for the organization. At the same time, this was the period of fastest growth in electricity systems in Europe, which in

some cases achieved even 10% of annual growth. Thus, from 1966, a new Study Committee structure began to operate, which lasted until 2002 (Table 1.4), or next 36 years.

Table 1.4 Structure of Study Committee in period 1966–2002

No. of SC	Name of SC
11	Rotating machines
12	Transformers*
13	Switching Equipment
14	HVDC Links and Power Electronic
15	Materials for Electrotechnology
21	HV Insulated cables
22	Overhead Lines
23	Substations
31	Transmission Systems**
32	System planning and operation**
33	Overvoltages and insulation coordination
34	Protection, automation and remote control devices
35	Communication
36	Interference

* SC Transformers as no. 12 was established in 1948 continuing up to 2002.
** SC 31 and SC 32 were changed in 1982 to three new SCs as follows: 37- Planning and Development of systems, 38- Analysis and technology of Systems, and 39- System operation and control

Participation of delegates at CIGRE biennial Sessions exceeded the number of 3000 in the year 2014. Increasing interest of CIGRE activity was probably the result of a new reform in years between 1998–2002 with a new framework of study committees and extension of membership in other parts of the world. Thus, the largest equivalent members of CIGRE came from new countries like Brazil, China, and India.

CIGRE membership comes from more than 100 countries, so it became the largest organization and source of power system expertise in the world.

In table 1.5 the newest scheme of the Study Committees beginning from 2002 is presented.

Table 1.5 Structure of Study Committees after 2002 with an upgrade in 2018

No. of SC	Name of SC
Group A – Equipment	
A1	Rotating electrical machines
A2	Power transformers and reactors
A3	Transmission and distribution equipment
Group B – Technologies	
B1	Insulated cables
B2	Overhead lines
B3	Substations and electrical installations
B4	DC systems and power electronics
B5	Protection and automation
Group C – Systems	
C1	Power system development and economics
C2	Power system operation and control
C3	Power system environmental performance
C4	Power system technical performance
C5	Electricity markets and regulation
C6	Active distribution systems and distributed energy resources
Group D – New Materials and IT	
D1	Materials and emerging test techniques
D2	Information systems and telecommunication

SEERC (South East European Region of CIGRE) is the world's fourth region of CIGRE and second European region. Motivation for establishing CIGRE region, was better cooperation between National Committees in Region, as well as increasing activities with entire CIGRE family and better understanding of many challenges facing the redesigning of the future system. At the time of beginning regional activities participation of the SEERC members in the CIGRE membership is evident in following table 1.6.

Table 1.6 Share of SEERC members in global membership of CIGRE

Year	World CIGRE eq. membership	Europe CIGRE eq. membership	SEERC* eq. membership	Share of SEERC in Europe %	Share of SEERC in World %	No. of countries in CIGRE
2012	12 421	5 688	1 247	22%	10%	88
2014	14 024	6 634	1 601	23%	11%	90
2016	14 665	6 769	1 681	24%	11,5%	96
2018	15 215	7 016	1 890	27%	12%	101

*SEERC region was established in 2013 and became active in 2014. It covers the area of 16 NC's all together. The largest three equivalent members in 2018 were Italy (323), Greece (232) and Austria (221).

"To know each other we must reach beyond the sphere of our sense perceptions."

– NIKOLA TESLA

1.3 History of CIGRE Leaders

In a century old history of CIGRE, the most important for sure were the governors: President and Secretary General. Table 1.7 presents the chronology of CIGRE Presidents since 1921 and table 1.8 presents chronology of Secretaries General as head of professional staff in Central office in Paris.

CIGRE's history could be defined by some critical periods as milestones, when crucial organizational changes and improvements were made. This book defines 6 such periods, as follows:

A. 1921, creation of conference and first conference, which gave the acronym CIGRE,
B. 1931, when CIGRE was established as independent International organization,
C. 1946–1963, after WW2, when period of intensive electrification and interconnection of power systems worldwide started,
D. 1963–1974, period after death of CIGRE's founder, Jean Tribot Laspiere
E. 1998–2002, re-organization of CIGRE and new SCs' structure for 21st century
F. 2014–2018, **opening CIGRE to the whole electric power sector** as a reaction to global changes of the energy sector in the direction of decarbonization and clean energy for all.

Table 1.7 Presidents of CIGRE since 1921

	Period	NAME	Years
1.	1921–1928	Rene Legouez (France)	7
2.	1928–1933	Marcel Ulrich (France)	5
3.	1933–1948	Ernest Mercier (France)	15
4.	1948–1957	M. Schmidt (Switzerland)	9
5.	1957 –1966	G. Silva (Italy)	9
6.	1966–1972	A. R. Cooper (United Kingdom)	6
7.	1972–1978	G. Jancke (Sweden)	6
8.	1978–1984	R. Guck (Germany)	6
9	1984–1990	W.S. White (United States)	6
10.	1990–1996	Jerzy Z. L. Lepecki (Brasil)	6
11.	1996–2000	Michel Chamia (Sweden)	4
12.	2000–2004	David G. Croft (Australia)	4
13.	2004–2008	Yves Filion (Canada)	4
14.	2008–2012	Andre Merlin (France)	4
15.	2012–2016	Klaus Fröhlich (Switzerland)	4
16.	2016–2020	Rob Stephen (South Africa)	4

Table 1.8 Vice Presidents and Delegate of Council (1921–1970). Re-named to Secretaries General of CIGRE from 1970

	Period	NAME	Years
1.	1921–1963	Jean Tribot Laspiere (France)	42
2.	1963–1970	François Cahen (France)	7
3.	1970–1976	M. Rene Pélissier (France)	6
4.	1976–1991	Gerard Leroy (France)	15
5.	1991–1995	Yves Porcheron (France)	4
6.	1995–1998	Yves Thomas (France)	3
7.	1998–2000	Marc Herouard (France)	2
8.	2000–2010	Jean Kowal (France)	10
9.	2010–2014	François Meslier (France)	4
10.	2014–	Philippe Adam (France)	

Many presidents will remain in our memory as great individuals with excellent professional skills for organization and personal responsibilities for global development of electric power sector. However, the key persons were also the

Heads of Central office in Paris, who were always keeping the wheels of organization running, so great gratitude must be expressed to them too. They were doing quality, sustained work and extraordinary progress in our organization, which is going to celebrate 100th anniversary of CIGRE operation.
It is well known that biannual CIGRE Sessions are in Paris from the beginning. Interestingly, table 1.9. shows the locations of CIGRE Sessions held in Paris in the last 99 years

Table 1.9 CIGRE Sessions in Paris since 1921

CIGRE Session	Years	location in Paris
1st, 2nd	1921, 1923	Association of USE (Union des Syndicats de l'Electricité)
3rd	1925	Foundation Rotchild Building, 11 Berryes
4th to 9th	1927, 1929, 1931, 1933, 1935, 1937	Salle Hoche 9 Avenue Hoche
10th	1939	Fondation Marcellin Berthelot 28, rue St. Dominique
After WW2 CIGRE Sessions in Paris are held in even years (from 1946)		
11th to 21st	1946, 1948, 1950, 1952, 1954, 1956, 1958, 1960, 1962, 1964, 1966	Fondation Marcellin Berthelot 28, rue St. Dominique
22nd to 27th	1968, 1970, 1972, 1974, 1976, 1978	UNESCO Building 7 Place de Fontenoy,
28th to 31st	1980, 1982, 1984, 1986	Grand Anfi-theatre, Assas University, Law Faculty
32nd to 47th	1988, 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018	Palais des Congrès de Paris Porte Maillot

"The past is never dead. It is not even past."

– WILLIAM FAULKNER, Nobel Prize 1949, literature

1.4 CIGRE present organizational flow chart

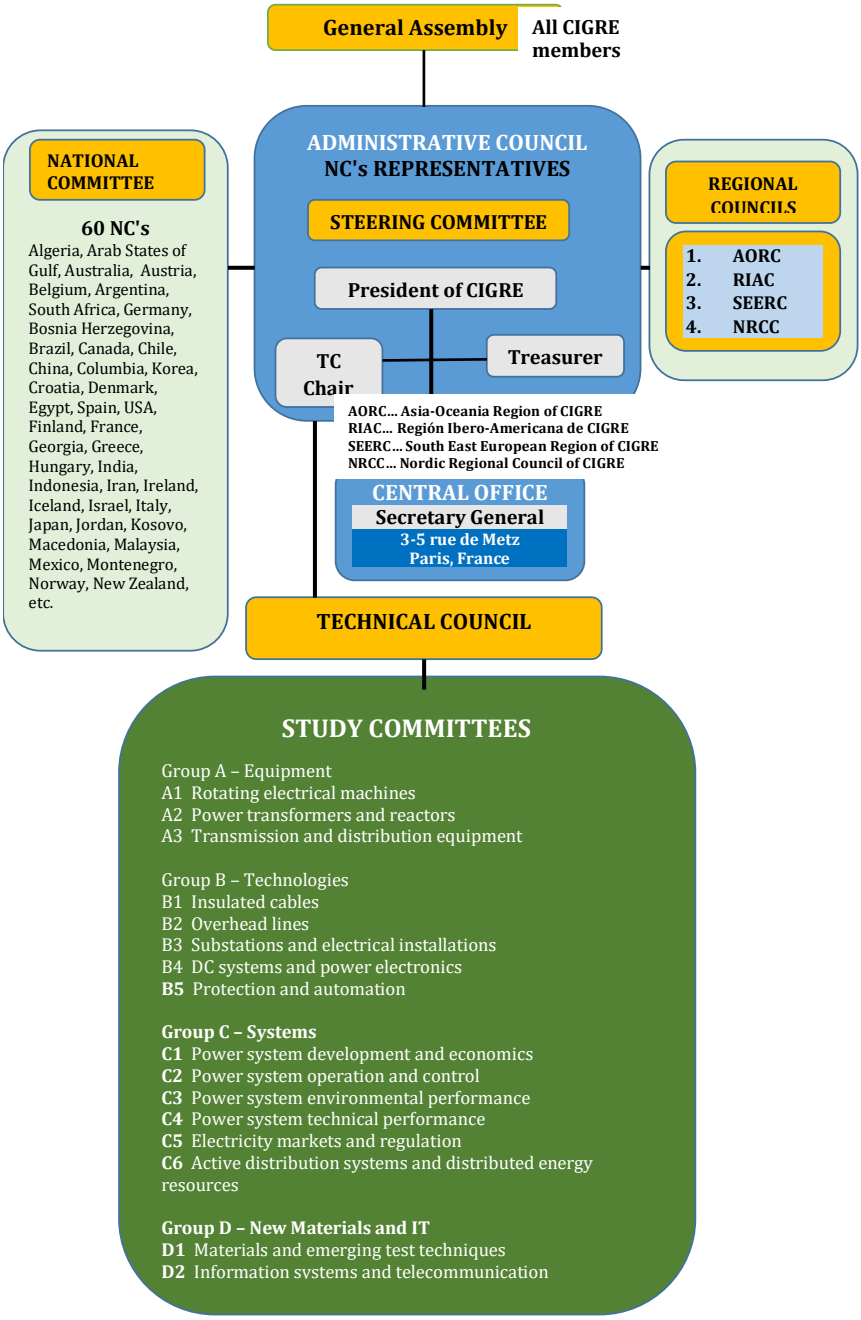


Fig. 1.5 Present organization flow chart of CIGRE

2. CIGRE GLOBAL REGIONS

Organization of the regions is a novelty of the global institution CIGRE, which started in the year 2000. However, before that, there have been a lot of discussions about this topic in the CIGRE Administrative council. In 1998, Ad Hoc group was set up for making analyses on modernization of the institutional arrangements, considering possibilities of regions, advantages, and disadvantages of that solution. Ad Hoc group recommended to National Committees, to form the regional CIGRE entities, among geographically related members. Soon afterwards, following regional CIGRE councils have been established:

- In 2000, **AORC – CIGRE** (Asia-Oceania Regional Council of CIGRE),
- In 2001, **NRCC – CIGRE** (Nordic Regional Council of CIGRE),
- In 2006, **RIAC – CIGRE** (Regional Ibero-American of CIGRE), and
- In 2013, **SEERC – CIGRE** (South-East European Region of CIGRE).

Later, regions are included in the new version of **CIGRE Statue – Article 17** with following wording:

REGIONS

National Committees may come together to form a Region, which is a set-up designed to enhance technical cooperation between countries and to promote and develop CIGRE. Geographical proximity is the primary motive for forming a Region, but other situations can be accommodated when they fall in with the basic objectives, i.e.:

a. *Contribute to the activities of the Study Committees, addressing and developing local issues;*
b. *Organize Regional Meetings or other local meetings (Colloquia…);*
c. *Coordinate with industry organizations.*
d. *Coordinate contributions to CIGRE main events (Session, Symposia);*
e. *Encourage and provide an incentive to increase CIGRE membership and create new National*

Committees, by incorporating countries without a National Committee in the working structure.

The existence of Regions has no impact on the governance structure of CIGRE - National Committees, Administrative Council, and Steering Committee - nor does it introduce any hierarchical notion in relations with National Committees or Study Committees.



Fig. 2.1 Location of CIGRE Regions. Spain and Portugal belong to RIAC.

2.1 AORC – Asia and Oceania Regional Council of CIGRE

Members of AORC are CIGRE NC's of **Australia, China, India, Indonesia, Japan, South Korea, Malaysia, New Zealand, and Thailand.** In 2014, AORC published the book "AORC-CIGRE History" Electricity empowering the Region, where three new CIGRE NC's were announced to join this region and they are as follows **Iran, Jordan and Gulf Cooperation Countries** (Saudi Arabia, Kuwait, United Arab Emirates, Qatar, Bahrain and Oman). Taiwan, Macau, and Hong Kong participate as observers. This exceptionally large CIGRE region is composed of 12 CIGRE National Committees and three observing members.

AORC – CIGRE was the first established region of CIGRE. Administrative Council members from Australia, China, India, Japan, and Malaysia agreed to form a "Region" called AORC-CIGRE, and that Japanese NC took over the role of preparing the initial blueprints of the constitution and working procedures. In May 2000, Constitutional meeting in Kuala Lumpur was held, where they determined draft of the statute, the action plan and selected JNC CIGRE to first take the lead (Mr. Tadao Amakasu as first Chairman and Mr. Hiroshi Suzuki as Secretary). The management mandate (chairman and secretary) lasts two years. Every year AORC organizes council meetings with representatives of all members' states, panels on different technical issues (i.e. panel B1, B2) and Task forces.

2.2 RIAC – Regional Ibero-American of CIGRE

Members of RIAC are CIGRE NC's of **Argentina, Brazil, Paraguay, Andes (Bolivia, Equator, and Peru), Columbia, Chile, Spain, Mexico, and Portugal.** All together 9 National Committees in 12 countries.
In Latin America CIGRE meetings of active experts in CIGRE started in 1986. Those meetings were called ERLAC (El Encuentro Regional Iberoamericano de CIGRE). In 2003, during regional meeting of ERLAC (Regional Meeting of Latin American CIGRE members) in Argentina, members (at that time Argentina, Brazil, Spain, Portugal, Mexico, Venezuela, and Paraguay) agreed to establish CIGRE Region and apply for official registration in CIGRE Paris. In August 2004, Administrative Council of CIGRE approved new region of RIAC (Regione Ibero America de CIGRE). Due to establishment of the third CIGRE region, Administrative Council of CIGRE submitted some changing of the Statute, which was approved on general Assembly in August 2006.
In May 2005, there was an inaugural meeting of RIAC in Paraguay. Basic arguments for initiative of RIAC were:

- work carried out jointly to promote CIGRE activities in Latin America,
- cultural identity,
- affinity for the two sister languages of the region (Portuguese and Spanish),
- knowledge of experts from these countries, and
- the possibility of developing a promising geographical area for CIGRE.

The objectives of the RIAC were:

- strengthening the ties of the Technological Union and disseminating information on electricity related issues between Latin American states,

- integrate all Latin American states into CIGRE network.

Result of these activities were the establishment of the Chilean NC CIGRE in 2003 and the Andean Committee in 2006 (Bolivia, Colombia, Ecuador, and Peru).

The leadership of RIAC (as available information from 2013) were:

- Chairman: Jorge Alberto Nizovoy (Argentina)
- Vice-chairman: Luis Imaz (Spain)
- Secretary: Oscar Ribeiro (Portugal)
- Vice-secretary: Helio Pereira (Paraguay)
- Chairman of Technical body: Ruy Menezes (Brazil).

RIAC organize Technical meetings in the scale of Paris Sessions. In addition, there are plenary Sessions and poster and exhibition on equipment and systems related to the electricity sector. The growth of the participants is continuous. The official languages are English, Portuguese, and Spanish.

2.3 NRCC – Nordic Regional Council of CIGRE

Members of NRCC are the CIGRE NC's of **Denmark, Estonia, Latvia, Lithuania, Finland, Island, Norway, and Sweden.**

Representatives of NRCC members organize at least one meeting every year, discussing CIGRE issues. Council leadership transfers on the duties after every annual meeting.

NRCC does not organize regional technical events like conference or symposia. Organization of workshops, colloquium or symposia is a subject of the National Committee organization.

The main tasks of the Nordic regional council of CIGRE are:

- Work to achieve added value to the individual National Committees in the Region,
- Building up CIGRE activities in an enlarged geographical area, and increase the interaction between experts from countries in the Region, and
- Stimulate activities at the regional level (Symposia, Colloquia, etc.) with a lower financial risk exposure and greater attendance, compared to an activity based solely on one nation.

2.4 SEERC – South-East European Region of CIGRE

Members of SEERC are the National CIGRE committees of **Austria, Bosnia/Herzegovina, Croatia, Czech/Slovak Republics, Georgia, Greece, Italy, Israel, Kosovo, North Macedonia, Montenegro, Romania, Serbia, Slovenia, Turkey, and Ukraine.** All together 17 countries, 16 NC CIGRE (Czech and Slovak Republic operate as one NC). Hungary is still a pending member, although it was active from the beginning of establishing SEERC region and belongs to this region.

Table 2.1 SEERC Leadership

Period	Chairman of SEERC Council	Chairman of Technical Advisory Committee	Technical Conference
2013–2016	Kresimir Bakic (Slovenia)	Maks Babuder (Slovenia)	June 7–8, 2016 Portoroz (Slovenia)
2016–2018	Yuriy Bondarenko (Ukraine)	Maks Babuder (Slovenia)	June 12–13, 2018 Kyiv (Ukraine)
2018–2020	Klemens Reich (Austria)	Wolfgang Hribernik (Austria)	November 29–December 2, 2021 Vienna (Austria)

More details about history of SEERC are in the Chapter 3 and 4.

3. HISTORY OF SEERC 2005–2020

3.1 The early years

First discussion about closer regional cooperation of National CIGRE Committees in the South-East Europe began during Administrative Council of CIGRE in 2005, in Bangalore (India). Amongst the representatives from Greece, Italy, Slovenia and others from central and southern Europe, an idea had developed to establish a new regional council, in accordance with CIGRE rules for better understanding of each other, better cooperation inside CIGRE family, particularly after hearing about the good results from already operating AORC CIGRE Region. After first informal discussion, quite a few years passed, until the first meeting happened. The president of the Slovenian NC CIGRE Kresimir Bakic invited the representatives of National Committees from Italy, Austria, Hungary, Croatia, Bosnia, Montenegro, Macedonia, Serbia, Greece, and Romania to Kranjska Gora, Alpine area of Slovenia, to meet and continue the discussion on possibilities of establishing CIGRE region in that part of Europe, on May 26, 2009. In the light of future development of electric power systems and CIGRE broad activities, he proposed a friendly discussion on common regional challenges in power sector and better cooperation between National Committees. Representatives from seven countries: Austria, Italy, Croatia, Serbia, Bosnia and Herzegovina, Hungary and Slovenia attended the meeting. Representatives from Greece, Romania, Montenegro, and Macedonia apologized and expressed interest to join this idea. The focus of the meeting was exchanging experiences and analysing mutual interests for better cooperation in accordance with CIGRE rules and spirit of CIGRE. Each NC presented its own position of interest. During the meeting, draft of Statute was also presented, like already existing ones in other CIGRE regions.



Fig. 3.1 Kick-of-meeting in Slovenia, Kranjska Gora, May 2009. From left side: Mrs. Mahmutćehaić (BA), Balázs Benkó (HU), Božidar Filipović-Grčić (HR), Rusmir Mahmutćehaić (BA), Karl Bauer (AT), Kresimir Bakic (SI), Enrico Maria Carlini (IT), Saša Dimić (RS), Desimir Bogičević (RS).

The result of the meeting was positive, but still with some doubts about organizing models and program framework as well as some political issues, which they tried to avoid following the CIGRE spirit. During the CIGRE Administrative Council in Seoul (Korea), a few representatives asked Kresimir Bakic (Slovenia) to organize second informal meeting during the CIGRE Session in Paris, in 2012.
Thus, in 2012 after Administrative Council meeting in Paris representatives of NCs continued the discussion about new CIGRE Region with one more country. Mr. Yuriy Bondarenko from NC CIGRE of Ukraine expressed interest to join this region and participate in all activities.
President of NC CIGRE Montenegro, professor Milutin Ostojic, invited representatives of all countries of interest to Montenegro next year to finalize all strives on founding new CIGRE Region. President of CIGRE, Professor Klaus Fröhlich strongly supported these activities of National Committees to find suitable model for intensive collaboration inside the mother organization of CIGRE. In 2012, there came to a final decision in a meeting in Paris, to invite all interested National Committees of CIGRE from Central, South, and Eastern Europe to the founding conference in May 2013, in Montenegro.

3.2 Founding conference of SEERC CIGRE Region

Communication between the members in 2012 continued through e-mails, trying to solve some non-technical issues. In March 2013, president of CIGRE, Klaus Fröhlich, wrote a letter to Kresimir Bakic, NCs group organizer, stressing attention to following aspects for creation and recognition of new CIGRE Region:

a. CIGRE Region needs to be officially recognized by Administrative Council (AM).
b. Statute of the Region should be strictly in coordination with CIGRE regulations.

Thus, the steps for beginning of the process were defined by:

- Mutual agreement as Memorandum of Understanding (MoU),
- Application for recognition to Administrative Council of CIGRE and set up working program.



Fig. 3.2 Founding Conference of SEERC CIGRE.
From left side: R. Taleski, A. Sekerinski (N. Macedonia), M. Rebolini (Italy), I. Hategan (Romania), Y. Bondarenko (Ukraine), M. Ostojic (Montenegro), K. Bakic (Slovenia), K. Fröhlich (President CIGRE, Paris), F. Meslier (Secretary General of CIGRE, Paris), D. Dotlic (Serbia), B. Filipovic-Grcic (Croatia), and R. Mahmutcehajic (Bosnia and Herzegovina).

The founding conference was organized by a kind invitation of the president of NC CIGRE Montenegro, Professor Milutin Ostojic, in Hotel Maestral, Resort & Casino, Przno, St. Stefan at Adriatic Coast. Special guests at the event were president of CIGRE, Professor Klaus Fröhlich and Secretary General of CIGRE, Francois Meslier, both in service at that time. Members of following National Committees (written in alphabetic order): **Bosnia & Herzegovina, Croatia, Italy, N. Macedonia, Montenegro, Romania, Serbia, Slovenia and Ukraine** signed Memorandum of Understanding as a basic document, expressing their wishes to cooperate in the new region of CIGRE. As the first Chairman of SEERC Region, president of the NC CIGRE Slovenia, Kresimir Bakic was unanimously elected.



Fig. 3.3 Photo of the participants at SEERC founding Conference in Montenegro after signed Memorandum of understanding

After the conference NC CIGRE Montenegro organized a tour to Montenegro's mountains, visiting Njegusi, a village, where Prince-Bishop of Montenegro, Petar Petrovic Njegos, famous poet was born and former royal capital called Cetinje. Road to the mountains from the sea level, passing the serpentine road with stunning views to the fjord of Boka Kotorska. This narrow road was designed and built in 1878, with 25 serpentines from then Austrian border over Kotor to royal city of Cetinje. As a unique architecture achievement in times of Austrian Empire, this road is known worldwide. It was an extremely exciting trip, with excellent hospitality of CIGRE colleagues from Montenegro.



Fig. 3.4 Stunning views from old Austrian road to a fjord Boka and town Kotor.

3.3 SEERC Memorandum of Understanding

SEERC Memorandum of Understanding, was approved by members, as the base document for establishing new CIGRE Region, contains the following:

1. Formation

Based on a common interest and former informal co-operation, the National Committees of CIGRE in Austria, Bosnia & Herzegovina, Croatia, Greece, Hungary, Italy, Macedonia, Montenegro, Romania, Serbia, Slovenia and Ukraine decided to set up a new Regional CIGRE council operating under the name SOUTH EAST EUROPEAN REGION of CIGRE (SEERC). The regional council was formed according to the statutes of CIGRE and will be endorsed as a region of CIGRE by the Administrative Council of CIGRE at the meeting in September 2013 in Kazan (Russia).

2. Objectives

The objectives of the SEERC are:

- *Work to achieve added value to the individual NC in the Region,*
- *Build up CIGRE activities in an enlarged geographical area and increase the interaction between experts from countries in the Region,*
- *Promote activities (Symposia, Colloquia, etc.) with a lower financial risk exposure and greater attendance, compared to an activity based solely on one national Committee,*
- *Promote and nurture new National committees in the Region,*
- *Encourage new regional activities in correlation with new energy policy and large regional energy projects.*

3. Methods

The SEERC achieves its objectives by appropriate methods and actions, which are in accordance with the policies of CIGRE.

The methods and actions of the SEERC include, but are not limited to, the following:

- *A yearly regional meeting is held between the chairman of the National Committees and the members of the Administrative Council from these countries. Topics for such meetings are:*
  - *Information about activities within each country,*
  - *Co-operation in the Study Committee level,*
  - *Co-ordination of proposals for new SC members,*
  - *Discussion of nomination of CIGRE officers,*

- *Discussion of specific Regional issues,*
- *Discussion on action plan,*
- *Update of the statutes and rules governing the activities of SEERC when needs arises. Such updating requires that the members of SEERC unanimously agree on these changes.*

- *The location of the meeting rotates among the member countries. Also, it is possible to organize meetings before or after CIGRE Administrative Committee annual meetings*

4. Member of the Region

The founding members of SEERC are NC's of ***Bosnia & Herzegovina, Croatia, Italy, Macedonia, Montenegro, Romania, Serbia, Slovenia, and Ukraine.*** *These participants will promote CIGRE membership to the countries which doesn't have national committee at the present time. A new country in the region can be approved as full member of SEERC at the annual meeting of this organization if the country in question has a National Committee fulfilling the requirements of CIGRE.*
Each member carries one vote in the case of making decisions by voting.

5. Application

Application for participation should be sent to the chairman of SEERC as an attachment or with a reference to document the applicant's status as "Having a national Committee fulfilling the requirements of CIGRE". According to SEERC's statutes this is a requirement for joining the region.

6. Chairmanship

The mandate period for the chairman of the SEERC is two years.
The chairmanship rotates among member countries in alphabetical order of NC or as agreed at the annual meetings. Starting chairmanship in 2013 will be Kresimir Bakic.

7. Secretary of SEERC

To assist the SEERC in practical matters like

- *Organising meetings of SEERC, issuing agenda and material prior to meetings, preparing minutes from meetings,*
- *Communicating with CIGRE's Central Office in administrative matters,*

SEERC has a secretary who will be appointed by the country which is to take over the chairmanship. This procedure is based on the idea that holding the secretariat in a period immediately before taking over the chairmanship will help to ensure continuity.

- *Web Site of SEERC*

8. Meetings

Apart from the yearly meeting, meetings can be called upon request of any member of the SEERC. Such a request should be sent to the chairman with motivation and suggested agenda. Meetings must be announced no later than one month before being held. Material for the meeting must be sent to participants no later than one week before the meeting. Decision on issues not on the agenda can only be made if all members are present and all accept that a decision can be made. Decisions are preferably reached by consensus. Failing that, decision can be made by simple majority. Changes of statutes require unanimity as specified in the statutes. Minutes from the meetings should normally reach participants no later than three weeks after a meeting. Minutes should be brief and mainly include decisions. It is left to participants to record details.

9. Information Exchange

To facilitate information exchange between members and to facilitate information provision for interested external parties, SEERC maintains its website. The website should allow members and candidate's members to keep up-to-date information about:
SEERC, Statutes, Membership, Key persons, for each member and aggregated, membership status, Study Committee chairman, Study Committee members, WG and TF members, activities of potential interest to SEERC members, proposed papers to the Paris CIGRE Sessions and other CIGRE events

10. Finances and Organization

The financial principle is that each National Committee should bear its own costs. Thus, no money will be allocated to the SEERC as such. The work within the region should be carried out without establishing any bureaucracy. The National Committees should continue their activities and maintain their status. All correspondence from CIGRE should go directly to the National Committees. The SEERC will keep the CIGRE Central Office informed of its activities and of changes in chairmanship as they occur.
Approved and signed by representatives of NC CIGRE by countries (9):
R. Mahmutćehaić (Bosnia and Herzegovina), B. Filipović-Grčić (Croatia), M. Rebolini (Italy), R. Taleski (Macedonia), M. Ostojić (Montenegro), I. Hategan (Romania), D. Dotlić (Serbia), K. Bakič (Slovenia) and Y. Bondarenko (Ukraine).

Following National Committees of CIGRE later signed Addendum to the Memorandum of Understanding:
Austria (2014), Greece (2014), Turkey (2014), Czech/Slovak Republic (2015), Kosovo (2017), Georgia (2018) and Israel (2019). NC CIGRE of Hungary participated

at the kick-off-meeting in 2009, but due to some organizational problems, they are still the associate member, without the signed basic MoU document.

New CIGRE Region was approved at Administrative Council meeting, in September 2013, in Russia with following words stated in the Minutes of Meeting:

Minutes of the 126th meeting held in Kazan, Russia, on 25th September 2013

SEERC: *'South East European Regional Council of CIGRE'*
- Kresimir Bakic (Agenda item 5: AC.13-05a) Refer to slides.

Klaus Fröhlich appreciated the initiative and thanked Kresimir for all his work.Administrative Council Members unanimously approved of this new Regional Council Klaus Fröhlich congratulated the first president of SEERC, Kresimir Bakic, and wished him luck.

CIGRE Administrative Council meeting in Kazan attended 8 members of SEERC Council as follows:
Y. Bondarenko (UA), C. Diaconu (RO), G. Dotlic (RS), J. Prochaska (CZ/SK), M. Rebolini (IT), T. Seric (HR), R. Mahmutcehajic (BA), and K. Bakic (SI). At that Administrative Council meeting, new National Committee of Turkey was approved, which also applied for membership in SEERC and became a regular member in 2014.

3.4 First meeting of SEERC Council in Rome 2014

First official meeting of SEERC Council was held on 27th January 2014 in Rome, organized by Professor Massimo Pompili from University of Rome (La Sapienza), and Massimo Rebolini, president of Italian NC CIGRE. On behalf of the University, the Dean of Engineering faculty, prof. Gentile welcomed SEERC members and has presented activities and importance of this Alma Mater. Massimo Rebolini shared a very interesting presentation, comparing SEERC Region and European CIGRE membership. He emphasized that in 2014, SEERC represented 21% of CIGRE European members, including Austria and Greece. In the meeting agenda was a point on exchanging technical information in between countries. Thus, manager of the TERNA Montenegro, Claudio Marchiori, presented the project of submarine cable under Adriatic Sea, between Italy and Montenegro in detail. Other participants from 9 countries presented news about projects and vision of cooperation in SEERC Region. The meeting concluded with actions to prepare two documents:

- **Position paper of SEERC** and
- **Questionnaire on mutual interests** for regional technical cooperation, conferences, and workshops.

Delegates formed an Ad Hoc group with following members: K. Bakic (SI), M. Pompili (IT), C. Marchiori (ME), D. Golubovic (RS), and Y. Bondarenko (UA) to prepare Position paper and the draft for first Questionnaire of SEERC.



Fig. 3.5 First SEERC Council meeting in Rome at University La Sapienza. Presidency of meeting: Massimo Pompili, Massimo Rebolini, and Kresimir Bakic (first Chairman of SEERC).



Fig. 3.6 Participants at the first SEERC Council meeting in Rome)

After the meeting NC CIGRE Italy and National Transmission system operator TERNA organized technical tour to substation **SAPEI2** – submarine link between Sardinia and Italy mainland, which presents the world record of the deepest sea cable at 1640 meters.



Fig. 3.7 Technical visit of substation SAPEI 2 linking Italy mainland and Sardinia with deepest submarine cable in the world.

ABOUT UNIVERSITY "LA SAPIENZA" – THE LARGEST UNIVERSITY IN EUROPE

University of Rome La Sapienza or Sapienza – Università di Roma (UNIROMA1) is a public university founded in 1303 and is one of the oldest and most renowned universities in Italy. With more than 120 thousand students it's also the largest European University. According to the international ratings University of Rome La Sapienza is among the best 5% worldwide. La Sapienza covers over 50 different teaching departments. Electric power engineering belongs to department for Electric Power Technology and Aeronautics.



ACKNOWLEDGMENT

Members of the SEERC council thank the University La Sapienza for the excellent organization of the first meeting in Rome, January 2014.

3.5 Tracing the way to working program

After the first meeting in Rome, representatives of SEERC members agreed to organize next unofficial meeting in Paris, during the 45th General Session and second official meeting of council in November, in Belgrade, after kind invitation by the Serbian NC CIGRE and his president Gojko Dotlic.

2nd SEERC Council meeting in Belgrade, November 6, 2014



Fig. 3.8 Second SEERC council meeting in Belgrade, November 6, 2014.

Belgrade meeting was in Crown Plaza hotel. It was a particularly important event for the beginning of active work. There were discussions on future organizational framework of SEERC on the agenda, approval of the new three National Committees (NC Austria, NC Greece and NC Turkey) and confirmation of two documents: **Position paper** on Regional Cooperation and **Questionnaire** with aim to collect proposals on future working program.

Position paper was approved as a document, which described the objectives and driving forces for cooperation in this SEERC region. It was decided to follow the guidelines of the Position paper. The document emphasized possible subjects of common interest between NCs of CIGRE region as follows:

- **Planning and development issues,** particularly large investments like undersea AC and DC cables across the Adriatic Sea as well as Mediterranean (linking Italy, Greece, Montenegro, Malta, Croatia, Albania, offshore wind parks, etc.),
- **Modernization of network,** implementation of intelligent technologies in

power systems, refurbishment of existing power system, asset management issues considering regional particularities,
- **South-eastern European electricity market,** designing specific regional issues,
- **Mutual supports and cooperation in the field of new technical standards,**
- **New European energy orientation** towards sustainable developments, regional issues, solar & wind technologies, smart grids, assessments of Environmental solutions (legal issues, EMF harmonization, aesthetic solutions, sustainable innovative technology solutions),
- **Dissemination of knowledge** from other advanced regions,
- **Innovative forums** in region using intellectual potentials in Central and SE Europe.

All these themes were later extended in accordance with the needs of NCs.

Analysis of Questionnaire was presented by Professor Massimo Pompili, member of Ad Hoc group, who set up the first meeting in Rome. Main aim of the document was surveying and collecting the opinions of the representatives of the CIGRE National Committees. AHG received answers from (10) countries: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Greece, Romania, Macedonia, and Ukraine, covering population of 150 million people. Total installed capacity in those 10 countries (as in 2012) where 58% thermal, 18% hydro, 8% solar, 7% nuclear, 5% wind and 1% other RES. Hydro pump storages counts 3% of all install capacity.

Technical fields of interest for regional cooperation were in following merits:
- 24% Systems and interconnection studies,
- 24% Renewables and Smart Grids,
- 22% Subsystems, Distribution
- 11% Institutional arrangements,
- 8% Environmental issues in power sector
- 6% Elements of Electric Power System, and
- 5% ICT in Power sector

Specific tasks of technical subjects of interest for regional WGs were emphasized:

a. **Power System development, Innovations and Standards**
   - Large Transmission regional projects and strategies,
   - OHL European Standardization and harmonization of standards **(RWG 01)**

- Power Quality Standards in South East Europe
- Protection of Cross-border OHLs
- Smart Grids development, innovations, and ICTs,
- HVDC transmission – environmental issues particularly with submarine cables,
- HVDC submarine interconnection – integration with mainland power system,
- Regional centres of WAMS,
- Future of Thermal Power Plants,
- ENTSO-E policy impact on the SEE Transmission grid,
- Harmonization of the environmental approaches,
- Aerospace assets and maintenance / recovery of regional HV Transmission systems,
- Reactors for HV Transmission networks, SEE issues **(RWG 02),**
- Environmental and technical assessment for Submarine cable siting issues **(RWG 03)**

b. Renewable Energy Sources (RES) and Power Energy Accumulation (PEA)

- RES as Mini Hydro, Micro Hydro, Solar, Biomass, Wind power,
- RES Integration, Support mechanism and Operational aspects,
- Power Energy Accumulation (PEA) issues: energy storages,
- Hydro Pump Storages, general issues, economic and technical evaluation **(RWG 04)**
- Influence of large installation of RES on System (including Hydro Pump storages),
- Reactive power planning considering large penetration of RES
- Environmental issues regarding to large Hydro Pump Storages

c. Market Design and Operation

- Cross-border capacity allocation in SEE and harmonization of Congestion management methods,
- Regional Market Issues,
- Development of SEE electricity exchange – possibilities for cooperation, gap analyses, harmonization,
- Experiences with RES integration and Market Design.

Technical subjects of interest for cooperation based on the Questionnaire 1 were considered as the topics for future regional working groups and for Regional CIGRE Conference.

Thus, Council approved the set-up of the first four Regional working groups (RWG) as follows:

- ***RWG 01 - Regional aspects on creation of NNA for new standard for overhead lines EN 5034,***
- ***RWG 02 - Regional perspective of shunt reactor introduction in the transmission system,***
- ***RWG 03 - Environmental and technical assessment for submarine cables siting issue in Mediterranean area,***
- ***RWG 04 - Technical and economical features of Hydro Pumped storage power plants (HPSPPs) in power systems.***

Conveners of the WGs have been approved:
RWG 01 – Kresimir Bakic, Slovenia, RWG 02 – Maks Babuder, Slovenia, RWG 03 – Massimo Pompili, Italy, and RWG 04 – Yuri Bondarenko, Ukraine.
Council at Belgrade meeting approved all the documents and SEERC started with a working program, which was in line with CIGRE strategic plans.

Next important decision was organization of governing bodies in the action 3.4 of MoM by majority of votes:

1. *Management Board (MB) of SEERC representing each NC CIGRE by one person, usually actual chairman of NC CIGRE. Meeting of Management Board of SEERC should be at least one meeting per year.*
2. *Ad Hoc Advisory Group (AHAG) of SEERC will be set up occasionally for strategic plans with a free selection of members.*
3. *Technical Advisory Committee (TAC) of SEERC will be set up for a preparation of topics for Regional CIGRE Conferences and for preparation of technical subjects for new Regional Working Groups. Members of this body will be the experts from Electricity Supply Industry, Universities as well as from Manufactures from SEERC countries. TAC of SEERC will represent at the same time the leadership of National Committee. Selection of experts by country is free.*
4. *Last day of each Regional Conference the new chairman of MB will be elected in accordance with MoU. At the first next meeting new chairman of MB will propose the new chairman of TAC of SEERC.*
5. *Regarding the frequency of Conferences, members agreed that Regional Conference will be held every one up to 4 years. Depending on the Chairing NC, the Regional Conference can be organized more frequently.*

Kresimir Bakic, the first Chairman of SEERC asked for Maks Babuder to be elected as a first chairman of Technical Advisory Committee (TAC) of SEERC. His term lasted until the end of the first Regional Conference in Slovenia, in 2016.
At the end of the meeting, it was decided to prepare a new document called **"Rule of Operation",** after the first SEERC conference, which would be in line with CIGRE's good practice and results.

Following the meeting, first SEERC Workshop with a theme of **"Maintenance and recovery of HV electricity transmission systems and aerospace assistance"** was organised. Massimo Pompili and Italian delegates explained a new project with European Space Agency dealing with roles of the aerospace assets on the electrical Overhead lines (Thermal ratings, OHL towers movements, structural vibrations, and vegetation and urbanization control). They proposed collaboration with other SEERC countries. For this reason, members of SEERC were asked to answer the questionnaire related to *Maintenance and recovery practice of HV electric grids.* Questionnaire was prepared by the Department of Electrical Engineering of University of Roma (La Sapienza).
Next interesting presentation was made by Kresimir Bakic, who presented *"State-of-art on Dynamic Line rating Technologies and future vision of this topic".* All presentations were published at the Serbian NC CIGRE website.

Thus, Belgrade SEERC meeting paved the way for further activities, extended number of NCs, approved Position paper and framework of the working program as well as organogram of organization.

In Belgrade meeting, new approaches for new National Committees joining SEERC, have been discussed. Members agreed that entry of the new National Committees to SEERC, would be the most appropriate with a signed Addendum on MoU, by current chairman of SEERC and chairman of new NC CIGRE. Of course, after all representatives of member states agreed as it was the case with Turkish National Committee of CIGRE, and after that with other NCs.

Organizational chart was approved as presented in the Fig. 3.9.

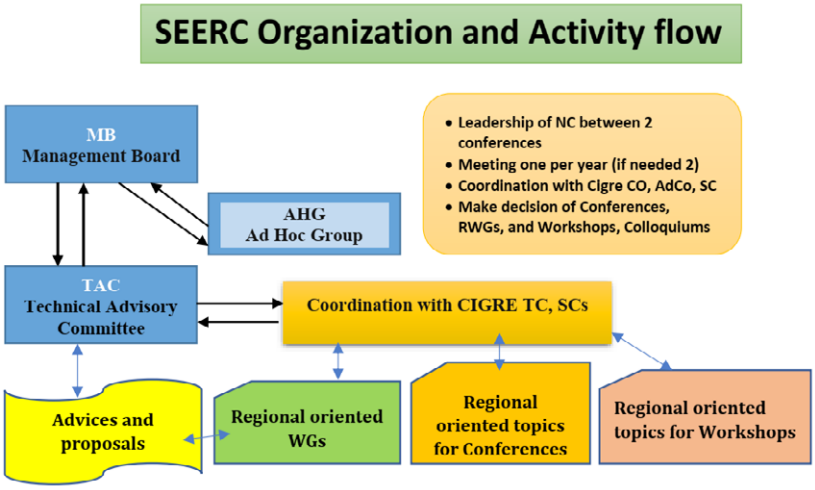


Fig. 3.9 Organigram of SEERC

Table 3.1 presents chronology of the SEERC meetings of representatives or Management Board as it was defined after Belgrade meeting.

Table 3.1 Meetings of SEERC governing Council from 2014 to 2019

No.	Location of MB	Date
1st	Rome, Italy	January 27, 2014
2nd	Belgrade, Serbia	November 6, 2014
3rd	Kyiv, Ukraine	June 23–24, 2015
4th	Portoroz, Slovenia	June 6, 2016
5th	Istanbul, Turkey	October 18–19, 2017
6th	Kyiv, Ukraine	June 11, 2018
7th	Paris, France	August 30, 2018
8th	Tbilisi, Georgia	July 8–9, 2019

3.6 Chronology of the SEERC events in period from 2015 to 2020

2015

First technical advisory committee (TAC) in Vienna, 25th March 2015

After establishing the framework of technical activities in November 2014, the first Technical Advisory Committee met in Vienna on 25th March 2015. Austrian NC CIGRE and their president Gerhard Christiner, kindly invited technical experts from SEERC Region to Vienna. Meeting was in premises of Austrian Electrotechnical Association (OVE). TAC was set up by a definition, as a responsible body for technical conferences, workshops, colloquiums, and regional working group's activities. Focus of the first meeting in Vienna, was on the program of the first regional CIGRE conference in Europe. Chairman of TAC, Maks Babuder, invited two honourable guests: president of CIGRE Professor Klaus Fröhlich and president of the European Academy of Sciences and Arts and Alma Mater Europaea, Professor Felix Unger. The reason was to extend discussion on general SE Europe issues and main technical challenges in the Region.



Fig. 3.10 Participants at the first SEERC TAC meeting in Vienna, March 2015

The meeting was focused on selecting the preferential subjects for the first SEERC Conference in Slovenia, in 2016, and having an academic debate on the issue of South-East Europe and how to bring people of the region closer together in particularly by the foreseen challenges of future uncertainties. Similar discussion happened in the European Academy. One of the conclusions was to open Academic Forum during the first SEERC conference and open a debate

for a conference framework, which was a vision of educating member countries for new challenges. It was also concluded with four topics for the conference as follows:

1. Energy and Environmental policy in the Region,
2. Submarine cables issues in the Region,
3. Regional Energy Market Aspects and
4. Innovation in electricity infrastructure in the Region.

It was also agreed, that SEERC conferences should be open for experts from all parts of the world.

After first Technical Advisory Committee in Vienna, it was agreed to organize second TAC meeting in Athens, in January 2016 with a focus on final selection of papers and conference technical program in Slovenia.

In discussion on Regional Working Groups issues, Yuriy Bondarenko presented the Term of Reference for RWG04 *"Technical and economical features of Hydro Pumped storage power plants (HPSPPs) in power systems"*. He pointed out the role of conventional hydroelectric pumped storage power plants which operate either as a turbine-generator set or reversible motor-pump set. Consequently, they can be used not only in the generating mode, but also as source of the rendering ancillary services, which contributes to optimization of the daily load curve and reliability improvement, hence overall supply quality. The capability of the HPSPP to store energy at night and return it to electric power system at the time of the highest load, makes them an efficient tool for aligning the electricity grid capacity. This was the lead for the proposal of the new Regional WG for Hydro Pump Storages in SEERC Region and TAC call for experts, which was also approved by chairman of CIGRE TC, Mark Waldron.

Table 3.2 presents all TAC meetings of SEERC in period from 2015 to 2020.

Table 3.2 Meetings of SEERC Technical body (TAC) from 2015 to 2020

No.	Location of TAC	Date
1st	Vienna, Austria	24–25 March 2015
2nd	Athens, Greece	14–15 January 2016
3rd	Prague, Czech Republic	15–16 March 2017
4th	Rome, Italy	25–26 January 2018
5th	Split, Croatia	28–29 March 2019
6th	Athens, Greece	23–25 January 2020

3rd SEERC MB meeting in Kyiv, 23–24 June 2015



Fig.3.11 Third Management Board (MB) meeting of SEERC in Kyiv

Third meeting of MB in Kyiv in premises of Ukrenergo - National Power Company. Meeting was focused on the following subjects:

- Discussion and approved results from the first TAC meeting in Vienna with Preferential subjects for First Conference in Slovenia, 2016, Reports from RWG meetings,
- Confirmation of the program for SEERC Conference in Slovenia,
- Beginning of the discussion on Rules of Operation, Exchange information regarding technical news from each country in region,
- Presentation of disturbances events (i.e. Turkey disturbances, Serbia ice storms, etc.),
- Exchange of information related to national CIGRE targets and events.

At the same time, NC CIGRE of Czech and Slovak Republics was approved as the 13th member of SEERC by correspondence and they participated at MB Kyiv meeting.

After meeting Ukrainian colleagues and his representative Yuriy Bondarenko, who kindly organized the visit to the Ukrainian National Dispatch centre, MB went on a Technical tour to NPP Chernobyl, which was in phase of decommissioning. Technical tour was an amazing technical experience.

UKRENERGO is a National Power Company and Ukrainian TSO with the functions of operational and technological control of the Integrated Power System of Ukraine (IPS), transmission of electricity via bulk power grids from generation to distribution networks, as well as commercial metering administrator and settlement administrator of the electricity market of Ukraine. More than 8 thousand employees maintain over 100 substations of 220–750 kV and over 19 thousand kilometres of transmission lines.



Fig. 3.12 Atmosphere at the 3rd meeting in Kyiv was very cooperative and friendly.



Fig. 3.13 Memory of NPP Chernobyl visit (June 2015) with a Destroyed unit no.4 in the back.



Fig. 3.14 Photo of NPP Chernobyl in 2020, after casing unit no. 4 with lead sarcophagus.



Fig. 3.15 Visit inside the destroyed power plant in Chernobyl.

NPP Chernobyl (4 x1000 MW) is now a closed nuclear power plant, about 100 km north of Kyiv. On 26 April 1986, the Chernobyl nuclear power plant's unit no.4 reactor exploded, sending a radioactive cloud across much of Europe. Following the explosion, radioactivity with an intensity equivalent to 500 bombs that destroyed Hiroshima at the end of World War II was measured in the atmosphere. Most of the external gamma radiation emissions at the site, are from the isotope caesium-137, which has a half-life of 30.17 years. As of 2016, the radiation exposure from that radionuclide has declined by half, since the 1986 accident. So, our visit in June 2015 was allowed and quite safe. During our visit inside units 2 and 3, we had dosimeters permanently checking radiation doses. In 2010, the Ukrainian Government passed a state law to transform the Chernobyl shelter facility into an environmentally safe system to protect the surroundings from radiation.

NPP Chernobyl was active since 1977 until 2000. After the accident in 1986, a fire broke out in the turbine hall on unit 2 in October 1991. Soon after that, unit was closed. In 1996, followed by the pressure from foreign governments, reactor No. 1 was shut down. The final reactor No. 3 was shut down in December 2000, after operating briefly since March 1999. Thus, all four units are in phase of decommissioning, which will last until 2065.

2016

2nd Second TAC meeting in Athens, 25th January 2016



Fig. 3.16 Second TAC meeting in Athens.

Second Technical Advisory Committee meeting was in Athens in premises of HEDNO, the Hellenic Electricity Distribution Network Operator, with a kind invitation of Greek NC CIGRE and their president Dimitris Michos. Main subjects of agenda were:

- Discussion and decision about scenarios of first Regional Conference in Slovenia,
- Discussion on the proposal for invited key speakers from EU Commission, CIGRE, European Academy, ENTSO-E, MEDRING,

- Report on the received Synopses (130) distributed in four preselected topics,
- Selection of chairing persons, reviewers, organizers of interactive panels, proceedings and final report editors, Suggestions for Conference conclusions and handing over of chairmanship, and
- Open discussion on possible technical cooperation concerning the most important actual regional issues.

Every SEERC meeting has on the agenda interesting technical presentations of new countries, which enables us to spread the knowledge between members of CIGRE SEERC Region.



Fig. 3.17 Organization of 2nd TAC meeting in Athens was excellent.





Fig. 3.18 Visiting Acropolis Museum in Athens, January 2016.

4th SEERC MB meeting in Portoroz, 6 June 2016



Fig. 3.19 Hotel Bernardin, Portoroz, Slovenia was the location of the first SEERC conference in June 2016.

Main points of the 4th MB meeting, which took place a day before the First conference of SEERC started, were following subjects:

- Presentation of the conference in details,
- Minutes from previous MB meeting in Kyiv and TAC meeting in Athens, and
- Election of a new SEERC chairmanship, in the period after the first and before the second SEERC conference, where Yuriy Bondarenko was elected, as the second president of MB SEERC.

Ceremony for passing on the presidency was presented by the president of the first conference Kresimir Bakic.

At the meeting following reports were also discussed:

- First meeting of Regions in Paris and preparation of new rules for Regions,
- Reports of activities of RWG 2 and 3 at the meeting in Ragusa, Sicily, Italy,
- Preparation for CIGRE Session 2016 in Paris, as well as exchanging the information regarding news in electric power systems by countries.

1st SEERC Technical Conference in Portoroz, 7–8 June 2016

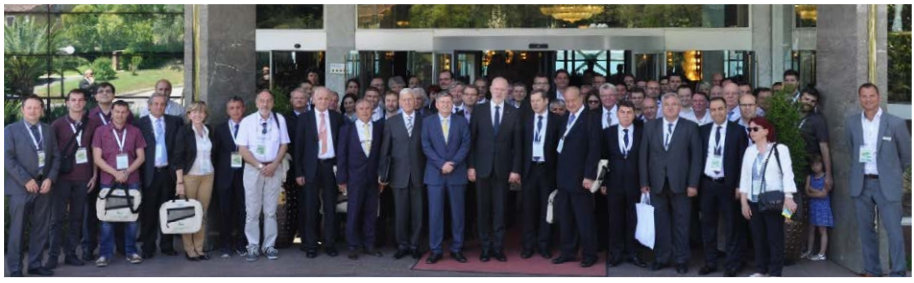


Fig 3.20 Participants of the first CIGRE SEERC Conference in Portoroz, Slovenia

The first South-East European regional CIGRE Conference took place in Portoroz, Slovenia on 7–8 June 2016 with 324 registered participants from 26 countries. Conference supported 19 sponsors from 7 countries from SEERC region (SI, AT, IT, HR) and from Germany, United Kingdom, and Finland. SEERC region conference covered 13 NCs with territory of 2.5 million km^2, populated with about 250 million inhabitants, which covers about 350 GW installed capacity of power plants in this area, where the peak load of the electric power system amounts to around 200 GW in total. Annual electric energy consumption in 2016 was 1100 TWh.

Changes of the energy system structure by introducing many renewable energy sources (RES-E), which are by their nature intermittent sources, requires a better cooperation between the participating sub-systems. The electricity market is evolving into a more complex and multi-level energy market status. Electric power systems are becoming heterogeneous and require more knowledge, new ideas, which could be upgraded in the synergy of international cooperation. Central and South-Eastern Europe is a promising area with important energy potential – natural, as well as human potentials. Therefore, our CIGRE, as one of the oldest international technical organizations involving stakeholders from the academic, equipment manufacturers and power utilities sphere, is determined to contribute to the future energy supply and demand side transition and electric power system development through suitable evolution of technology. Although there are strong National CIGRE organizations in this part of Europe, the intention was to promote better CIGRE cooperation on several operation levels. That way, it may be expected to produce much better results being inescapable for the future challenging systems.
For the First SEERC CIGRE Conference, the Technical Advisory Committee (SEERC TAC) selected the following preferential subjects (PS):

A. **Views on the future education procedures considering the new energy transition with prevailing electrical power sources, electric mobility and smart grids with ICT and sensors technologies.**
B. **Views on the development of the transmission system operators (TSOs) and Energy Markets in the region until 2030.**
C. **Regional Energy and Environmental policy focused on green technologies.**
D. **Submarine cable networks and ecological requirements.**
E. **The development of a Regional Electricity Market and**
F. **Innovation in infrastructure in the Region of Central and South-Eastern Europe.**

The Conference lasted two days, covering first two PSs in the first day of Sessions, and the last four PSs, during the second day.

Opening ceremony speakers came from all parts of CIGRE stakeholders: academic, utilities and manufacturers side. All speakers welcomed the participants and emphasized the importance of this kind of regional CIGRE conferences and in such a way promoted the cooperation of the southeast corner of Europe.

Invited speakers prepared lectures on three extremely interesting topics for this Region:

a. On CIGRE's fingerprint on the Electric Power system, dealing with challenges on future electric grid, interaction with environment, global grid issues and visions of the new technologies; all as CIGRE working field (Klaus Fröhlich, president of CIGRE)
b. On Electricity Market development in the region of Energy Community, for non- EU members. Exciting lecture covering 8 countries (5 of them are members of SEERC) presenting legal and technical procedure for energy system accommodation with EU. (Janez Kopac, Director of Energy Community, Vienna)
c. On HVDC Transmission Technologies, which is a topic of high interest in many countries due to Energy transition requirements. Presentation of state-of-art of HVDC Technology was very instructive and involving most recent techniques (Michael Muhr, Professor at Graz University of Technology).

On the first day of the Conference there were 18 invited presentations.



Fig. 3.21 Over 300 experts attended the Opening ceremony and Academic Forum.

Academic Forum Session

Contributions at Academic Forum were from:

- **Felix Unger,** President of the European Academy of Science and Arts,
- **Tadej Bajd,** President of the Slovenian Academy of Sciences and Arts,
- **Stanislav Artyukh,** Aleksandr Lazurenko - University of Kiev,
- **Zlatan Stojkovic** - University of Belgrade,
- **Massimo Pompili** - University of Rome (La Sapienza),
- **Igor Papic** - University of Ljubljana,
- **Ramazan Caglar** - Istanbul Technical University and
- **Alexander Voloshin** - National Research University, Moscow Power Engineering Institute.



Fig. 3.22 Speech of Professor Felix Unger, President of the European Academy of Science and Arts

Quality of education and the needs for new technical profile personnel in the future will have a significant impact on the development of the energy transition process; therefore, it is necessary to pay more attention to the quality of education. Framework of educational procedures for engineers, working in increasingly complex energy systems, is going to be replaced in the future. It will need more interdisciplinary and collaborative techniques with other disciplines, such as economics, law, sociology and others.

The use of local and foreign languages in the terminology is to be wisely balanced and not to restrain the regional and European cooperation. Of course, even in the future systems the fundamental knowledge of physics and electrical system basics will play a key role in the introduction of new and promising technologies. Linkage to educational institutions and commercially oriented power utilities have been underlined in the Academic Forum discussions as very important.

The special guest and speaker of the Academic Forum was the President of the Slovenian Parliament in 2016, Professor Milan Brglez, who is now a delegate at European Parliament in 2020. He contributed his standpoint of the future education needs as a Professor of Sociology at the University of Ljubljana.



Fig. 3.23 System Development Session was led by M. Hrast (Slovenia), Massimo Rebolini (Italy) and Georgios Georgantzis (Greece).

Central and South East European Electric Power Systems have shown interesting development plans of power infrastructure and also a vision of the operating markets. Eight reports were presented: G. Christiner (Austria), M. Mesic (Croatia), M. Rebolini (Italy), L. Knezevic (Montenegro), Z. Vitalii (Ukraine), M. Marincek (Slovenia), R. Taleski (N. Macedonia) and D. Michos (Greece).
These reports pointed the most important issues – the incorporation of a large number of small Renewable Sources (RES) in the System, implementation of new technologies supporting the redesigning of power structures, re-designing of the regional electricity market in the direction of better accessibility to market participants, better operation transparency and technological improvement of systems using more and more capable smart grid techniques, with new generation of sensor technologies as well as ICTs.

Four Sessions – 93 presented papers
Second day of the Conference covered presentations and discussions on accepted papers in four Sessions (4 topics).
Organizers of the Conference received 144 synopses altogether, 124 of them were accepted for the Conference. From those 24 synopses, 112 papers were accepted (20 per topic and 32 per poster Session) for the Conference. Finally, 93 papers were presented: 16 papers for topic 1, 17 papers for topic 2, the same amount for topic 3 and 4, and 26 papers for interactive poster presentation.
Papers presented in the four topics Sessions were of good quality, introducing reports on many interesting research done in Region (majority of papers) and also papers coming from other countries. Technical Advisory Committee accepted 20 papers per topic.

Topic 1 Session – Regional Energy and Environmental Policy.
Needs, opportunities, standards, security issues, environmental harmonization, competition vs. cooperation, cases/examples of good practices, green strategies, scientific methodology. (Fitting to working program of CIGRE SC C1).
Session was chaired by M. Muhr (AT), Sabalic (HR), and Koronides (GR). From 17 papers 81% came from SEERC Region.
Session papers have shown a variety of interesting ideas. Due to the fact, that R&D of this subject is significantly impacting further development of the Electrical systems, so it desired to continue discussions on this topic in the next SEERC meetings. One exceptional presented paper received the best paper award, which reported on a long term (50 years in advance) strategy of low carbon Electrical sector development. Some papers focused on security of the future system, considering the impact of large number of RES.

Best paper in Session 1 was paper by authors **Željko Tomšić, Ivan Rajšl, Matea Filipović (Croatia): *"Low Carbon strategy development of the Croatian Electric Power Sector up to 2070".***

Topic 2 Session – On Submarine Cables Issues in Region.
Adriatic projects, Mediterranean projects, other long-term projects, submarine environmental issues, deep undersea cases, acquired good practice, economy of projects, new technologies of submarine cables. (fitted to working program of CIGRE SC B1).
Introductory presentation was made by Pierre Argaut, chairman of CIGRE SC B1 – Insulated Cables.

Session was chaired by M. Pompili (IT), M. Ostojic (MN), and F. Muzi (IT). 76% of papers were from SEERC.

Session have shown several excellent papers with great achievements of the submarine projects in this Region. Projects from Italy, and Greece in the Mediterranean Sea, showcased the excellent achievements. New project of crossing Adriatic Sea between Italy and Montenegro was also presented in detail. Some papers were dealing with environmental issues, alongside other energy efficiency papers. A paper from Montenegro, dealing with Magnetic Fields of the Bipolar HVDC cable, was selected and published in the CIGRE Scientific and Engineering Review.

Best paper in Session 2 was written by authors **J. Kabouris, K. Tsirekis, A. Georgopoulos, I. Aravanis (Greece):** ***"The Interconnection of the Cycladic Islands: A Major Innovative Transmission Project for the Greek EPS".***

Topic 3 Session – On Regional Energy Market Aspects.
Vision of future Central and South East European Energy Market, Metering issues in the Region, Market aspects, Trading issues, Impact of interconnections, New OHL interconnections in the region, Demand side involvement in market. (fitted to working program of CIGRE SC C5 – Electricity Markets and Regulation). Session was chaired by N. Stefanovic (RS), U. Salobir (SI), and T. Kapetanovic (AT). 100% of all papers were from SEERC.

Session was very well attended. 17 interesting oral presentations have shown intensity of the Regional Market development and new ideas for redesigning Market in accordance with new requirements of system development (RES intensity), underlining importance of system security of supply issues.

For best paper in Session 3 was elected paper by authors **D. Martinčić (Montenegro), D. Međimorec (Croatia), A. Mijušković (Montenegro):** ***"Regionally coordinated auctions of cross-border transmission capacities between South East European Transmission System Operators".***

Topic 4 Session – Innovation in Electric Power Infrastructure of the Region. *Smart Grid projects, Technical and Non-technical innovations, Demand side readjustments, Penetration of Electrical vehicles, Innovations in system operation processes, new business frameworks, intelligent utilities. (fitted to working program of CIGRE SC C6 – Distribution Systems and Dispersed Generation).*

It was an intense Session. Organizing Committee received 4 times the amount of synopsis, than was expected. It seems, that R&D and innovation is the most important topic for engineers and experts in this Region. Interest for new power technology in Region is remarkably high. Authors have shown novelties related to Overhead lines techniques, electrical mobility, battery storage systems and other primary subjects of contemporary Electric power systems. Specific of this Region is an explosion of new ideas for future novel energy system. This proves good expectations for future CIGRE activity.

Best paper in Session 4 was presented by authors **Klemens Reich, Michael Leonhardsberger, and Herbert Lugschitz (Austria):** ***"Test-run for uprating of Overhead Lines using innovative Technologies at APG".***

In addition, 6 papers were chosen for possible publication in a scientific journal of CIGRE, as follows:

1. 1–19: Gorazd Bone, Rafael Mihalic (Slovenia): A dynamical equivalent for the electric power system,
2. 2–05: Milutin Ostojic, Martin Calasan (Montenegro): Magnetic Field of the Bipolar HVDC Cable Italy–Montenegro in the See and in the Land Section
3. 3–04: C. Todem, A. Kaiser, V. Wiedner, H. Wornig (Austria): T European network codes - Bidding Zone Review Impacts on the SEE region resulting from an Austrian -German market split
4. 4–15: Massimo Muggiasca (Italy): Unsymmetrical Spacer Damper designed to control the sub span oscillation of a conductor bundle,
5. 3–15: Guido Guida, Mauro Caprabianca, Federico Quaglia, Luca Luzi, Carlo Bruno, Marta Maria Emolumento, Matteo Simone Stori (Italy): Innovative tool for the outages plan optimization in the Italian Transmission Network
6. 4–21: George Messinis, Aris Dimeas, Vasilis Rogkakos, Kostas Andreadis, Iraklis Menegatos, Nikos Hatziargyriou (Greece): Utilizing Smart Meter Data for Electricity Fraud Detection.

All papers from First SEERC CIGRE Conference are available at e-CIGRE portal.



Fig. 3.24 Maks Babuder, chairman of TAC, presented the Award for Best paper in Session 4 to Michael Leonhardsberger, from Austrian APG.



Fig. 3.25 Gala Dinner was on the terrace by the Adriatic Sea with a beautiful view of the sunset



Fig. 3.26 Gala Dinner atmosphere, enjoying the sounds of the sea waves

Thoughts and reflections of the First Conference by Chairman Kresimir Bakic

"Despite many dissimilarities between nations, countries, histories, cultures and religions in this part of Europe, the ***Electric Power Systems is connecting us*** *all, bringing advantages for better living, comfort, prospects of faster social and economic development, wealth, etc. Therefore, energy experts in the region need to come together and build a reliable, resilient and safer electric power system for the good of our people. This is the time for big energy system structural changes and technological breakthroughs. These kind of connections between experts will be crucial in building a new and even more electric power prevailing energy system, during promising energy transition. Incorporation of the large number of RES and the accompanying adaptation of the electrical grid to a new grid-outline, is a great challenge. Together we can build a cost-effective, new and more complex interconnected power system, than trying alone. The CIGRE platform is an ideal framework for cooperation, due to well known* ***"spirit of CIGRE",*** *that translates to free technical thinking, possibility of working in several expert groups, education through colloquia, meetings, seminars, and conferences. At the same time, we witnesses and admired voluntary work, which helped bringing faster progress and success to all."*

Takeover of SEERC leadership



Fig. 3.27 Conference concluded with Best paper Awards and passing on Presidency of SEERC ceremony.



Fig. 3.28 President of CIGRE, Klaus Fröhlich, officially ran the Ceremony of passing on CIGRE SEERC Presidency leadership to Ukraine.

Statement of the first SEERC Chairman at the end of Conference

"Many participants of the First SEERC Conference expressed gratitude and satisfaction over the Conference and emerged potentials for regional cooperation, and from this reason I strongly hope that my successors (the leadership of the Region SEERC was transferred to NC CIGRE of Ukraine) will continue successfully as we did, since the SEERC creation up to its first Conference."

2017

3rd TAC meeting in Prague, 15–16 March 2017

As a new member of SEERC, Czech and Slovak NC CIGRE and their President Professor Zdenek Muller, kindly invited experts of SEERC TAC to third technical meeting in Prague, 15th–16th March in 2017. The location of the meeting was on a boat-hotel called Botel Admiral on Vltava river (March 15th) and National Technical Library (March 16th).
Third Technical Advisory Committee (TAC) meeting in Prague was the first step for preparing for the 2nd Conference under Ukrainian NC CIGRE leadership. Yuriy Bondarenko, as new chairman of SEERC Council, asked Professor Maks Babuder from Slovenia to be Chairman of TAC on behalf of the NC CIGRE Ukraine and support them with his experiences for the second SEERC Conference in 2018. Maks Babuder kindly accepted this function.
Focus of the meeting agenda were the following subjects:

- Draft program for the Second SEERC Conference in June 2018,
- Analysis of Questionnaire 2 as starting point for selection of preferential subjects,
- Reports on the situation in the Regional working Groups (RWG),
- Report from Ukraine on the Electric power system cyber-attack,
- Reports from members on the Electric power system disturbances in winter 2016/2017 (ice storms, blackouts),
- Working plan for period 2017-2018.





Hotel Admiral – ship on the Vltava River in Prague

Fig. 3.29 First part of the meeting was held in hotel Admiral anchored on the river of Vltava.



Fig. 3.30 Second part of the meeting was held in the National Technical Library, in Prague.

At the meeting interesting cases of cyber security and weather disturbances in the Electric power systems in winter 2016/2017 were presented as follows:

1. **Ukraine:** Problems on Information Security in Energy Objects Control Systems (A. Denysenko),
2. **Italy:** Severe climatic conditions in Italy (M. Rebolini),
3. **Turkey:** Electric System Disturbances in Turkey (A. Merev),
4. **Croatia:** Information about disturbances in Croatian Electric Power System (M. Mesic),
5. **Austria:** Current Developments in Austrian Power Grid (K. Reich)
6. **Italy:** New Terna research Centre in Florence (M. Rebolini)

Two new RWGs were proposed in the discussion report of Regional working groups' activities:

- RWG 05 - Future of HVDC transmission lines in the region.
- RWG 06 – Smart grid regional implementation issues.
- RWG 03 on Submarine cables environmental issues was cancelled due to merging with global CIGRE WG in SC B1.

Slovenian delegates invited experts from SEERC to participate at Slovenian CIGRE Conference in May 2017, in Maribor, on SEERC Panel, discussing the topic: *"The Major Technical Challenges for Regional (SEE) Electric Power Systems caused by Side Effects of Large RES Penetration".*

Massimo Rebolini from Italy invited members of SEERC to HVDC International Workshop in Venice (March 28-30), dealing with Operational experience and technological development for HVDC worldwide application.



Fig. 3.31 Photo of Third TAC meeting participants in Prague at the end of event

5th SEERC MB meeting in Istanbul, 18–19 October 2017



Fig. 3.32 Fifth MB meeting was in Istanbul

Fifth Management Board (MB) meeting of SEERC was in hotel Armada, Istanbul, hosted by Turkish NC CIGRE with a kind invitation from NC Chairman Ercument OZDEMIRCI from 18-19 October.
In the meeting agenda were following main subjects:

- Progress report on Rules of Operation,
- Results from the 1st SEERC Conference in Portoroz,
- Results of the revised SEERC Questionnaire,
- Results from the Third TAC in Prague,
- Program for the Second SEERC Power Conference in Kiev, in 2018,
- Reports from the members NCs on Technical news in 2017.

According to results of Questionnaire 2 there was a debate on interests of SEERC members in technical fields as presented in Fig 3.33. The largest interest was in exchanging information about interconnections and regional market.

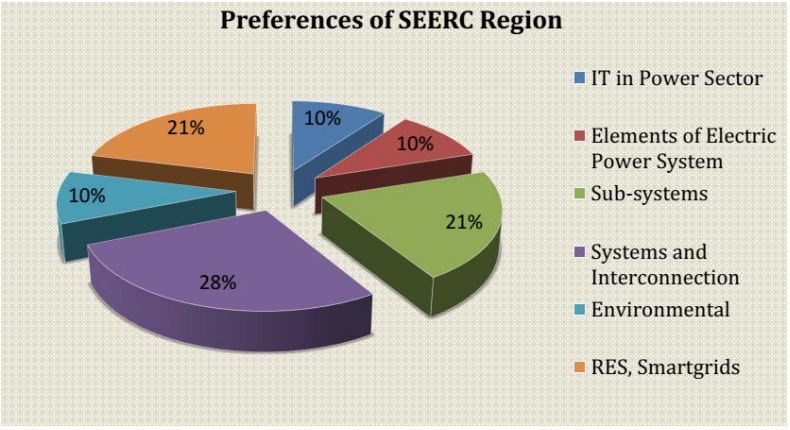


Fig 3.33 Technical fields of interest in Region as a result of Questionnaire 2

Preferred tasks for future regional WGs were as follows:

1. *Regional cooperation in certain standards uprating,*
2. *Regional initiatives for innovation in Power sector,*
3. *Large regional project issues (covering more CIGRE SCs)*

Mainstream production of equipment in SEERC Region are:

- *Transformers,*
- *Cables, and*
- *Metering equip*ment.

Administrative Council of CIGRE at the meeting in Auckland approved NC Kosovo, which enabled extension of SEERC with a new member. Thus, representatives of NC Kosovo attended SEERC-Region meeting as the 14th member. One of MB meeting result was a decision to continue discussion on Rules of Operation at the next MB meeting in Kyiv in June 2018 just before the second SEERC conference. MB also approved the program for the second SEERC conference in Kyiv.



Fig. 3.34 Photo of participants at the top of the hotel Armada located in old city of Istanbul.

Near SEERC MB meeting location in old city of Istanbul were many opportunities to visit famous monuments of our civilization. We were amazed by an amazing architecture of Hagia Sophia, (Turkish Ayasofya, Latin Sancta Sophia, also called Church of the Holy Wisdom or Church of the Divine Wisdom), an important Byzantine structure in Istanbul and one of the world's greatest monuments. It was built as a Christian church in the 6th century (532–537) under the direction of the Byzantine emperor Justinian I. Just across the Great Park, there is also monumental Sultan Ahmed Mosque, also known as the Blue Mosque, is an Ottoman-era mosque. A functioning mosque was constructed between 1609 and 1616 during the rule of Ahmed I. Not far from there is famous Grand Bazaar (Covered grand Market), which is one of the largest and oldest covered markets in the world, with 61 covered streets and over 4,000 shops.



Fig. 3.35 Hagia Sofia, important Byzantine structure, one of the world's greatest monuments.

2017

4th TAC meeting in Rome, 25–26 January 2018



Fig. 3.36 Fourth TAC meeting was hosted by University of Rome (La Sapienza)

Technical Advisory Committee (TAC) was held in Rome by an extended invitation of the Italian NC CIGRE and President Massimo Rebolini. Location of the SEERC meeting was at the University of Roma (La Sapienza), where first discussions started in 2014. Professor Massimo Pompili organized a Workshop on the second day called **"Resilience of grid: events and solutions".**
Focus of the TAC meeting discussion was the following:

- Survey of received Abstracts for the Conference, Criteria for paper selection, First round of the Chair selection and Paper allocation (work in three groups),
- Details about the Conference timetable and Final Conference program.

January TAC Meetings on even years are important, due to good preparation of SEERC conferences, which are in June. Second topic of the meeting was continuation of the debate about new Rules of Operation, in the line with CIGRE rules and modernization of Regional conferences. The meeting resulted in a Draft Proposal for the SEERC RoO, according to CIGRE rules. Document was postponed for approval at the MB meeting in Kyiv, in June 2018.

Workshop on **Resilience of Grid** was very well organized with interesting presentations, as follows:

1. K. Reich: *Resilience of overhead lines in Austria,*
2. M. Champakis: *Some aspects on Greek electricity system resilience,*

3. E.M. Carlini: *Italian Resilience Plan 2017 ... for a more reliable grid,*
4. G. Amoroso, G. Valtorta, M. De Masi: *Resilience of Distribution Systems against extreme weather events: risk evaluation and mitigation,*
5. M. Pompili, L. Calcara: *Effect of Ambient Temperature on Failure Rates of Cable Joints,*
6. P. Berardi, M. Forteleoni: *Severe climatic conditions in Italy and risk mitigation on HV transmission lines,*
7. C. Candia: *The Resilience in the Future Power Systems, Transformation trends affecting the electrical grids,*
8. P. Dobruna-Kryeziu: *The role of 400 kV interconnection line Kosovo B-Tirana 2 for the security operation of South East European Transmission network,*
9. M. Deretic: Resilience of grid: *events and solutions - Experience of the Montenegrin TSO,*
10. 1M. Hrast: *Grid resilience - recovering and preventing ice storm consequences in Slovenia,*
11. A. Denisenko: *Cyber threats for energy infrastructure of Ukraine,*
12. M. Bno Airiian: *Ukrenergo: Resilience of Grid – events and solutions.*



Fig. 3.37 Participants at SEERC Workshop, 26 January 2018, University of Rome, Italy

Table 3.3 presents 4 Workshops in history of SEERC. All presentation are available at SEERC website.

Table 3.3 SEERC Workshops in period 2014 to 2020

No.	SEERC Workshops title	Location	Date
1st	"Maintenance and recovery of HV electricity transmission systems and aerospace assistance"	Belgrade	8 November 2014
2nd	"New ideas how to efficiently use new technologies for future power system"	Marina di Ragusa	8 October 2015
3rd	"Resilience of Grid: Events and Solutions"	Rome	26 January 2018
4th	"TSO & DSO, Interaction in operation and planning"	Athens	23 January 2020

6th SEERC MB meeting in Kyiv, 11 June 2018



Fig. 3.38 MB Meeting in Kyiv, a day before Second SEERC Conference in June 2018

Sixth MB meeting in Kyiv was organized a day before the Second SEERC CIGRE Conference in the premises of the Ukrainian National grid company Ukrenergo, as Third MB meeting before in 2015.

The representative of NC Georgia Mr. Giorgi Arziani solemnly signed the Addendum to Memorandum of Understanding (MoU) that was unanimously greeted and applauded by all the present Attendees. **NC Georgia became 15th member of SEERC.**

This meeting was focused on following subjects:

- Presentation in details of the 2nd Conference program in Kyiv,
- Decisions about Rules of Operation,
- Procedure for improving paper reviewing,
- Passing on the leadership of SEERC to Austrian NC CIGRE
- Reports from the members,
- Proposals for next SEERC MB and TAC meetings in 2019,
- Information from CIGRE Paris and plans for Paris Session 2018.

Chairman of Technical program, Maks Babuder presented conference framework with 3 topics:

1. Regional aspects of the electricity market development and transition,
2. Resilience issues of Electric Power Systems in SEERC Region, and
3. Innovation in the Electric power infrastructure in the Region.

He reported that 97 synopses were uploaded, 15 were rejected and 74 accepted.

In accordance with 4th TAC meeting in Rome following criteria was applied for paper reviewing:

- *Relevance and contributing impact of the topic presented*
- *Novelty of the topic and originality in dealing with*
- *Methodological consistency*
- *Importance of the topic for the author's environment*
- *Significance for the whole CIGRE community*

All accepted papers were allocated in 3 groups (topics) as follows: T1-20, T2-22, and T3-32.

The largest number of papers came from Ukraine 19, Croatia 10, Turkey 10, Italy 8, Slovenia 7, four papers were from Greece, Serbia, and Kosovo, and two papers from Austria and N. Macedonia. Hungary, Bosnia and Herzegovina, Israel and Bulgaria contributed one paper each. This time there were no papers outside of SEERC region.

Regarding the Rules of Operation delegates postponed this decision to a new appointed MB meeting in Paris, which would be organized by Austrians with the new upcoming presidency of SEERC. For new MB meeting in 2019 members agreed to accept the invitation of a new member of NC CIGRE of Georgia in July 2019, in Tbilisi. Before that was as agreed the TAC members meeting in Split, Croatia in March 2019. It was obvious that SEERC CIGRE became more and more popular in this Region.



Fig. 3.39 Participants of 6th SEERC MB meeting in Kyiv 2018 in front of Ukrenergo Head office

2nd SEERC Technical Conference in Kyiv, 12–13 June 2018



Fig. 3.40 Second SEERC CIGRE Conference was held in Congress and Exhibition centre "Parkovy" in Kyiv.

The second South-East European regional CIGRE Conference took place in Kyiv, Ukraine on 12th-13th June 2018, with over 250 registered participants from 17 countries. Conference was supported by National Company Ukrenergo as a general sponsor and 8 other sponsors. Media partner was RBC-Ukraine and 10 other media and social organizations as supporters. After the first SEERC Conference, two new members NC CIGRE Kosovo and NC CIGRE Georgia. Joined SEERC CIGRE Region, which accounts to 15 National CIGRE committees from Central and SE Europe.

Technical Advisory Committee proposed the following three preferential subjects:

TOPIC 1: ***Regional aspects of electricity market development and transition***
Vision of future Central and South East European Energy Market, metering issues in the Region, new Trading issues, new interconnections (OHL and cables, submarine cables, HVDC), Demand side involvement in market.
(Fitted to working programs of CIGRE SCs: B1, B2, C1, C2, C5, and D2).

TOPIC 2: ***Resilience issues of Electric Power Systems in SEERC region***
Examples of the Electricity system outages (Ice storms, Floods and Storm surge, cyber-attacks, major operation errors, physical attacks, wildfires, earthquakes), management of resilience issues taking into account novel grid codes, preparation programs, examples of good practice.
(Fitted to working programs of CIGRE SCs: B2, B5, C2, and D2).

TOPIC 3: ***Innovation in electric power infrastructure of the Region***
Technical and non-technical innovations in electricity sector in region, Microgrids and Smart Grids projects, Demand side readjustments, penetration of Electrical vehicles, innovations in system operation processes, new business frameworks, intelligent utilities.
(Fitted to working programs of CIGRE SCs: A2, A3, C1, C6, D1 and D2).

At **Opening Ceremony** Organizing Committee shared following presentations:

- Yuriy Bondarenko: *Why CIGRE?*
- Philippe Adam: *Highlights of CIGRE 2017*
- Klaus Fröhlich: *Impact of Energy Transition on the Development of the Electric Power system*
- Andriy Vovk: *ENTSO-E System Development Prospects in SEERC Region*
- Kresimir Bakic: *Future Global Electrical Network*
- Maks Babuder: *Survey of the Technical program in Conference.*

Leadership of the group 1 – Regional aspects of electricity market development and transition
CHAIRMAN: Ninel Čukalevski (NC SERBIA)
CO-CHAIRMEN: Klemens Reich (NC AUSTRIA) and Alexander Denissenko (NC UKRAINE)
From 20 accepted papers in this group, all papers were orally presented.

Best paper in group 1 was selected paper no. 1-6 by author **Goran Jakupović (Serbia):** ***"Imbalance netting optimization algorithm based on linear programming for SMM LFC control block".***



Fig. 3.41 Secretary General of CIGRE Awarded Goran Jakupovic from Serbia a plaque for the Best paper on topic 1.

Leadership of the group 2 – Resilience issues of the Electric Power Systems in SEERC Region
CHAIRMAN: Miroslav Mesic (NC CROATIA)
CO-CHAIRMEN: Marko Hrast (NC SLOVENIA), and Ahmed Merev (NC TURKEY)
From 22 accepted papers in this group, 20 papers were orally presented, and 2 papers presented in posters.

Best paper in the group 2 was paper 2-75 authors **Spela Vidrih, Andrej Matko, Janko Kosmac, Tomaz Tomsic, and Ales Donko, (all Slovenia):** ***"Operational Experiences with the Dynamic Thermal Rating System".***



Fig. 3.42 Secretary General of CIGRE Awarded Janko Kosmac and Spela Vidrih from Slovenia a plaque for the Best paper on topic 2.

Leadership of the group 3 – Innovation in Electric Power infrastructure of the Region

CHAIRMAN: Massimo Rebolini (NC ITALY)

CO-CHAIRMEN: Champakis Markos (NC GREECE), Ciprian Diaconu (NC ROMANIA) and Pranvera Dobruna (NC KOSOVO)

From 32 accepted papers in this group, 20 papers were orally presented, and 12 papers presented in posters.

Best paper in the group 3 was paper 2-75 by authors **F. Scatiggio, F.M. Pepe, S. Sacco and C. Serafino (all Italy):** ***"Increased Loadability of Transformers Through the use of Natural Esters".***



Fig. 3.43 Secretary General of CIGRE awarded authors F. Scatiggio, F. M. Pepe, S. Sacco and C. Serafino from Italy a plaque for the Best paper on topic 3.

Conclusive Session was led by Yuriy Bondarenko (Chairman SEERC), Olexandr Svetelik (President of Ukrainian NC), Maks Babuder (Chairman of TAC), Ninel Čukalevski (Chairman of Topic 1), Miroslav Mesic (Chairman of Topic 2) and Massimo Rebolini (Chairman of Topic 3). Leaders of each group made their conclusions and suggested the best paper, which caused the most interesting discussion.

Presidency of SEERC was passed to Austrian NC CIGRE and the new chairman of SEERC, Klemens Reich, up to the Third SEERC CIGRE Conference, which was planned to be in Vienna, in 2020. All 74 papers from Conference in Kyiv are available at the SEERC website.



Fig. 3.44 Three chairmen of SEERC, from left to right Klemens Reich (Austria), Kresimir Bakic (Slovenia) and Yuriy Bondarenko (Ukraine).



Fig. 3.45 Final photo of the audience at the end of second SEERC CIGRE Conference in Kyiv, Ukraine.

7th SEERC MB meetingin Paris, 30th August 2018



Fig. 3.46 Participants of Paris MB meeting in 2018

New chairman of SEERC, Klemens Reich from Austrian NC CIGRE organized the first official MB meeting in Paris during 47th CIGRE General Session. Meeting was focused on debate and final decision of new Rules of Operation. Other items on the agenda were the nomination of the new TAC chairman from Austria, updating of Position paper, update of the SEERC website, update of Questionnaire to version 4, exchange of technical news, and registration to CIGRE's KMS system of information network.

New chairman of TAC Dr. Wolfgang Hribernik, Head of Centre for Energy at the Austrian Institute of Technology and secretary of the Austrian NC CIGRE was approved.

New Rules of Operation for SEERC Region were approved and published at SEERC website.

Massimo Pompili prepared new upgraded version of Questionnaire 4, with more clear definitions for questions regarding Academic issues. Also, KMS system is now available to all SEERC members, as well as all RWGs.

Year 2018 was concluded with great improvements of SEERC organization and activities.

2019

5th TAC meeting in Split, 2019



Fig. 3.47 Discussion on questionnaire 4 as a starting point for a new conference

First meeting in 2019 was TAC meeting in Split, in hotel Radisson Blue by a kind invitation of the new president of NC CIGRE Croatia, and new chairman of the Management Board of the Croatian electricity transmission system operator HOPS, Mario Gudelj. Meeting was led by a new TAC chairman Wolfgang Hribernik. Focus of the agenda was a debate on 3 topics for the next SEERC CIGRE Conference in Vienna. The meeting was attended by representatives from the following countries: Austria, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Greece, Ukraine, Romania, and Georgia. Representatives from the Czech Republic, Hungary, Serbia, and North Macedonia were missing. The first part of the meeting was presentation by the Austrians with topics for the 3rd Regional Conference, in Vienna, in June 2020. The TAC members approved the topics with minor corrections. In the second part of the meeting various experts elaborated on technical news from their countries. Italy discussed about the energy status of the region and interests of cooperation in the region.

Kresimir Bakic reported on his vision, supported by CIGRE WG C1.35 activity, in presentation prepared for this SEERC event "Global electrical network as a support to our path in de-carbonation of energy sector" with focus on increasing global interconnections and regional cooperation.

After well-organized meeting NC CIGRE Croatia organized Technical Tour to one of the largest HPP in Croatia.



Fig. 3.48 Technical tour to HPP Zakučac 486 MW

8th SEERC MB meeting in Tbilisi, 8–9 July 2019

SEERC MB meeting in 2019, was held in Tbilisi by a kind invitation of NC CIGRE of Georgia and their president Giorgi Amuzashvili. MB meeting was in Radisson Blue hotel on 8th July. Before MB meeting NC organized a visit to National dispatch centre and head office of National TSO GSE (Georgian State Electrosystem). On the second day MB went on a Technical tour to Akhaltsikhe HVDC Converter Station, close to border with Turkey, and visited a famous Borjomi mineral water centre and museum complex Rabati.

Focus of the meeting was to finish Rules of Operation and presentation of the Third Conference in Vienna by Austrian NC CIGRE. Chairman of SEERC council Klemens Reich updated Rules of Operation and sent template for electronic voting. Section Rule 7 of RoO was adapted and the new SEERC Chairmanship consensually approved. Last approved version of RoO is on the SEERC website.

Next action by chairman was preparation of guidelines for Regional WGs. They are similar to CIGRE Rules for Working Groups and are only slightly adapted to SEERC procedures. The procedure of the creation of RWGs as well as the responsibilities of participants are outlined in the new proposal of guidelines. Next item of discussion was organization of the first SEERC Colloquium in Sarajevo, 24th to 26th of October about *"Energy climate strategies up to 2030"*. Idea for the first Colloquium was very well accepted by all members. The framework of colloquium was approved. Chairman proposed, that Edhem Bičakčić (president of NC Bosnia and Herzegovina and chairman of Colloquium), Wolfgang Hribernik as chairman of TAC, and Kresimir Bakic cooperate with other members related to presentation content.

Next was Klemens Reich's presentation of the program of Third SEERC CIGRE Conference planned in June 2020 in Vienna. Members agreed with the program. Title of the Conference: **Cooperation - Sustainability – Future.** Topics of the Conference: (1) *Transition to Future Power Systems in the South East European Region of CIGRE,* (2) *Cross Border Cooperation in the South East European Region of CIGRE,* and (3) *Innovation and New technologies in the South East European Region of CIGRE.* Subtopics and more information on conference is available on Conference website: http://CIGREvienna2020.at/.

History panel was proposed as a part of the conference and Kresimir Bakic responsible for the organization of the panel. Participation on history panel was possible only invitation. Next TAC meeting in Athens would finalize program of the panel. For the next 6th SEERC Technical Advisory Committee Meeting in Athens, 23rd–24th January 2020, Regional Workshop on ***Interactions between TSO and DSO*** was announced.
MB meeting accepted the decision to realize History book *"SEERC CIGRE History book".* All members should participate with about 10 pages of text relating to early history of electrification, development of electric power system, activities of NC CIGRE and foreseen of RES development up to 2030. Book's editor would be Kresimir Bakic and Slovenian NC CIGRE as publisher.

Klemens presented the abstract of the SEERC paper for the Paris Session 2020 related to resilience in our Region. He asked for Kresimir's and Massimo's cooperation. Deadline for full paper was by the end of the year.
Klemens Reich informed Management Board regarding the **Application of NC Israel** to join SEERC and asked for e-voting until the end of July. Meeting in Tbilisi was very well organized and with fruitful results.



Fig. 3.49 Participants of 8th MB meeting in the Dispatch Center of Georgia



Fig. 3.50 SEERC CIGRE Meeting was on the TV news program.



Fig. 3.51 Technical visit to HVDC convertor back-to-back station 500 kV/400 kV Akhaltsikhe, 2 x 350 MW connecting Georgia and Turkey.

Georgia is a remarkably interesting country in the Caucasus region of Eurasia with a territory of some 70.000 km² and population of 3.7 million. History of country is dating back to 13th century BC (Iberia, Colchis). United Georgian Monarchy even further from 1008, always between three large empires of Persia, Russia and Turkey. It is a cradle of wine. Word "Hvino" in Georgian means wine and is probably the origin of the English word wine. In Georgia there are more than 500 types of vines. They have history of producing wine over 6000 years. In Georgia they still use the original method for wine storages like underground amphora, which they call kvevri (a clay vessel for the production and storage of wine).





Fig. 3.52 Kvevri are clay vessels for the production and storage of wine in Georgia

First SEERC Colloquium, Sarajevo, 25 October 2019



Fig. 3.53 Sarajevo, Bosnia and Herzegovina was the location for the first SEERC Colloquium

No.	SEERC Colloquium title	Location	Date
1st	"Energy-climate National strategies 2030 and challenges for electric power sector"	Sarajevo, BH	25 October 2019

The first colloquium of SEERC members was aiming to present energy and climate strategic plans by countries and influences on the development of electricity energy systems. Introductory lecture by KEMA representative on *"trends in the development of the electro-mechanical industry up to 2050"* was followed by presentations of SEERC members Austria, Bosnia and Herzegovina, Croatia, Georgia, Italy, Serbia, Slovenia, Turkey and Ukraine. Four EU representatives presented the work plan by the end of the year 2019. All presentations can be found on the SEERC website.

Some countries plan to build an exceptional range of Renewable sources by 2030. I.e. Serbia around 3000 MW in wind farms (mostly in Banat); despite the termination with subsidies, Croatia has over 2000 MW of applications for new wind farms (mostly in Dalmatia). Italy has 30% of RES planned by 2030 and Austria 46%. Slovenia is planning to reach only 27% up to 2030. Based on the presentations, there is a significant dynamic in the transformation of the electricity system in all SEERC Member States. Both Turkey and Ukraine plan to develop an exceptional level of RES over the next 10 years. The representative of Ukraine also presented their efforts and studies for the gradual integration into the ENTSO-e European interconnection system. All presentations are available at SEERC website www.CIGRE-seerc.org.



Fig. 3.54 Participants of colloquium after walking tour in old city of Sarajevo

2020

6th TAC meeting in Athens, 23–24 January 2020



Fig. 3.55 Participants of 6th TAC meeting in Athens, January 2020

Sixth meeting of Technical Advisory Committee of SEERC was organized after a kind invitation by Greek NC CIGRE and their president Markos Champakis. It was last physical meeting of SEERC activities just before corona virus pandemic. Athens SEERC event was very well-organized as **TAC meeting and as a Workshop.**

A day before official TAC meeting was organized, we had a kick-of-meeting of a new RWG on History of electricity. Interest for this WG was quite high, starting with a history in the old ancient city of Athens. The RWG members were coming from 10 SEERC member countries: Austria, Italy, Greece, Croatia, Serbia, Bosnia and Herzegovina, Kosovo, Slovenia, Turkey, and Ukraine. Approved actions at the Athens meeting were: acceptance of the RWG Terms of Reference (ToR), decision about program of the First Panel on History of electricity, to be held in Vienna during the Third European Regional CIGRE Conference, and context of the next RWG meeting planned for one day before the Panel Session in Vienna. ToR encompasses four significant periods to be studied: Early electrification up to the establishment of CIGRE, Time of systems conception (1921–1951), Time of rising interconnected systems (1951–2000) and Electrification after the energy market introduction. Topics of each period should cover system elements and components, plants, network, education, and system issues. As a first convener of this RWG Maks Babuder from Slovenia was nominated. It was agreed that History WG would be a permanent group, which will organize panels in all future SEERC conferences.



Fig. 3.56 Participants at the kick-off-meeting of RWG History of electricity in Region



Fig. 3.57 K. Reich, W. Hribernik and M. Champakis led 6th TAC meeting in Athens

Focus of Athens meeting was on following subjects:

- 3rd Conference in Vienna, reviewing process for papers, program of the opening Session,
- History book issue
- Leadership of presidency of SEERC after the conference in Vienna,
- Future of SEERC, new ideas on technical challenges, new generation network.

Meeting was attended by 20 experts from 12 countries. Klemens Reich gave an overview of the submitted papers. 129 papers were received, 121 papers were accepted. At least two reviewers should be assigned for each paper in the Full Paper Review Process. 9 tutorials were announced from SCs: A2, D2, C2, B3, B5, C3, B4, C6 and C1, to be presented at conference. Before closing Session two panels were planned: Young Generation Network panel, and History panel with presentation of 6 countries.

Workshop followed TAC meeting

The Greek CIGRE National Committee successfully organized a remarkable Workshop entitled ***"TSO & DSO Interaction in operation and planning",*** which were regionally oriented topics. This event was a part of a regular SEERC (South East European Region of CIGRE) Technical Advisory Committee meeting. All SEERC member countries had the opportunity to report on present significant activities in their electric power utilities.

Presentations came from TSO and DSO utilities from Greece, Italy, Serbia, Turkey, Kosovo, and Austria. The reports were prepared and presented by:

- Ioannis Margaris (IPTO, Greece): *TSO System Development*
- Enrico Maria Carlini (TERNA, Italy): *Visibility & Control of distributed resources*
- Aleksandar Kurcubic (EMS, Serbia): *TSO&DSO Interaction in operation and planning*

- Eirini Leonidaki (HEDNO, Greece): *TSO/DSO Coordination*
- Oytun Alici (ELDER, Turkey): *TSO/DSO Cooperation in Turkey*
- Rexhep Selimi (CIGRE NC Kosovo): *TSO&DSO, Interaction in operation and planning*
- Nikos Hatziargyriou (CIGRE Honorary Member): *Optimal use of Distributed Energy Resources for system flexibility*
- Ninel Cukalevski (PUPIN Institute, Serbia): *TSO-DSO interfaces and IT supported flexibility control*
- Wolfgang Hribernik (AIT, Austria): *TSO/DSO Cooperation in Austria*
- Ioannis Kabouris (IPTO, Greece): *Development of a Regional Security Coordinator at Thessaloniki*

The SEERC Managing Technical body agreed to continue organizing Workshops, which gives the opportunity for exchanging experiences between experts, on topics relevant to regional local conditions and circumstances.



Fig. 3.58 Participants at the Workshop "TSO & DSO Interaction in operation and planning", in Athens, on 24th of January 2020

A day after the Workshop, NC CIGRE Greece colleagues organized a Technical tour to Greece Dispatch Centre out of Athens and a visit to a water reservoir of Athens in Marathon Dam on the Charadros River, near its junction with the Varnavas Stream. At the end of the Technical tour followed visit a famous place of the Marathon battle.



Fig. 3.59 Technical visit of Greek Dispatch centre after the TAC meeting and the Workshop.

3.7 Unofficial SEERC meetings

Between 2009 and 2018 were 6 unofficial meetings with a different agenda. All these meetings were intended to socialize and improve the programs of activities. Table 3.4 presents those SEERC members meetings. First two unofficial meetings were discussed above. Following photos present some friendly atmosphere at all those meetings.

Table 3.4 Unofficial SEERC meetings since 2009

No.	Location of unofficial SEERC meetings	Date
1st	Kranjska Gora, Slovenia	May 26, 2009
2nd	Paris, France	August 29, 2012
3rd	Paris, France	August 28, 2014
4th	Skopje, N. Macedonia	October 10, 2014
5th	Paris, Embassy of Ukraine	August 23, 2016
6th	Vienna, Austria (TAC)	November 8, 2018

3rd Unofficial SEERC Meeting in Paris, 18th August 2014



Fig. 3.60 Meeting in Paris 2014 intended to update working program.

4th Unofficial SEERC Meeting in Skopje, , 10th October 2014



Fig. 3.61 SEERC Meeting in Skopje 2014 with president and new secretary general of CIGRE.

5th Unofficial SEERC Meeting in Paris, 23rd August 2016



Fig. 3.62 SEERC Meeting in Paris was organized in Ukrainian Embassy by Yuriy Bondarenko.

6th Unofficial SEERC Meeting in Vienna, 8th November 2018



Fig. 3.63 Klemens Reich invited SEERC members to an unofficial meeting to Vienna for a discussion on future activities of SEERC

3.8 Regional working groups meetings and Workshops

After first Technical Advisory meeting in Vienna (March 2015) was set up four regional working groups (RWG) were ready to start with activity. Terms of Reference of RWG were confirmed by CIGRE Technical Council chairman Mark Waldron. Kick-off meeting of two RWGs (2 and 3) were announced soon after the TAC meeting that was organized by the Italian NC CIGRE. Location of the meeting was selected close to the project of the submarine cable between Italy and Malta. This project is the longest cable (about 100 km) in the world of submarine cables of 220 kV AC. Cable is leaving Italy (Sicily) near the place of Marina di Ragusa.

WGs worked hard and experts exchanged many interesting information in 2 days meeting. RWG 2 was focused to reactors technology and voltage regulation in modern network with large penetration of renewables. As a result of the meeting came the decision to renovate ToR and invite more experts with system knowledge. Convener Maks Babuder decided to prepare a questionnaire on this topic for all regions and completely renovate ToR.

Second group RWG 3 dealing with submarine cables and environmental issues leading by Massimo Pompili after the meeting decided to merge this regional group with global CIGRE WG and continue working in a new group. From this reasons RWG 2 was abandoned.



Fig. 3.64 The atmosphere for a meeting in typical Sicilian pub was something special



Fig. 3.65 Participants of RWGs at the coast of Marina di Ragusa, Sicily



Fig. 3.66 End OHL tower 220 kV line in Ragusa substation, where OHL passes to the cable.

After WG meetings Professor Massimo Pompili organized a Workshop in collaboration with University of Rome (La Sapienza) on the topic: ***"New ideas and how to efficiently use new technologies for future power system".*** It was a very interesting workshop with a lot of new ideas. Table below presents history of SEERC RWGs activity in the last 5 years:

No.	SEERC Regional working groups (RWG) meetings	Location	Date
1	RWG 2 (Reactors for HV Transmission networks) RWG 3 (Environmental and technical assessment for submarine cables siting issue in Mediterranean area	Marina di Ragusa, Sicily, IT	October 8–9, 2015
2	RWG 1 (Regional aspects on creation of NNA for new standard for overhead lines EN 50341) RWG 4 (Hydro Pump Storages issues)	Zagreb, HR	September 22–23, 2016
3	RWG 1 (Regional aspects on creation of NNA for new standard for overhead lines EN 50341)	Vienna, AT	May 30, 2018

Kickoff meeting of the Regional WG 1 and 4 in Zagreb

Croatian NC CIGRE kindly invited SEERC experts to a meeting of the two working groups, RWG 1 dealing with creation of **National Normative Aspects for the new European standard for construction and design of overhead lines EN 50341,** and RWG 4 dealing with **Hydro Pump Storages issues.** It was a 2-day meeting, first day with the experts for overhead lines in the Region.

Convener of RWG 1 meeting was Kresimir Bakic and on the second day RWG 4 Yuriy Bondarenko convened with a particularly important topic for this Region and even wider Europe. It was the first time that CIGRE focused with an expert group to an HPS issue. In this region there are many Hydro Pump Storage plants, at least one in every SEERC country. First meeting of experts revealed the number of issues regarding the development, economics, and technologies. Today's global HPS presents 99% of all storages of electricity. Group decided to continue work with the renovated ToR.

First meeting of OHLs experts was concentrated to exchange a practice in different countries. Majority of them are members of Cenelec, which are obliged to prepare National Normative Aspects. Exchange of experiences was continued in Vienna RWG 1 second meeting hosting by Austrian NC CIGRE, in May 2018.



Fig. 3.67 Kick-off meeting of RWG 1 in Zagreb, 22nd September 2016



Fig. 3.68 Kick-off meeting of RWG 4, in Zagreb, 23rd September 2016

3rd SEERC-CIGRE Conference in Vienna (Austria) 2020



Austrian NC CIGRE was preparing the Third Conference in accordance with the Technical Advisory Committee of SEERC. Conference was announced to be in Vienna in **June 2020,** but due to coronavirus pandemic situation is postponed to **29th November–2nd December 2021.**

Conference is focused to following topics:

1. *Transition to Future Power Systems in the SEERC Region,*
2. *Across the Border Cooperation in the SEERC Region, and*
3. *Innovation and New Technologies in the SEERC Region.*

Chairman of Conference is Klemens Reich from Austrian Power Grid (APG), and Chairman of Technical Board: Wolfgang Hribernik, from Austrian Institute of Technology.

Organizing and Technical Committee **approved 102 papers** as qualified for presentations at the conference.
For the first topic **38 papers** were selected, for second topic **12 papers** and for the third topic **52 papers.**
All papers were peer reviewed. Papers are coming from 27 countries. The largest number of accepted papers is coming from Austria and Croatia (16).
Each Session covers one topic. It will be 20 papers presented in one Session. Other papers will be at the poster Session.
Session Chairs – Parallel Sessions are.

- Topic 1 - Transition to Future Power Systems in the SEERC Region: Thomas Strasser (Austria),
- Topic 2 - Across the Border Cooperation in the SEERC Region: Kresimir Bakic (Slovenia)
- Topic 3 - Innovation and New Technologies in the SEERC Region: Enrico Maria Carlini (Italy).

The conference will be held at the Radisson Blu Park Royal Palace Hotel in Vienna, which is situated next to some of Vienna's famous tourist attractions – Schloss Schönbrunn, the Museum of Technology and the Palm House greenhouse. Conference program also consists of two panels: **History of electricity** and **New Generation Network** with participation of young engineers from different countries in Region.

Info source for the next CIGRE-SEERC Conference: http://CIGREvienna2020.at/conference/.

All photos used in these 3 chapters are published by credit of the National Committees members of SEERC.

3.10 References for chapters 1, 2, 3

1. The History of CIGRE, *A key players in the development of electric power systems since 1921.* CIGRE Paris, 2011.
2. *The History of CIGRE National Committees, A major contribution to the International history of CIGRE:* Creation and Development of National Committees since the 1920s, CIGRE Paris, 2013.
3. Ishkin V. K., International Council on Large Electric Systems: *"CIGRE History activity 1921–2006",* Orgenergoservis, 2006.
4. *AORC – CIGRE History, Electricity Empowering the Region, Asia-Oceania Regional Council of CIGRE,* Berita Publishing, Kuala Lumpur, 2016.
5. JUKO CIGRE *40 years of work,* 1951–1991. JUKO CIGRE, Zagreb, 1991.
6. *A Fifty year's activities of CIGRE in Croatia,* 1951–2001. Croatian National Committee of CIGRE, Zagreb, 2001.
7. K. Bakič, D. Papler, *The life of the electric power profession in Slovenia, 65/25 years of activity of CIGRE in Slovenia; 25 years of National Committee of CIGRE,* Publishing by NC CIGRE Slovenia, Ljubljana, 2018.
8. *Congres International des Electriciens* 1881, Report of Congress publish by editor G. Masson, Academy of Medicine, Paris, 1882.
9. K. B. Beauchamp: *Exhibiting Electricity,* IEE History of technology series 21, IEE, 1997.
10. K. Bakič, M. Babuder: *Milan Vidmar – A world-renowned electrical engineer,* The Slovenian Association of Electric Power Engineers, Publishing by NC CIGRE Slovenia, Ljubljana, 2011.
11. Albert Čebulj, *Nikola Tesla and creation of polyphase systems,* Symposium dedicated to Nikola Tesla's 120 years, Yugoslav Academy of Science and Art, Zagreb, Smiljan, 1976.
12. F. Hillebrand, *Zur Geschichte des Drehstromes (On the history of the three-phase current),* ETZ 80, pages, 409-461, Berlin, 1959.
13. Rene Pelissier, *Development in CIGRE Organization 1921–1971,* ELECTRA Special Issue Jubilee, Page 159, Paris 1972.

14. A. Cooper, F. Cahen, *The New ELECTRA*, Special Issue Jubile, Page 13, Paris 1972.
15. P. Ailleret, *CIGRE and the Development of the Large Electric Power Transmission Systems*, Special Issue Jubilee, Page 5, Paris 1972.
16. A. Silvestri, *Il Centenario AEI e Galileoo Ferraris, Associazione Elettrotecnica ed elettronica italiana*, 1997.
17. M. Deprez, *Sur le synchronisme électrique de deux mouvements relatifs et de son application a la construction d'une nouvel bussol électrique*, Comptes rendus, No. 96, page 1193, Paris, 1883.
18. A. du Bois-Reymond, *Ein neues System von Wechselstrom Motoren und Transformatoren von Nikola Tesla* - ETZ, Berlin, Juli 1888, S. 343.
19. C. Linsboth, *The Monarchy becomes modern* 1815–1913, www.habsburger.net/let-there-be-light-gas-and-electricity-light-vienna.

4. RESULTS FROM QUESTIONNAIRE

4.1 General on European Regional Cooperation

Part of the data gathered in the outlooks presented in the first part of this section come from ENTSO-E's publications. As of today, ENTSO-E gather 42 TSOs from 35 member countries with the purpose of pursuing "the cooperation of the European TSOs both at the pan-European and regional level" along with actively contributing to the European rule setting process in the field of electricity.
The legislative driver that led to the establishment of ENTSO-E is the Third Legislative Package for Internal Market in Electricity of the European Union, that is the part of the Third Market Package that addresses electricity, consisting in Directive 2009/72/EC and two regulations: Regulation (EC) 713/2009 and Regulation (EC) 714/2009.
For the electricity market, the Third Market Package promotes regional cooperation in order to develop the electricity infrastructures of EU member countries towards the constitution of a single EU integrated market for electricity.
ENTSO-E members share the objective of setting up the internal energy market and ensuring its optimal functioning and of supporting the ambitious European energy and climate agenda. One of the important issues on today's agenda is the integration of a high degree of Renewables in Europe's energy system, the development of consecutive flexibility and a much more customer centric approach than in the past.
ENTSO-E is committed to develop the most suitable responses to the challenge of a changing power system while maintaining security of supply. Innovation, a market based approach, customer focus, stakeholder focus, security of supply, flexibility, and regional cooperation are key to ENTSO-E's agenda.
ENTSO-E shares Europe in different parts and, among them, Continental South East Europe (CSE) are aggregated. According to the 2012 Ten-Year Network Development Plan (TYNDP) package that concerns the CSE region is called the "Regional Investment Plan for Continental South East".
The CSE region of Europe includes the countries listed in the Figure 1, along with their ISO code.

- Romania RO
- Bulgaria BG
- Hungary HU
- Serbia RS
- Montenegro ME
- FYR of Macedonia MK
- Greece GR
- Slovenia SI
- Croatia HR
- Bosnia and Herz. BA
- Italy IT

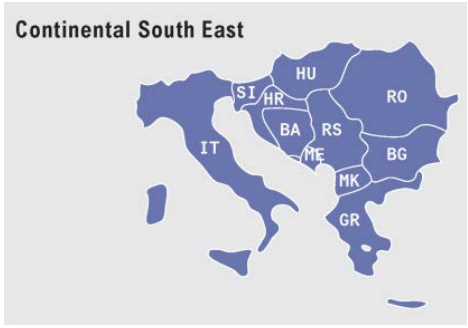


Fig. 4.1 CSE Europe

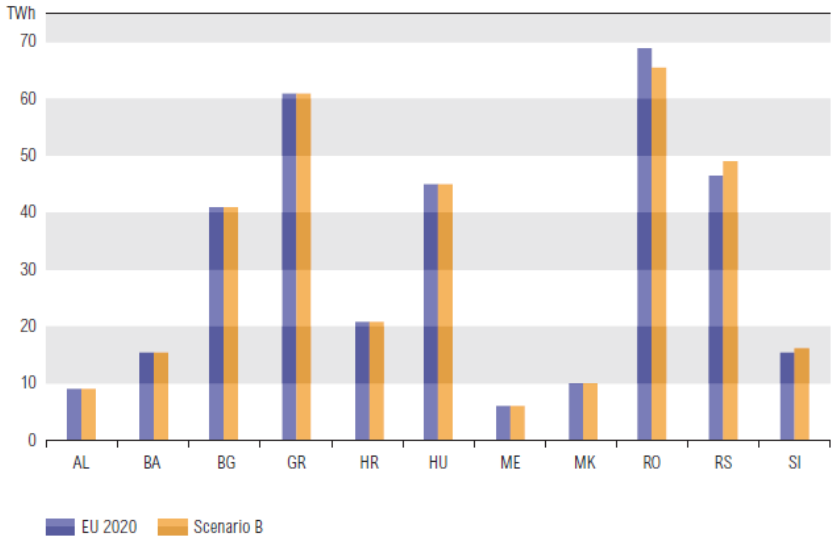
It must be noted that Kosovo was not yet included in the TYNDP 2012 as a sovereign nation. Nowadays, it is considered separately from Serbia. Moreover, Albania is not part of the considered CSE region yet, even if it is at its center. This fact is due to Albania not being part of ENTSO-E as of now. However, Albania cooperates with ENTSO-E, submitting the required data for calculating region wide quantities.
According to the last update (2019), the countries who joined CIGRE - SEERC are: Austria (AT), Bosnia and Herzegovina (BA), Croatia (HR), Georgia (GE), Greece (GR), Hungary (HU), Israel (IL), Italy (IT), Kosovo (XZ), Montenegro (ME), North Macedonia (MK), Romania (RO), Serbia (RS), Slovakia (SK), Slovenia (SI), Turkey (TR) and Ukraine (UA).

According to ENTSO-E, the scenario 2020 consists of the following forecasts:

- Demand [TWh]
- Installed Capacity [GW]
- Detailed Generation [TWh]
- Net Import Balance [TWh]
- CO_2 Emissions

According to TYNDP 2012, the expected energy consumption for the year 2020 is shown in Figure 2.
Two different scenarios have been simulated by ENTSO-E for the entire region, both for the year 2020. They represent different possibilities of the main variables involved in the behavior of the systems and thus, the markets:

- the first scenario has been referred to as the "EU 2020", and represents a context in which all objectives of the European 20-20-20 are met (20% of RES in the final energy, 20% reduction of GHG, and 20% increase in energy efficiency);
- a second scenario has been referred to as "Scenario Best Estimate", or "Scenario B", and represents the best estimate conditions of the TSOs, regardless of whether or not European objectives are globally met.



	AL	BA	BG	GR	HR	HU	ME	MK	RO	RS	SI
	9	15	41	61	21	45	6	10	68	46	15
	9	15	41	61	21	45	6	10	65	49	16

Fig. 4.2 Forecast of Demand in 2020

The demand should reach an aggregated value of approximately 340 TWh. There are very few differences between the two scenarios. Only Serbia and Slovenia have forecasted a small increase of demand in Scenario B with respect to EU2020 while Romania is expecting a decrease in demand for the same framework.

4.2 Questionnaire

One of the deliverables of the cooperation is the compilation of the results of the CIGRE - SEERC Questionnaire on the creation of the activity program. This document is aimed at surveying and collecting the opinions of the representatives of the SEERC National Committees. The survey is essential in establishing a platform of common interests and voluntary commitment to manage better the Regional CIGRE cooperation.
The first Questionnaire was launched in 2013 with reference at the year 2012. This first questionnaire concerned simply items referred to the following items:

1. technical data of the member's country;
2. important questions for building cooperation arrangement:
    - technical field of electric power engineering for regional CIGRE cooperation;
    - technical areas that the representative would like to chair at a regional level;
    - proposal of technical subjects that are regionally interesting;
    - survey on the possible managerial bodies of CIGRE - SEERC, considering efficiency of operations;
    - suggestions on publication methods and information exchange between CIGRE - SEERC members;suggestions on the kind of conferences in competency of CIGRE - SEERC.

The countries that responded to this first questionnaire were Bosnia and Herzegovina, Montenegro, Croatia, Serbia, Ukraine, Slovenia, Italy, Macedonia, Romania and Greece. The results were gathered and organized by Prof. Massimo Pompili of University of Roma "La Sapienza" and were presented at the Belgrade CIGRE - SEERC Meeting, that took place in November 2014.
During the 2018 it was launched a second 2019 SEERC Questionnaire with the aim to update (year 2017) and enlarge the technical data of SEERC common interests, looking also at the development of further cooperation among the SEERC members. Due to voluntary approach of the present activity it is possible that inhomogeneous results sorted out which are anyway very useful for the development of SEERC activity.
In this chapter are reported the results of the second SEERC Questionnaire which includes sections related to energy technical data, academia, technical areas of interest and additional proposals. Other information reported here comes from World Bank database. First results on CO_2 reduction efforts are

also reported in view of the present and future challenges to tackle the climate changes inside SEERC region.

The countries that responded to the Questionnaire were: Austria, Bosnia and Herzegovina, Croatia, Georgia, Greece, Hungary, Israel, Italy, Kosovo, Montenegro, Romania, Slovenia, Turkey and Ukraine. At the printing moment, some results from Czech Republic, North Macedonia and Slovakia are still missing.

The results were again organized in aggregate graphs and tables by Prof. Massimo Pompili of the University of Roma "La Sapienza"; the same results were anticipated and discussed at the 5th SEERC TAC Meeting held in Split (Croatia) on March 2019. Such results are reported in the forthcoming sections and are divided as in the following parts:

- general data in CIGRE - SEERC member countries;
- energy situation in the CIGRE - SEERC member countries;
- assets and employments in electrical sector for CIGRE - SEERC member countries;
- academia situation for CIGRE - SEERC member countries;
- mutual cooperation and field of common interest for CIGRE - SEERC member countries.

4.3 Results of 2019 Questionnaire in CIGRE – SEERC member countries

a) General data

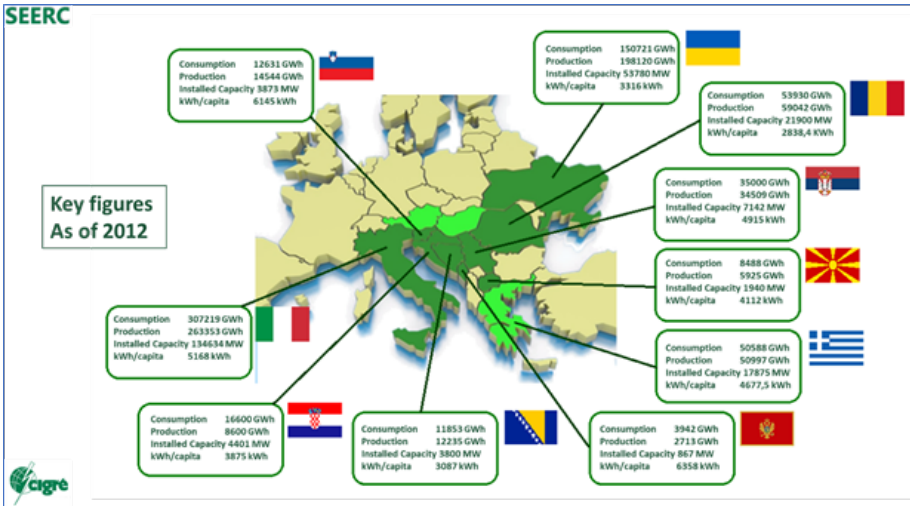


Fig. 4.3 Key data for CIGRE - SEERC member countries in (2012)

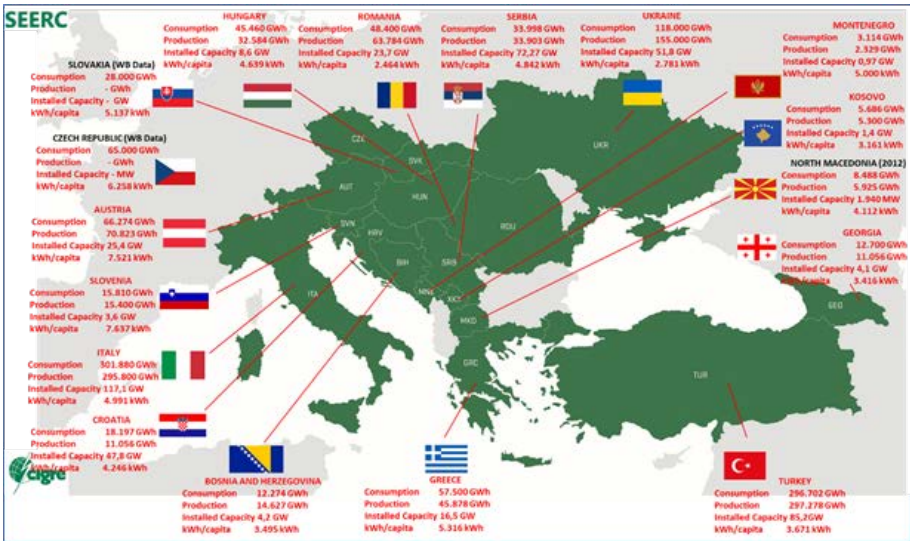


Fig. 4.4 Key data for CIGRE - SEERC member countries in 2017[2]

[2] Israel became a SEERC member in 2019.

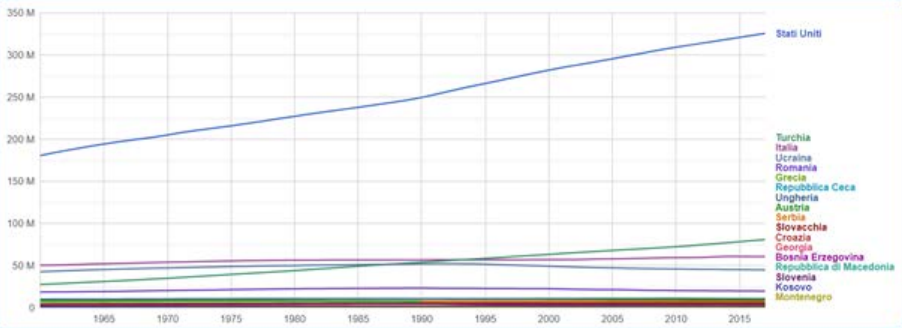


Fig. 4.5 Population of CIGRE - SEERC member countries compared with USA (WB data)

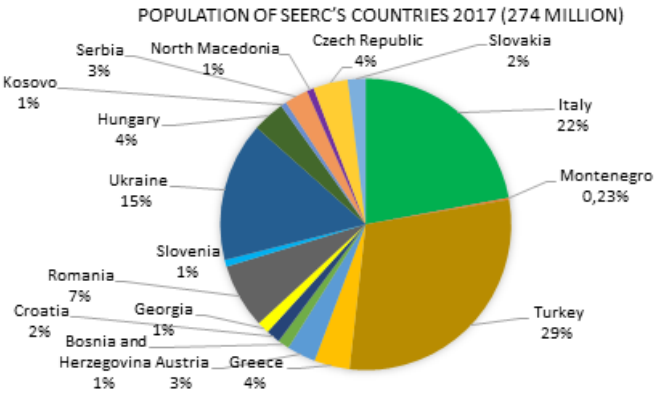


Fig. 4.6 - Population of CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia are estimated

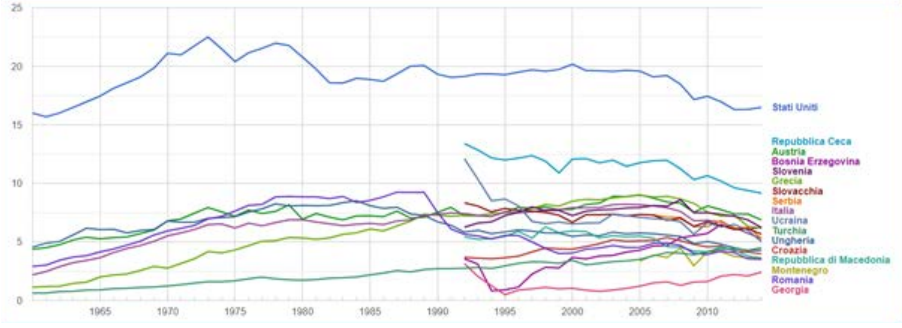


Fig. 4.7 CO_2 emission [ton/capita] of CIGRE - SEERC member compared with USA (WB data)

b) Electrical outlook

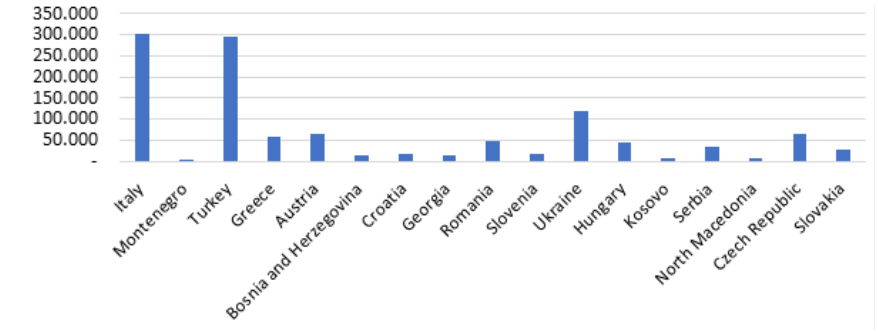


Fig. 4.8 Electrical consumption (GWh) of CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia are estimated. Total in SEERC member countries: 1,138,000 GWh

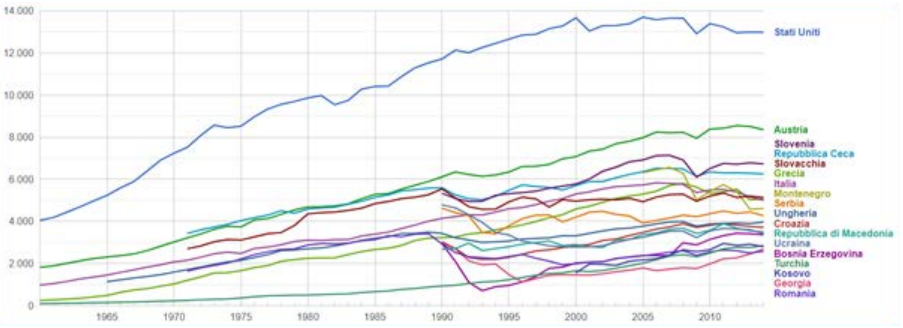


Fig. 4.9 Consumption/capita (kWh/capita) of CIGRE - SEERC member countries (WB data)

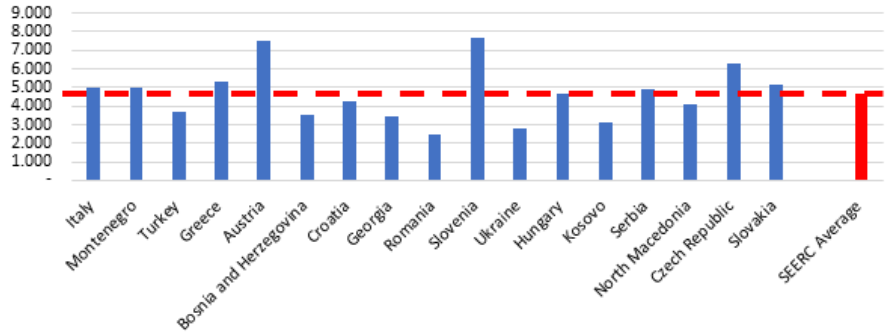


Fig. 4.10 Electrical consumption/capita [kWh/capita] of CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia are estimated

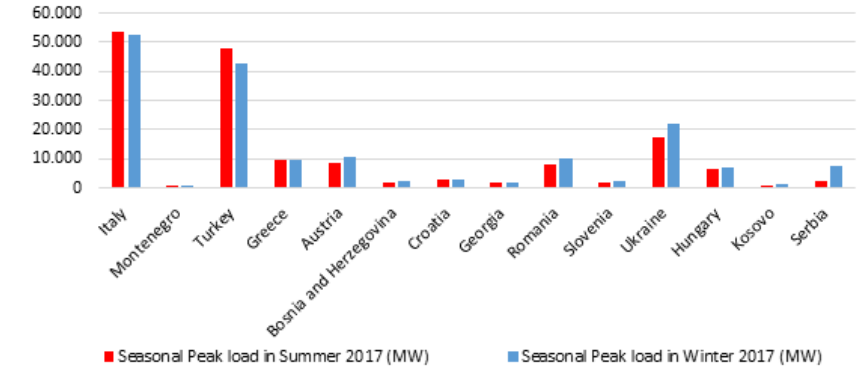


Fig. 4.11 Seasonal electrical peak load in 2017 (MW) of CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia are not available

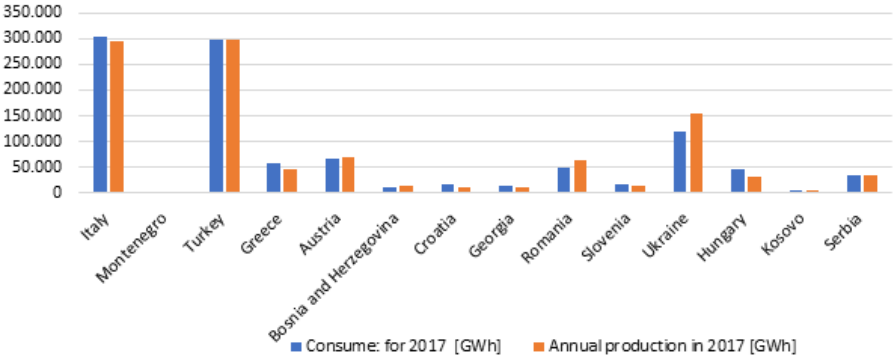


Fig. 4.12 Electrical demand and production in 2017 (GWh) of CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia N.A.

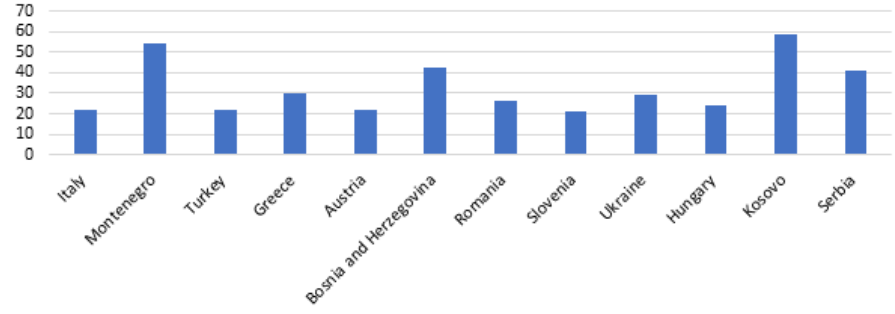


Fig. 4.13 Electrical household demand [%] of CIGRE - SEERC member countries in 2017. Data for Croatia, Georgia, North Macedonia, Czech Rep. and Slovakia N.A.

c) Assets and employments in electrical sector

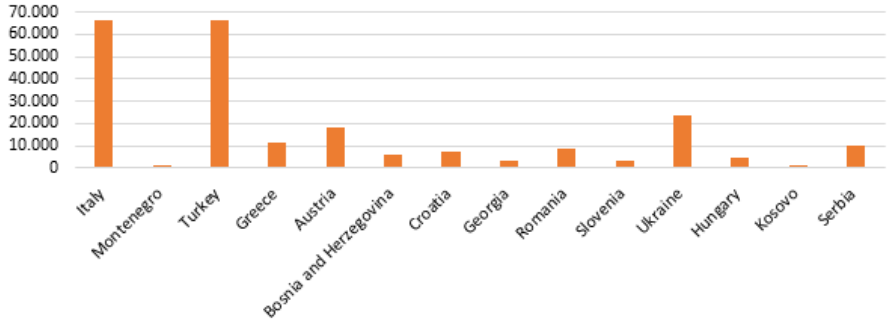


Fig. 4.14 Extension (km) transmission and distribution overhead lines and underground/ undersea cables (100–750 kV) in CIGRE - SEERC member countries in 2017. Total extension in SEERC: 233,000 km (2017). Data for North Macedonia, Czech Rep. and Slovakia N.A

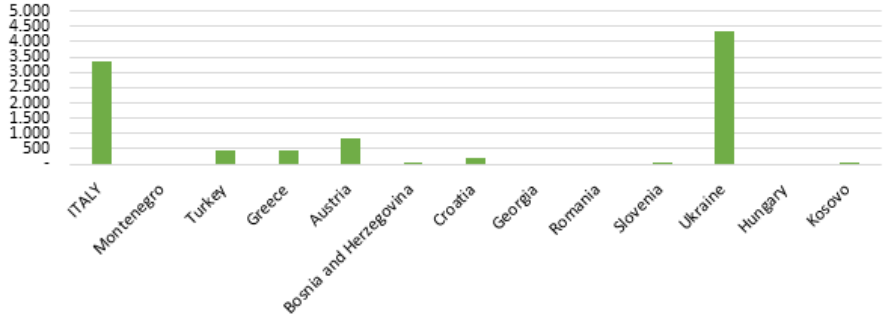


Fig. 4.15 Extension (km) of electrical transmission underground/undersea cables (100–750 kV AC and DC) in CIGRE - SEERC member countries in 2017. Total extension in SEERC: 9,605 km (2017). Data for Serbia, North Macedonia, Czech Rep. and Slovakia N.A.

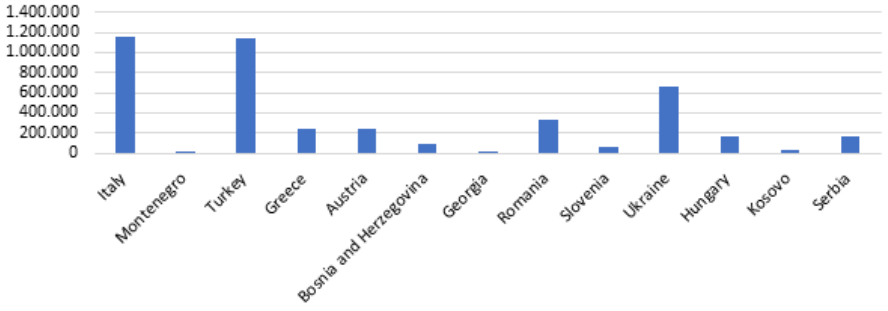


Fig. 4.16 Extension (km) of electrical distribution network (0,4–100 kV) in CIGRE - SEERC member countries in 2017. Total extension in SEERC: 4,300,000 km (2017). Data for Croatia, North Macedonia, Czech Rep. and Slovakia N. A.

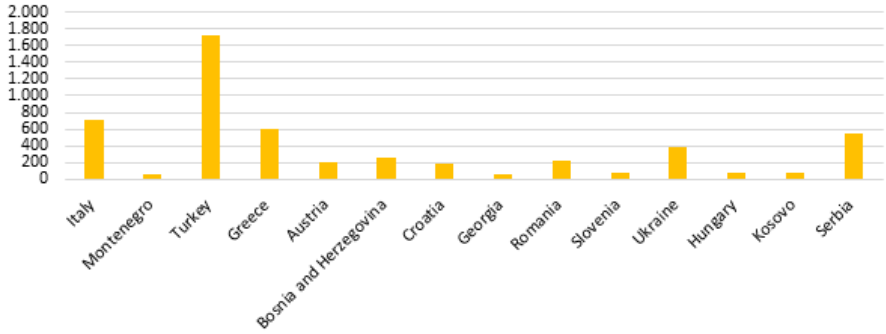


Fig. 4.17 Number of power transmission transformers (100–750 kV) in CIGRE - SEERC member countries in 2017. Total units in SEERC >5,200 (2017). Data for North Macedonia, Czech Rep. and Slovakia N.A.

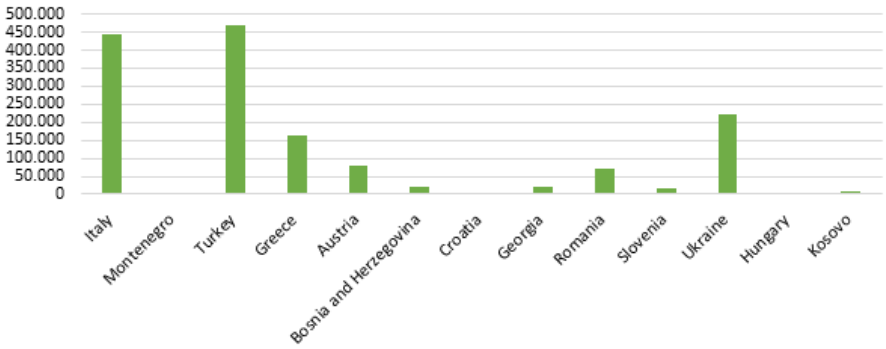


Fig. 4.18 Number of distribution transformers (0,4–100 kV) in CIGRE - SEERC member countries in 2017. Total units in SEERC > 1,522,000 (2017). Data for Croatia, Hungary, Serbia, North Macedonia, Czech Rep. and Slovakia N. A.

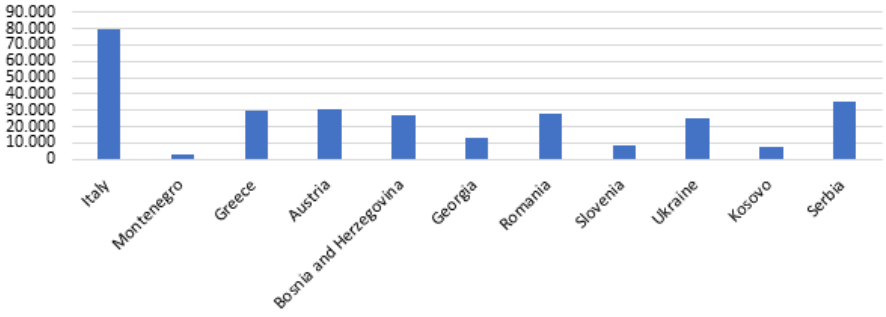


Fig. 4.19 Level of employment in the electric industry of CIGRE - SEERC member countries in 2017. Total employee in electricity industry >290,000 (2017). Data for Croatia, North Macedonia, Czech Rep., Slovakia, Turkey N.A. Hungary not represented being inhomogeneous.

d) Academia

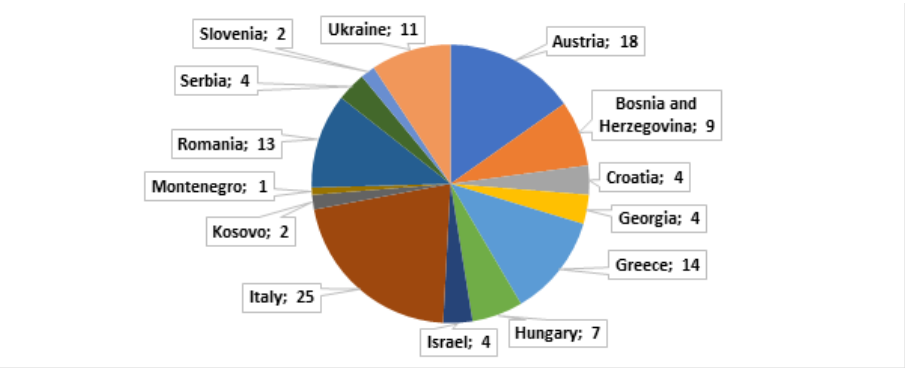


Fig. 4.20 Number of universities having electrical engineering courses in CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia N.A. Turkey not represented being inhomogeneous.

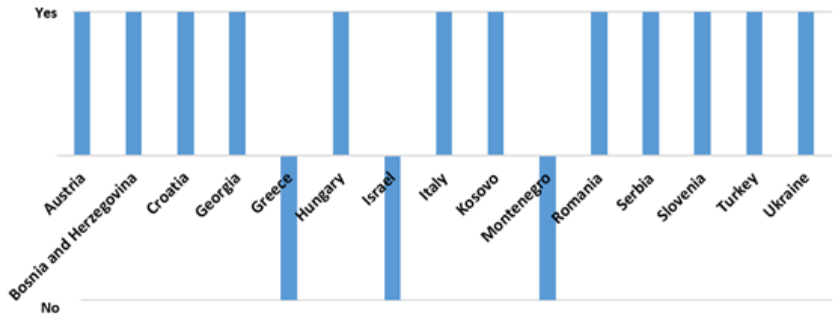


Fig. 4.21 Presence of electrical courses (bachelor, master, PhD) given in English in CIGRE - SEERC member countries in 2017. Data for North Macedonia, Czech Rep. and Slovakia N.A.

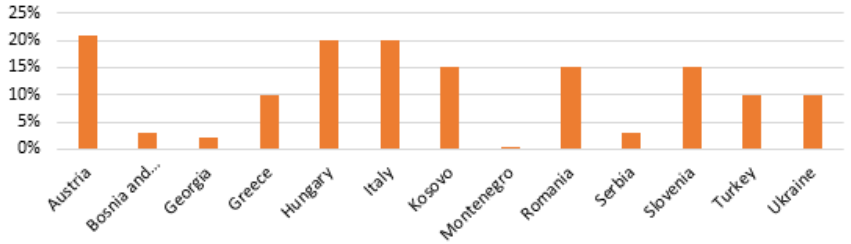


Fig. 4.22 Master and bachelor students (in %) moving abroad within Erasmus or similar international cooperation programs in CIGRE - SEERC member countries in 2017. Data for Croatia, North Macedonia, Czech Rep. and Slovakia N.A.

e) Cooperation and field of common interest

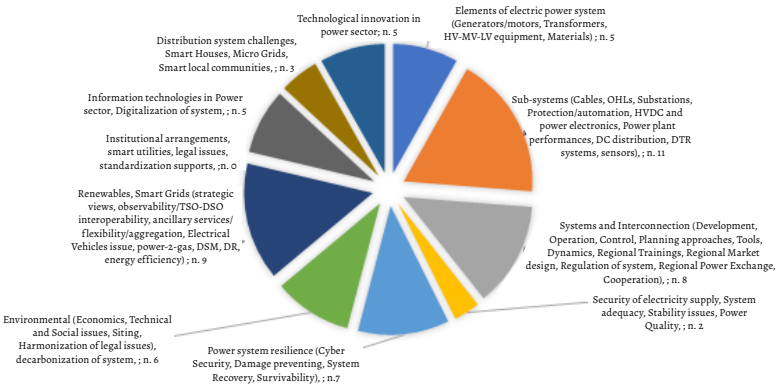


Fig. 4.23 Technical fields of interests for Regional CIGRE cooperation of CIGRE - SEERC member countries in 2017. Data for Serbia, North Macedonia, Czech Rep. and Slovakia N.A.

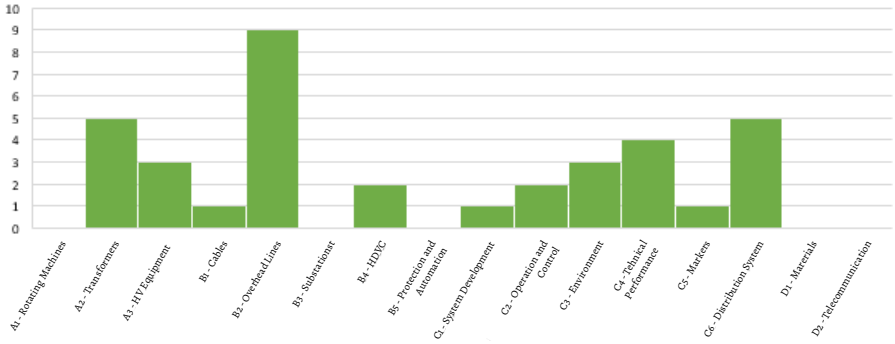


Fig. 4.24 Technical areas to contribute of CIGRE - SEERC member countries in 2017. Data for Serbia, North Macedonia, Czech Republic and Slovakia N.A.

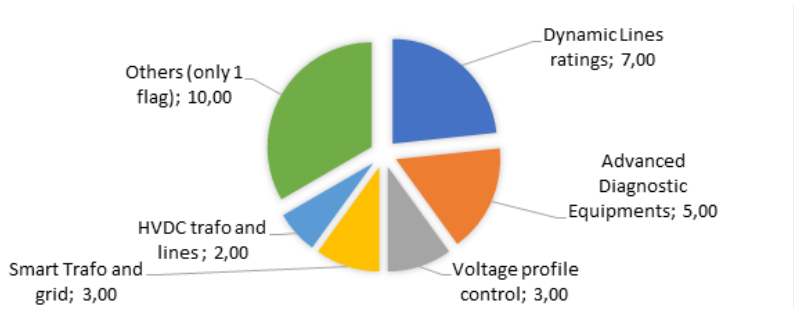


Fig. 4.25 New topics recently introduced in CIGRE - SEERC member countries (2017). Data for Serbia, North Macedonia, Czech Rep. and Slovakia N.A.

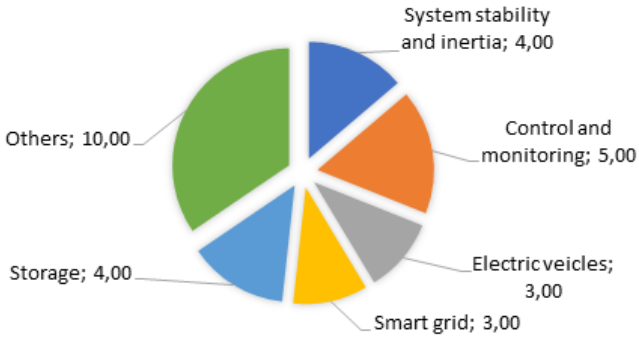


Fig. 4.26 Mature topics for WG/TF of SEERC member countries (2017). Data for Serbia, North Macedonia, Czech Rep. and Slovakia N.A.

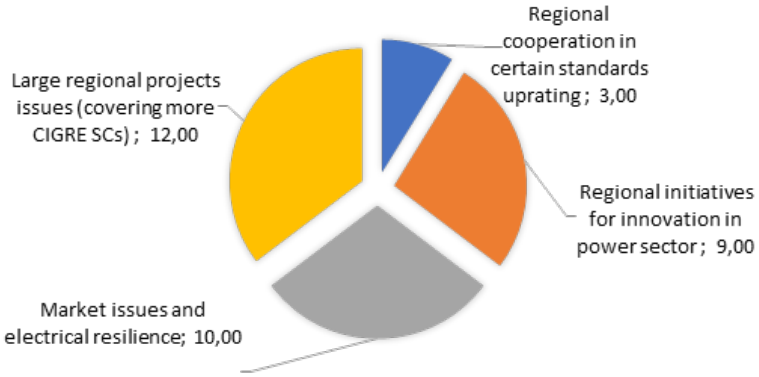


Fig. 4.27 Specific areas of interest in SEERC member countries (2017). Data for Serbia, North Macedonia, Czech Rep. and Slovakia N.A.

4.4 References

1. ENTSO-E (2012), "Regional Investment Plan Continental South East 2012", final, July, 2012.
2. World Bank statistics 2018 (https://www.worldbank.org/)
3. ENTSO-E (2020), "TYNDP 2020 Scenario Report", June 2020

5. NC CIGRE AUSTRIA

5.1 History of the electric power sector

a) History of electrification before 1945

The development of the electricity industry in the Austrian-Hungarian Monarchy started in 1873, when an electric machine supplied the industrial company Krupp with electrical energy for the first time. In 1878, the first arc lamps burned at the Vienna ice-skating ring, in 1883, the first 120 kW generator was put into operation and since 1886 the first public electricity company has supplied the city of Scheibbs in Lower Austria with electricity. The breakthrough came with the International Electrotechnical Exhibition in Vienna 1883.

International Electrotechnical Exhibition in Vienna 1883
The exhibition was a great success with 870,000 visitors and 575 national and international exhibitors. The event is generally considered as the turning point of electricity in the region, which at that time was the Austrian-Hungarian Empire, and over whole Europe. An electric narrow-gauge railway transported visitors in the big area of the exhibition.

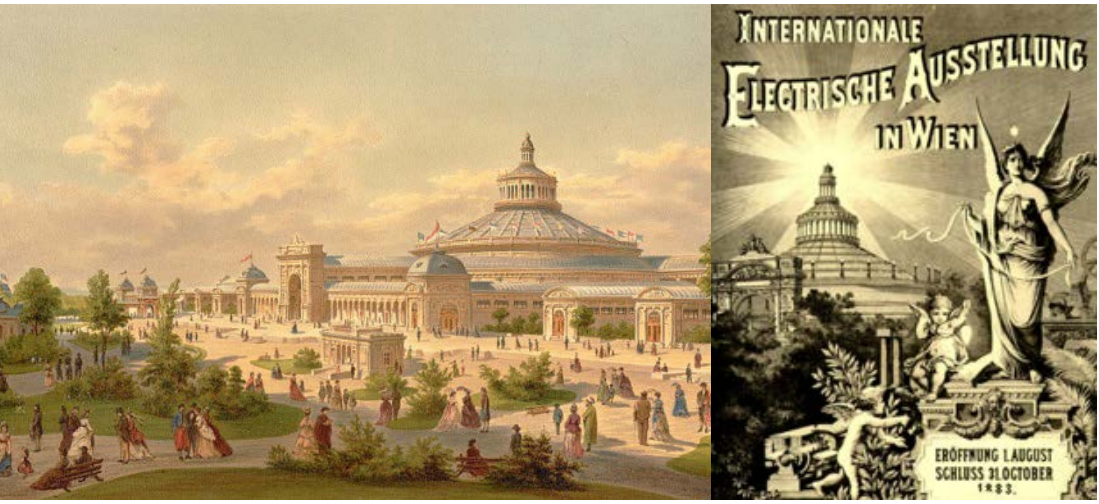


Fig. 5.1 International Electrotechnic Exhibition in Vienna 1883, Location "Rotunde"

The place of the exhibition "Rotunde" was the largest cupola building in the world for almost one century. Electric lamps produced in Czechia, Germany as well as Hungary illuminated the exhibition with the power of more than ten thousand candles. Zipernowsky also presented a 150 PS steam powered single-phase generator, which was a big step for the alternating current industry respective for the AC supporters. Werner Siemens presented a transatlantic cable and the necessary apparatus.
Another highlight of the exhibition was the electric tram between Mödling and Hinterbrühl south of Vienna, over a length of 4.4 km. The trains ran with 500 V DC, it was worldwide the first permanent railway which was feed by an overhead contact line. The route was dismantled 1932.

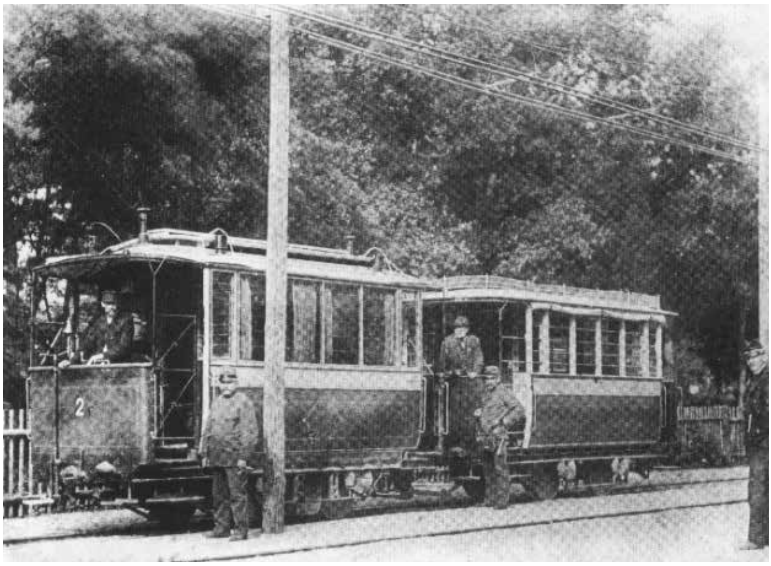


Fig. 5.2 The electric tram from Mödling to Hinterbrühl, south of Vienna 1883

The first electric elevator was presented, but its cost were too high for immediate general applications. An electric boat with 78 accumulators was able to transport up to 40 people on 60 km of Danube river from Vienna to Bratislava (today in Slovakia). The International Electrotechnic Exhibition was an important booster for the future development of electrotechnics in the whole region.

Development in the late 19th and early 20th century

After the International Electrotechnical Exhibition in Vienna 1883, the rapid expansion of local generating capacity continued within hundreds of communities and private utilities until 1918. Cheap coal was available from Bohemia, Moravia and Silesia, provinces of the Monarchy at the time. This led to a big number of coal-powered plants, whereas hydropower was of limited economic interest. After the First World War, coalmines of former Monarchy´s regions were now in other counties and Austria had to find other sources for electricity production. The construction of hydroelectric equipment was promoted rapidly and from 1918–33 the hydraulic generating capacity increased from 240 MW to 725 MW. Depending on the local geographic and topographic conditions, in the east of the country steam and in the west and south hydroelectric plants were built.

In 1930, the first 110 kV power overhead lines were put into operation, one line connecting Styria and Vienna and another connecting Upper Austria and Vienna. Several big electricity utilities were established, with strong participation from regions, big cities, banks and private investors. E.g., the Viennese municipal utility was founded in 1899.

The idea to develop Austria´s hydropower resources in a broader European view dates back to the 1920ies. Large power plants were built e.g. in Vorarlberg with the partial goal to deliver energy abroad, mainly to Germany. The plans for strong international transmission line connections were developed and their building started.

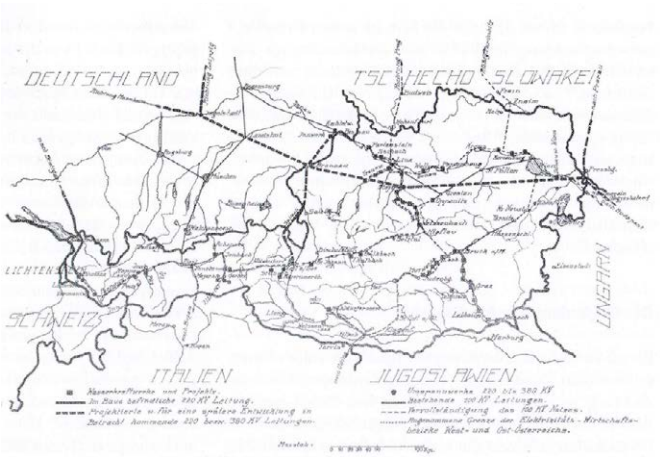


Fig. 5.3 Transmission line projects in Austria and interconnecting lines to neighboring countries, map from 1929

The annexation to the German Reich in 1938 signified the inclusion of Austrian power resources as part of the German overall planning. E.g., the Electricity Law was introduced in Austria and the "Alpen-Elektrowerke AG" were established. This development served as the base for many big hydropower projects. Prisoners of war and from concentration camps had to work on many building sites for these plants.

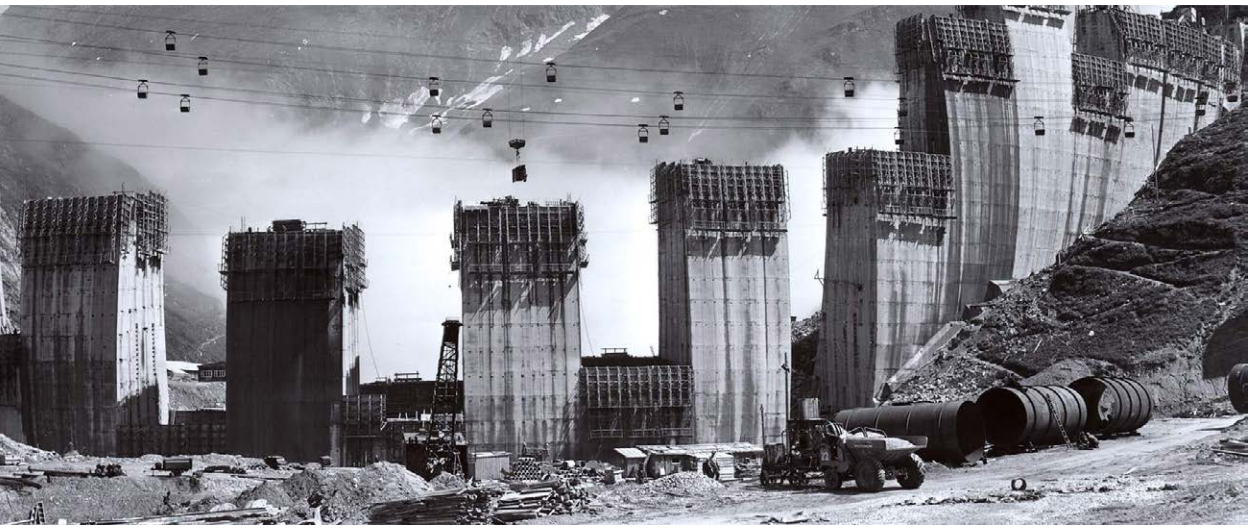


Fig. 5.4 Building the dam for the pump-storage power plant Glockner-Kaprun in the 1940ies

b] History of the electric power sector after 1945

At the end of the Second World War several power plants were destroyed or damaged. Some plants were under construction and needed to be completed. The electricity supply in the first years after the war was characterized by insufficient production, outages and missing transport capacities. The private and industrial consumption raised. To overcome this problem, a federal law in 1947 gave the rules for the new organization of the Austrian power economy. The company "Österreichische Elektrizitätswirtschafts AG - Verbundgesellschaft" (now VERBUND) acting as a holding company for the Federal State was founded. Most of the private and communal utilities were nationalized.
Four "Sondergesellschaften (Special Companies)" were established with the goal to reactivate and build new run of river and (pump) storage plants:

- Ennskraftwerke
- Österreichische Donaukraftwerke
- Österreichische Draukraftwerke
- Tauernkraftwerke
- "Landesgesellschaften (Provincial Companies)" and large municipal utilities got the duty to provide the distribution and to deliver energy to the consumers in their provinces. Today they are joint stock companies with the stock majority owned by the Federal Provinces:
  - KELAG in Carinthia
  - NEWAG in Lower Austria
  - OKA in Upper Austria
  - SAFE in Salzburg
  - STEWEAG in Styria
  - TIWAG in Tyrol
  - VKW in Vorarlberg
  - WEW in Vienna

Five electricity companies provided electricity to the regional capitals of Graz, Linz, Salzburg, Klagenfurt and Innsbruck. Industry-owned power plants were built to supply the enterprises. Apart from these plants, hundreds of smaller privately owned power plants existed and exist.
A very important help after the war for the country in general and also for the establishment of the power sector came from the European Recovery Program ERP "Marshall-plan". As an economic stimulus plan from the USA, the plan mainly included food, raw materials, goods and credits. Between 1948 and 1954 roughly 3 billion Schilling were available from the Marshall-plan for the development of the electricity supply.
The installed capacity in 1945 was 1,500 MW (1,200 hydro, 300 thermal) and grew to 2,200 MW in 1951 (1,500 hydro, 700 thermal). 1959 approximately 2,050 plants with more than 10 kW power existed, which were owned by 1,100 companies. 500 of these companies, with around 1,000 power stations of more than 200 kW produced 99 % of the entire electrical energy.
The increase of electricity consumption in Austria in the years after the war was remarkabe:

- 1946–1951: +60%
- 1951–1956: +240%

This increase was much higher than in other Western European countries in the same time.

Until today, the pump storage power plants Glockner-Kaprun (1955) and the run of river plant Ybbs-Persenbeug on the Danube river are national symbols for the reconstruction and recovery after 1945. The "Lünerseewerk"in Vorarlberg was the most powerful pump storage power plant in the world at that time.



Fig. 5.5 View of the pump storage power plant Glockner-Kaprun (energized 1955)

Many ideas and studies for power plants from the 1920ies and 1930ies and even older, were updated under the new environment and led to ambitious new and big projects in the high Alps and along rivers. An example of such projects is the chain of run of river plants at the Danube River from the Austria / German border near Passau to the Austrian / Slovakian border near Hainburg. Not all of them have been built yet.

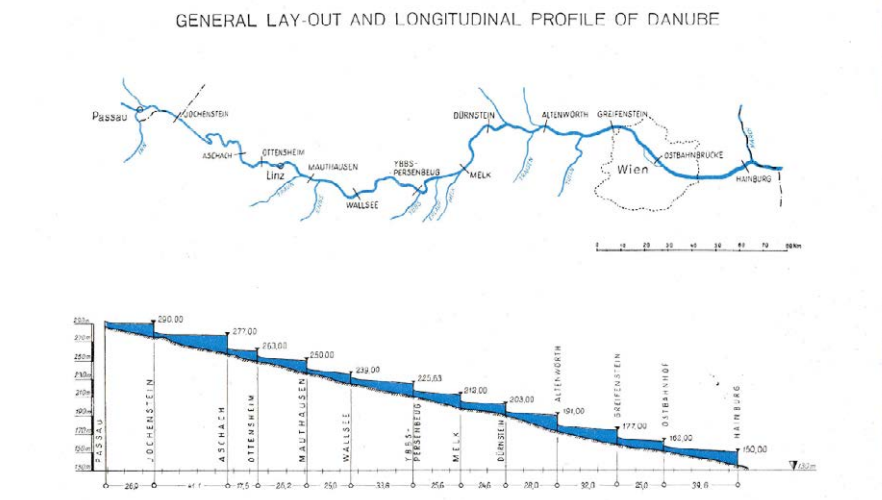


Fig. 5.6 Projects of hydro power plants along the Danube river from the 1940ies

New overhead lines became necessary to connect the centers of production with the centers of demand. Special importance had the main east-west transmission 220 kV line from Kaprun (Salzburg) via Ernsthofen (Lower Austria) to Bisamberg (Vienna). This line was built in two sections: Kaprun -Ernsthofen

was energized in 1949 and the whole connection from Kaprun to Bisamberg only two years later in 1951. Another east-west line was the 220 kV line from Kaprun via Gerlos (Salzburg/Tirol) to Bürs (Vorarlberg) to connect the hydro power stations in Tyrol and Vorarlberg with the eastern grid of the country. Transmission lines from Vorarlberg to Germany´s plants in the brown coal area allowed the exchange of power between peak load and base load. The line from Bürs via Herbertingen to Brauweiler is an example for such a line. Connections to Italy crossing the high Alps were projected.



The picture below shows existing 220 kV and 400 kV transmission lines and projects as from 1949. Austria in this presentation is concerned with lines to Germany, Italy, Czechoslovakia and Switzerland.

Fig. 5.7 Existing 220 kV and 400 kV transmission lines and projects in 1949

Another important step for the security of the grid and the public transport was the coupling of the public network with the 16 2/3 Hz grid of the federal railways to take into account the substitution of steam traction by electric traction.
The route length of Austrian transmission lines as from the year 1952 show 552 km 220 kV lines and 1,721 km 110 kV lines for the country.
To support the European interconnections, the "Union pour la Coordination de la Production et de Transport de l´ Electricité" UCPTE was established (later UCTE and now ENTSO-E). Austria supported this processes from the beginning.

In the late 1980ies a High Voltage Direct Current HVDC back-to-back link was built in the substation "Wien Südost" to connect the western and eastern European grids with a capacity of 500 MW. More of such back-to-back link projects were cancelled after the fall of the iron curtain in 1989 and the connection of the both grids systems a few years later.
Till to the 1990ies big power plants were built, old ones being upgraded as storage plants in Tirol, Carinthia, Vorarlberg and along the rivers Danube, Drau and Ill. Nowadays the storage power plants allow the exchange of energy from wind and solar production and became partners for the energy transition.
Nuclear energy has been used and forced in many countries, mainly to compensate thermal production. In 1978 the Austrian population voted against the use of nuclear energy in the country. A constitutional law was issued to forbid the use of atomic energy. This situation is unchanged till today. As substitution for the planned nuclear power plant in "Zwentendorf", coal fired plants in Dürnrohr and Styria were built, both are shot down now. But also the increased construction of hydro power plants is being criticized more and more. In 1984 the projected Danube run of river plant in "Hainburg" east Vienna was cancelled due to the ongoing protests. The last project and most probably final one along the Danube was the plant in Vienna 1998.
From the 1980s on ecologic aspects and measures got more and more attention and are nowadays standard during planning, erection, maintenance and extension of all electric facilities for production and transmission of electricity.
The structure of the electrical energy business in Austria has been altered during the last decades. From 1987 privatizations up to a certain percentage were legally possible and many of the above mentioned companies went partially public. Especially in the last decade, the production from wind energy increased significantly in Austria.

c) People shaping the Austrian Electricity Sector

Josef Stefan



Josef Stefan (1835–1893) was a mathematician and physicist of Slovenian mother tongue from Carinthia.
After studying mathematics and physics at the University of Vienna Dr. Stefan finished his doctorate in 1859 and habilitated in mathematical physics and became a professor of higher mathematics and physics at the University of Vienna in 1863. Only 28 years old, he was the youngest full professor at the time in the k. u. k. Monarchy. Two years later he became the director if the Physics Department, and in 1876 he became the rector of the University of Vienna. Throughout his career Josef Stefan published over 85 scientific articles. Amongst a wide variety of different topics he also calculated induction coefficients of wire coils. However, he made his most significant scientific contributions to the kinetic gas theory, as well as the radiation of black bodies. Stefan and Helmholtz succeeded in implementing Maxwell's theory in Europe, which deals with electromagnetic fields in static media.
In 1879 he expressed the radiation law which was named after him and Ludwig Boltzmann in 1897. This law was theoretically differentiated by his student Boltzmann in 1884. This was the first time Stefan was able to calculate the temperature of the sun's surface. Nowadays the "Stefan-Boltzmann constant" is one of the differentiated natural constants.
Dr. Josef Stefan also worked for his industry beyond his company's boundaries. In 1883, together with Prof. Ernst Mach and Siegfried Marcus he was one of the founders of the "Elektrotechnischer Verein in Wien (EVW)", today known as Austrian Association for Electrotechnics (OVE) and became its first president.

Franz Pichler



Franz Pichler (1866–1919) was an engineer and inventor and is considered one of the pioneers of electrical engineering in the Monarchy.
In 1892 Franz Pichler founded the "Weizer Elektrizitätswerke F. Pichler & Co." He built his first power station at the same time to present the city of Weiz in Styria in a new (electric) light. Pichler also developed a variety of measuring instruments and transformers. From these

early beginnings the ELIN industrial group emerged, which now has become part of the Siemens group (transformers) and Andritz AG (generators).
Building on the pioneering work of Franz Pichler in Weiz, one of the largest private power supply companies in Austria, the Pichlerwerke developed, which were eventually taken over by Energienetze Steiermark.

Josef Stern



Josef Stern (1849–1924) was a building contractor and civil engineer in Vienna. He pioneered technologies in the railway, electricity and mining sector. In 1883, together with Franz Hafferl, he founded the engineering bureau Stern & Hafferl in Vienna and the construction company Stern & Hafferl OHG, which was responsible for the realization of numerous mechanical and electrical facilities in the Monarchy.
By building numerous hydropower plants and overland lines, Stern created a rapid and comprehensive supply of electrical power in most of Upper Austria and beyond. He built several local railways in Upper Austria and these lines are still in operation today. The Vienna University of Technology awarded him a honorary doctorate in 1911 for his services to technical development in the energy sector. He also became known as the author of specialist books such as *The Economics of Local Railways, The Steam Tramway, Construction and Operation* and *The Stone Crash and Its Insurance Buildings*.

Franz Hafferl



Franz Anton Hafferl (1857–1925) graduated in Karlsruhe, Germany, where he studied civil engineering.
While working at Krauß & Company Locomotive Factory he met Josef Stern. Together they founded the Engineering Bureau Stern & Hafferl in Vienna and the construction company and electricity plants Stern & Hafferl AG. The two friends carried out the electrification of Upper Austria and Salzburg. Franz Hafferl was responsible for the routing of electric power lines as well as the planning and installation of railway systems. In addition to numerous railways in the Alps, he designed railways in other European countries, such as Galicia, Bukovina, Romania and Bosnia and became an internationally recognized expert. After

the death of his friend and Cofounder Josef Stern in 1924, Hafferl became appointed President of the power plant Stern & Hafferl AG and the Gmundner Elektrizitätswerke AG in Upper Austria.
With a wide range of interests, he achieved success in the further development of surveying technology, photography, zoology and paleontology. Study trips took him to Norway, Russia, Algeria and Egypt. In 1910 and 1911 he carried out photogrammetric investigations of the movement of the Lower Aare Glacier (Switzerland). In 1912 he studied the remains of prehistoric horse breeds in Pikermi near Athens. Hafferl is one of the pioneers of photogrammetry in modern land surveying.

d) Companies shaping the Austrian Electricity Sector

A wide range of various companies helped shaping the national landscape of the electricity sector. In the following chapter selected companies and chapters of the Austrian history are presented.

The example of the electrification of the railway system
In 1883 the first electrified section of the Austrian railway was officially put into operation. This railway, operated by the "Österreichische Südbahngesellschaft", had an operating voltage of 550 V DC at a gauge of 1,000 mm. As the electrical equipment proved to be reliable, it was rented out as early as 1887 and sold in 1896.
In the gunpowder factory of the "Wöllersdorfer Werke" in Lower Austria, the company´s railway was electrified with three-phase current. The reason was to avoid flying sparks from the dangerous steam operation. This led to the development of the world's first high-voltage locomotive. The limited controllability of three-phase motors at that time and the complicated overhead line led to the fact that this system was not pursued further in Austria.
The solution became apparent in 1903, when single-phase alternating current with a frequency of 25 Hz was first applied on an experimental track in Berlin. The report and the 1906 application for the electrification of the Mariazeller-Bahn in Lower Austria was the basis for the introduction of single-phase alternating current technology to operate Austrian railways. The Mariazeller-Bahn was built from 1907 to 1911. Taking into account the difficult alpine terrain, the narrow tunnels, the small radii of up to 80 m and finally the

necessary new design developments, this was an enormous achievement for many fundamental questions of railway electrification. In contrast to trams, the overhead contact line was constructed using massive supporting structures and steel masts. It was not possible to fall back on extensive experience. The bar-driven locomotives of the original series "Reihe E" could remain in service for 103 years and did not have to be replaced by new railcars until 2013. The power stations for the supply of energy were built under the most difficult conditions in the mountainous landscape, were also used to supply the region with electricity and formed the foundation stone for the Lower Austrian provincial energy company NEWAG, today EVN AG.

The construction of the Austrian-German Mittenwald Railway, which opened in 1912, and the Außerfernbahn Railway, which opened in 1913, both between Austria and Germany, established principles that are still valid today. During the planning of the railway, a comparison of the traction types led to the conclusion that only electric traction was a viable option due to the steep gradient; otherwise the route would have been much longer, more complex and above all more expensive. However, responsible persons were still so divided on the question of the traction power supply system that three different options were pursued. At the time of the project's constitution in 1908/09, the single-phase system with 10.000 V was considered the most probable form. It was not until 1911 that the technical committee in the Association of German Railway Administrations decided on the traction power system with 15,000 V single-phase alternating voltage with a frequency of 16 2/3 Hz, which is still valid today with the ÖBB, DB, SBB, NSB in Norway and SJ in Sweden.

The end of the Habsburg Monarchy also meant a dependency on coal imports. The rapid expansion of domestic hydroelectric power and the electrification of the railways were considered essential for survival. In 1919 a separate electrification office was established at the Austrian State Railways. The electrification of the Arlberg and Salzkammergut Railways was started immediately. Electrification efforts ranged from the construction of the railway's own power plants and transmission lines to the development of electric locomotives and much more. In 1930 the continuation of electrification was highly uncertain due to a calculation published in 1927 by the board of directors of the Federal Railways, explaining the higher efficiency of steam locomotives. The electrical industry countered with a memorandum and a binding offer for the electrification of the Westbahn from Salzburg to Vienna, far below the price used by the Federal Railways in their calculations. An academic study was commissioned by the

politicians. However, the eight professors could not agree on a joint report. The majority considered the calculations of the Federal Railway to be a miscalculation and advocated the continuation of electrification, but three professors considered this to be insufficiently proven and wrote a minority report. Without waiting for the result, the Federal Railways commissioned the construction of new steam locomotives for the Westbahn. For the Tauern Railway, on the other hand, the supporters of electric traction were able to prevail. In 1935, the third largest mountain railway in Austria, after the Arlberg and Brennerbahn, was fully electrified. In 1937 it was decided to electrify the Westbahn from Salzburg to Linz, also as part of a job creation program. At the end of the Second World War, almost 1,000 kilometers were electrified.
After the end of the war, the Austrian Federal Railways ÖBB were in favor of full electrification. In 1952 the last section of the Westbahn was handed over to electrical operation. The festively decorated opening procession, which included Federal President Theodor Körner, was greeted along the route by onlookers and schoolchildren with red-white-red flags. In occupied post-war Austria, the electrification of the Westbahn, which crossed the American-Russian border on the Enns Bridge, had a symbolic significance. It was a signal for the striving for economic independence and against the division of the country.
In 1981, 3,000 km (51.3%) of the Austrian railway network were electrified. Today, about 7,900 km of the approximately total 11,000 km (71.8%) of tracks of ÖBB are electrically operated.

The example of the electrification of Vienna
At the end of the 19th century, energy supply, public transport and funeral services in Vienna were provided by private companies which were later municipalised. All remaining horse-drawn tram lines were converted to electric operation, the steam tram lines in Vienna were purchased and also converted. In 1899 the municipal gasworks in Simmering were commissioned, the first luminous gas was introduced into the pipeline network. The first steam power plant went into operation in 1902, which supplied electricity to the Vienna tram network. In 1923 the then Austrian Federal Railways (ÖBB) was leased and therefore operated by the City of Vienna. The municipality of Vienna converted the lines taken over into a tram network electrified and now municipal tram rail network. The lines of the Austrian railway network were further completely separated from the new electric tram rail system.

After the Second World War the following businesses were under Viennese governmental control:

- Electricity supply and distribution
- Gas power plant and distribution
- Public transport system
- Urban funerals
- Municipal announcement companies
- Brewery of the city of Vienna
- Port administration (Danube river)

In 1946, the three municipal enterprises Elektrizitätswerke, Gaswerke and Verkehrsbetriebe were being merged and led to the founding of "Wiener Stadtwerke" in 1949. Further changes in the companies' structure led to the reorganization from 2011 and divided into a regulated division (gas and electricity grid) and a competitive division (district heating, distribution, energy comfort). In 2013 "Wien Energie" outsourced the new company "Wiener Netze", responsible for electricity, natural gas, district heating and telecommunications networks.

The example of Verbund

The 2nd nationalization law in 1947 led to the founding of "Österreichische Elektrizitätswirtschafts-AG" known as VERBUND, at a time when electricity was in short supply in Austria. VERBUND was given the task to rebuild and expand Austria's electricity system. With the help of the Marshall-plan important projects such as the hydropower plants Glockner-Kaprun and Ybbs-Persenbeug could be implemented respective finalized in the first few years.

Since 1988 49% of VERBUND shares are privatized. At the end of the 1990ies, VERBUND anticipated future EU regulations, such as the unbundling under company law of the business areas "generation" and "transmission" of electricity, the later in Austrian Power Grid AG. Before the turn of the millennium, VERBUND was well positioned for the complete opening of the electricity market, implemented in 2001.

Now VERBUND has business relationships in more than 20 countries and has 13 branches or interests in Europe and one in Turkey. VERBUND also invests in the renewable energy sources, mainly in wind power.

The example of ELIN

In 1892 the engineer Franz Pichler founded the company Pichler Werke in Styria. The company produced electrical machines including dynamos for nickel-plating and DC shunt dynamos. Five years later, the company was renamed "Weizer Elektrizitätswerke Franz Pichler & Co".

After the Viennese "Gesellschaft für Elektrische Industrie" joined the company as a silent partner, new machines and tools were purchased. In the following years new developments, such as 800 kW generators, multipole DC machines and the cooling fin patent were made.

In 1908 the company got converted into a joint stock company in order to raise more equity capital. The now called "ELIN Aktiengesellschaft für elektrische Industrie" offered a wide range of services from electrical machinery and switchgear construction to drive and welding technology.

During the First World War, sales to private customers declined significantly, while armaments orders were increased. The company produced bullets, motors and transformers for the k.u.k. Army and also received a secret contract to manufacture electrical equipment for submarines. It was at this time that the factory was connected to the railway network, making the transport more efficient.

After the death of Franz Pichler in 1919, engineer Emanuel Rosenberg became his successor, a renowned technician and inventor (e.g. "Rosenberg-generator").

In the course of Austria merging into the German Reich the company was completely restructured. ELIN was merged with the German company Schorch-Werke AG, resulting in changes in organization and production. With the beginning of the Second World War, large armament orders for submarine equipment, engines, transformers and welding converters for the navy and the army were received. After the war, the occupying Soviets removed almost all machines and tools, and the damaged factory had to be rebuilt. In 1946, ELIN was government-owned. After a reorganization and by obtaining foreign loans, ELIN was soon able to carry out major projects again. For example, the Glockner-Kaprun power station project, in the construction of which ELIN played a major part.

In 1959, in the course of the industry-related amalgamation of nationalized companies, AEG-Union was merged with ELIN under the name "ELIN-UNION AG für elektrische Industrie". In 1967 and 1971, contracts were concluded with the Siemens Group which, in addition to splitting the production program, provided amongst other benefits the access to licenses. At the same time ELIN

became the largest Austrian company in the High Voltage sector, active in almost all fields of electrical engineering and electronics.
The oil crisis at the beginning of the 1980ies led to a worldwide economic slump, which was reflected in the nationalized industry by a sharp decrease in orders. The pressure of competition, loss of market shares, rising costs with falling profits, and low investment activity in the Austrian economy forced a reorganization in 1989 to "Elin Energieversorgung Ges.m.b.H." and the "Elin Energieanwendung Ges.m.b.H.". The transformer division was spun off into an independent subsidiary "ELIN Transformatoren GmbH" and "ELIN Motoren GmbH". At the end of the 20th century all sub-companies received the State Award and were allowed to use the Austrian national coat of arms in business transactions.
After several restructurings, ELIN became a member of the Ortner Group and Siemens AG Austria in 2008, operating under the name ELIN GmbH & Co KG and since 2011 the ELIN brand has been fully owned by the Ortner Group.

The example of Mosdorfer

Another traditional company in the field of electrical engineering is based in Weiz, the Mosdorfer family business, founded in 1712. In the beginning, the water power of a nearby stream was used to produce axes and sickles on forge hammers, or swords in times of war. After the Second World War, when the reconstruction of electrical infrastructure boomed, Mosdorfer changed its product range to high-quality overhead line fittings (clamps, damping systems, warning spheres, spacers, etc.) and is now one of the largest suppliers worldwide.
Over the years, the KNILL family (family tree Mosdorfer) formed a worldwide operating group of companies in the field of power systems and mechanical engineering.

The example of voestalpine

The origins of today's voestalpine go back to hammer mills in the 15th century in Donawitz in Styria. Many changes in the structure of the iron processing plant led to the 1st Styrian puddle steel production in 1837. Changes in ownership, the construction of the Donawitz-Vordernberg railway line to reduce transport costs and the building of the 1st Martin furnace in 1878 led to a new era in steel production. The construction of a coke furnace and the extension of the railway line Vordernberg-Eisenerz initiated the era of mass steel production. With the construction of a new beam and rail rolling mill in 1892, Donawitz became

the center of smelting in the Austrian Hungarian Monarchy. In 1912 Donawitz grew and became the largest unified steelworks plant on the continent. Fuel shortages led the plant into great turbulence during the period around the 1st World War.



Fig. 5.8 view of the Donawitz steel production in Styria in the early 20th century

In 1938 a subsidiary of the company "Reichswerke AG Alpine Montanbetriebe Hermann Göring" was founded in Linz an der Donau. The factories could not have been built and the military equipment could not have been produced without foreign labours, also prisoners of war, and from the end of 1942 prisoners from concentration camps. At this time, the main focus was on war production, with the plants in full operation. The number of workers at the Linz plant reached its peak in 1944. 1945, after the end of the war, the company was seized as German property. According to orders of the US military government the company was renamed to Vereinigte Österreichische Eisen- und Stahlwerke AG (VÖEST). They were separated from Alpine Montan AG. The Marshall-plan helped much to reconstruct the facilities.
One of the most significant metallurgical developments in the 20th century is the "Linz-Donawitz LD-steelworks", developed at voest, which went into operation in 1953. Steel production following this LD process produce the most steel (60%) worldwide. Large quantities of pig iron and scrap can be processed economically, and crude steel of special quality can be supplied. In October 1995, VOEST-ALPINE STAHL AG was privatized and successfully floated on the stock exchange.

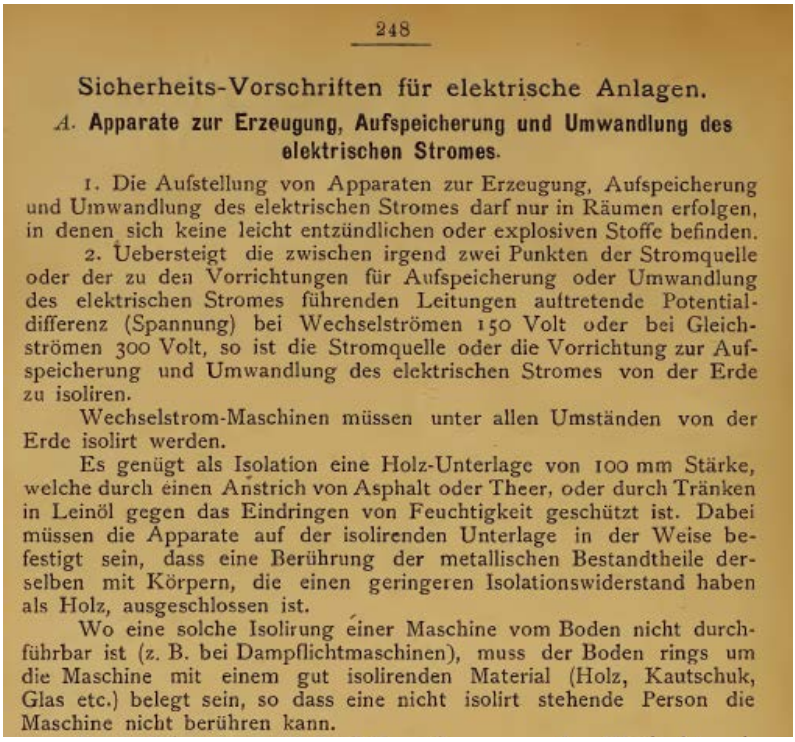
Austrian Standards, Regulations

In Austria the "Österreichischer Verband für Elektrotechnik OVE - Austrian Association for Electrotechnics" (former ÖVE) publishes regulations and standards for all aspects of electrotechnics. This means that OVE covers the standardization for hand held drilling machines as well as for the design of overhead lines. For this work OVE is split up into Technical Committees. The Austrian Electricity Law and the Electricity Directives define the responsibility and application of standards.

The Austrian Association for Electrotechnics was established in 1883 as "Elektrotechnischer Vereins in Wien (EVW)" and is among the oldest standardization institutes in the world. Honorable persons like Ernst Mach, Siegfried Marcus, Josef Stefan, Ludwig Boltzmann were founding respective early members of OVE. The duties of the young organization at that time were:

- Support developments in the field of electrotechnics
- Take care of safe application of electrotechnic facilities
- Create and support the contact between universities and industry
- Support the intensive exchange of information among experts and interested groups in this young and revolutionary technologyToday OVE is a private non-profit organization with approximately 1,800 members and 39 employees (2019). The duties are defined by law and cover the representation of interests, standardization and certification. OVE issues Austrian national standards for electrotechnic and represents the country in many national and international organizations like IEC and CENELEC. Milestones in the history of OVE are:
- 1883 Establishment of "Elektrotechnischer Vereins in Wien (EVW)" today „Österreichischer Verband für Elektrotechnik" OVE
- 1888 The first electrotechnic regulation in Austria was issued by EVW
- 1906 Establishment of IEC (Austria was founding member)
- 1953 OVE becomes member in CEE "International Commission for Conformity Certification of Electrical Equipment"
- 1965 Electricity law defines mandatory legislation for electrotechnics
- 1973 Establishment of CENELEC (Austria was founding member)
- 2017 The electricity law defines OVE as representative of Austria in IEC and CENELEC
- Since 2018 OVE is member in the IEC Standards Management Board SMB

Between 1938 and 1945 many standards of Austria and Germany were merged, but considering specific national and regional assumptions. After 1945 the standardization separated again. Several electric facilities which were built in the 1930ies are still working in the Austrian grid, which proofs the high developed standardization in these times.



248

Sicherheits-Vorschriften für elektrische Anlagen.

A. Apparate zur Erzeugung, Aufspeicherung und Umwandlung des elektrischen Stromes.

1. Die Aufstellung von Apparaten zur Erzeugung, Aufspeicherung und Umwandlung des elektrischen Stromes darf nur in Räumen erfolgen, in denen sich keine leicht entzündlichen oder explosiven Stoffe befinden.

2. Uebersteigt die zwischen irgend zwei Punkten der Stromquelle oder der zu den Vorrichtungen für Aufspeicherung oder Umwandlung des elektrischen Stromes führenden Leitungen auftretende Potentialdifferenz (Spannung) bei Wechselströmen 150 Volt oder bei Gleichströmen 300 Volt, so ist die Stromquelle oder die Vorrichtung zur Aufspeicherung und Umwandlung des elektrischen Stromes von der Erde zu isoliren.

Wechselstrom-Maschinen müssen unter allen Umständen von der Erde isolirt werden.

Es genügt als Isolation eine Holz-Unterlage von 100 mm Stärke, welche durch einen Anstrich von Asphalt oder Theer, oder durch Tränken in Leinöl gegen das Eindringen von Feuchtigkeit geschützt ist. Dabei müssen die Apparate auf der isolirenden Unterlage in der Weise befestigt sein, dass eine Berührung der metallischen Bestandtheile derselben mit Körpern, die einen geringeren Isolationswiderstand haben als Holz, ausgeschlossen ist.

Wo eine solche Isolirung einer Maschine vom Boden nicht durchführbar ist (z. B. bei Dampflichtmaschinen), muss der Boden rings um die Maschine mit einem gut isolirenden Material (Holz, Kautschuk, Glas etc.) belegt sein, so dass eine nicht isolirt stehende Person die Maschine nicht berühren kann.

Fig. 5.9 Excerpt from the first Electrotechnical regulation in Austria 1888, issued by EVW (today OVE).

5.2 History of the Austrian Cigre National Committee

Austria has been contributing to CIGRE since 1932. In 1985 when the Austrian National Committee of CIGRE was established it was integrated into the alread existing Austrian Electrotechnical Association (OVE) organization structure.

The Austrian NC Chairmen and Secretaries since 1985 are:

	Chairman	**Secretary**
1985	–	H. Allmer
1992	W. Gmeinhart	H. Allmer
1994	R. Käfer	H. Allmer
1999	P. Morawek	E. Vierlinger
2008	K. Bauer	H. Struber
2014	G. Christiner	W. Hribernik



Fig. 5.10 First meeting of the SEERC Advisory Technical Committee in 2015 in Vienna at OVE

In 2020, Austria has 14 delegates in the 16 CIGRE Study Committees:

SC	Title of SC	Austrian SC-Member
A1	Rotating Electrical Machines	Gerfried Maier
A2	Power Transformers an Reactors	Gerald Leber
A3	Transmission & Distribution Equipment	Georg Brauner
B1	Insulated Cables	Michael Klein
B2	Overhead Lines	Klemens Reich
B3	Substations and Electrical Installations	Uwe Schichler
B4	DC Systems and Power Electronics	Alexander Gaun
B5	Protection and Automation	Gernot Druml
C1	Power System Development and Economics	Udo Bachhiesl
C2	Power System Operation and Control	–
C3	Power System Environmental Performance	Christof Sumereder
C4	Power System Technical Performance	Stephan Pack
C5	Electricity Markets and Regulation	–
C6	Active Distribution Systems and Distributed Energy Resources	Thomas Strasser
D1	Materials and Emerging Test Techniques	Wojciech Koltunowicz
D2	Information Systems and Telecommunication	Stefan Zierlinger

5.3 Austria's current electricity sector profile and integration of Renewable Energy Resources

The Austrian state spreads over an area of 83,850km^2 in Central Europe. The current population is 8.8 Million people. About 2 Million people live in Vienna. Austria has a highly industrialized economy with a high amount of renewable energy integration compared to other European countries. There are two Transmission Grid Operators: Austrian Power Grid AG (100% subsidiary of VERBUND AG) and Vorarlberger Übertragungsnetz GmbH (VÜN) with Austrian Power Grid being the main one. 122 operators are responsible for the distribution network.

The unbundling of "generation" and "transmission" of electricity started in the 1990ies with the goal of the complete opening of the electricity market. Austria introduced the electrical energy and organization law in 1999 in line with EU regulations and the opening. The liberalization of the electricity market began, earlier than in other European countries, on October 1st 2001. Customers are now able to obtain their electricity from any provider, not just from the regional providers. Fully exercised unbundling became reality throughout the EU in 2007. The transmission grid's natural monopoly is regulated by the state via the regulatory authority "Energie-Control Austria" (E-Control) for the regulation of the electricity and gas industries. E-Control has administrative power, but also monitors and supervises the competition. Today the Austrian electricity sector has an estimated turnover of approx. 6.4 billion euros and employs approximately 21,000 people.
In 2018 Austria produced 68 TWh of electrical power of which 76% was sourced from renewable energies and a peak load of approximately 11 GW. Compared to the previous years electricity consumption is slightly growing, which fits in the overall upward trend of consumption in Austria.

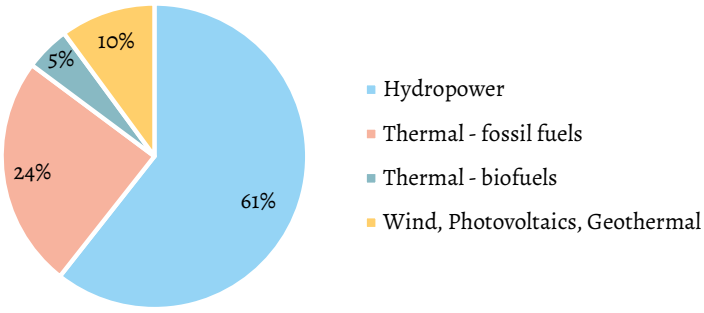


Fig. 5.11 Shares of electricity generation in Austria (approximate figures)

Due to the country´s topography, the two main renewable energy sources hydropower and biogenic fuels are easily accessible. These two resources account for the largest share of domestic primary energy production, with the share of hydropower tending to decline slightly and the share of biomass rising. Other renewable energy sources, especially the use of ambient heat in heat pumps and primary energy production from wind and photovoltaics are also growing steadily and significantly.

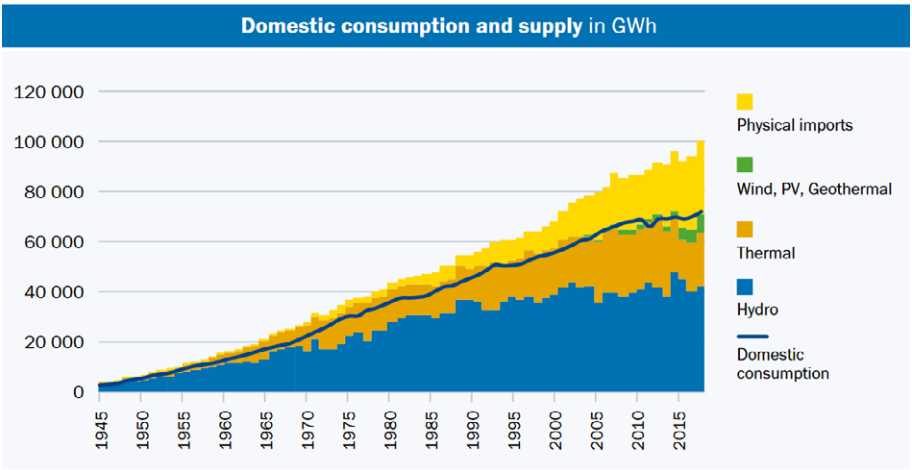


Fig. 5.12 Electricity consumption in Austria (E-Control 2018)

The Austrian government formulated the goal of producing 100% electricity from renewable domestic production by 2030.
In the last years the installation of wind power rose significantly. The following figure shows the development.

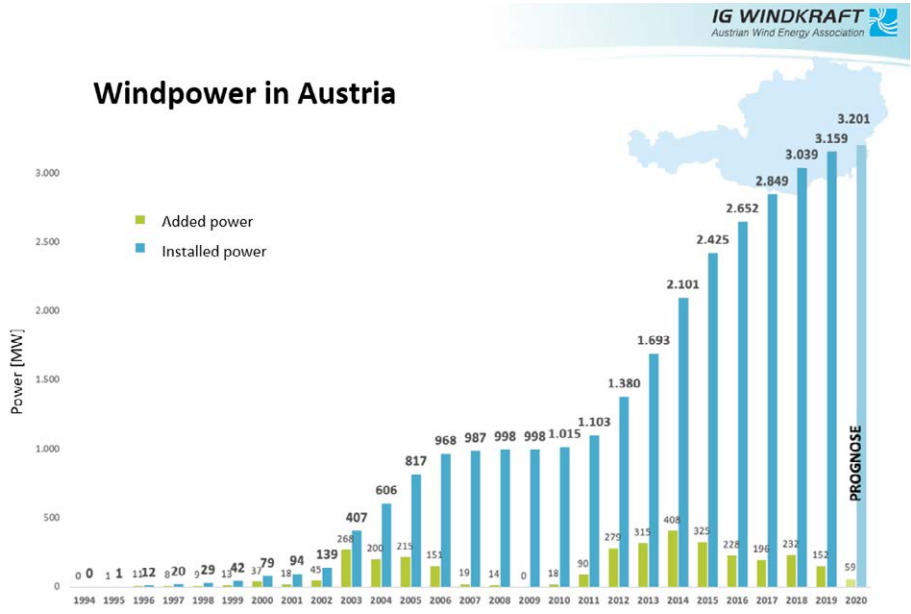


Fig. 5.13 Installation of wind power in Austria

The figure below shows the principles of the exchange of energy from solar and wind and hydro energy from the high Alps. The pump storage plants can store energy from renewables which is not used at the moment. In this respect the picture shows also the interchange with neighboring countries. The Eastern part of Austria is well suited for the installation of solar and wind power.

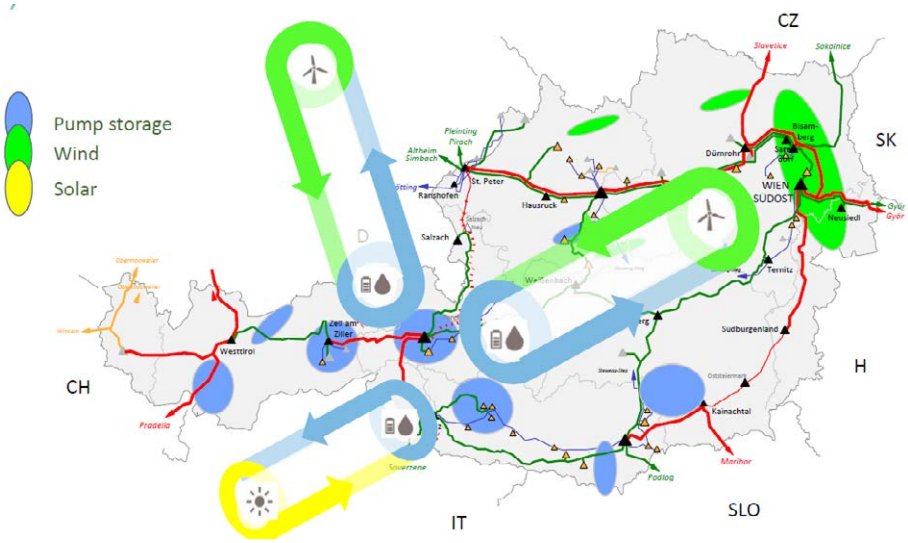


Fig. 5.14 Electricity production and storage in Austria

In order to meet the given targets from the Austrian government for 2030 and to facilitate the switch to more renewable energy resources, a strong and reliable grid, connecting renewable power plants in the east and storage plants in the Austrian high Alps, is essential.

5.4 References

- Österreichische Elektrizitätswirtschaft 1947–1957, by Bundesministerium für Verkehr und Elektrizitätswirtschaft sowie Elektrizitätsversorgungsunternehmen Österreichs, Vienna 1957
- Austria´s Hydro Power Resources and their utilization for European Power Supply, by Federal Ministry of Transport and Nationalized Enterprises, in cooperation with the Federal Chancellery, ERP Central Office, "Österreichische Elektrizitätswirtschafts AG and the Power Supplying and Projecting Companies concerned, Vienna 1951

- Wasserkraft. Elektrizität. Gesellschaft. Kraftwerksprojekte ab 1880 im Spannungsfeld, Volume 104 of „Schriftenreihe Forschung in der Verbund AG“, Rathkolb, Hufschmied, Kuchler, Leidinger, Vienna 2012
- Energie in Österreich, Bundesministerium für Nachhaltigkeit und Tourismus, Vienna 2019
- https://austria-forum.org/af/AustriaWiki/Lokalbahn_Mödling–Hinterbrühl
- https://de.wikipedia.org/wiki/Elektrizitätswirtschaft_in_Österreich
- https://de.m.wikipedia.org/wiki/Internationale_Elektrische_Ausstellung_1883
- https://www.ove.at/ove-network/ueber-uns
- https://de.wikipedia.org/wiki/Elektrizitätswirtschaft_in_Österreich
- https://austria-forum.org/af/AustriaWiki/Elektrizitätswirtschaft_in_Österreich
- https://de.wikipedia.org/wiki/Elektrizitätswirtschaft_in_Österreich
- https://www.voestalpine.com/stahldonawitz/de/unternehmen/geschichte/
- https://geschichte.univie.ac.at/de/personen/josef-jozef-stefan-stefan-prof-dr
- https://www.meinbezirk.at/weiz/c-lokales/spuren-der-monarchie-im-bezirk-weiz_a2938947#gallery=default&pid=16141542
- https://www.stern-verkehr.at/geschichte/
- https://www.stern-verkehr.at/bilder-geschichte-hafferl-franz/
- https://www.e-control.at/documents/1785851/1811597/e-control-statistikbroschuere-2018-englisch.pdf/ee740431-1047-e373-d9a9-324406ffaa8b?t=1542042035952
- https://www.igwindkraft.at/mmedia/download/2020.02.11/1581411092469671.pdf

6. NC CIGRE BOSNIA-HERZEGOVINA

6.1 History of electric power sector

It is an indisputable fact that the electric power, horse-drawn tram, electric tram and water supply system in Bosnia and Herzegovina have been functioning for more than 130 years. Electricity activity in Bosnia and Herzegovina was recorded back in 1888 (the first electric lighting in Bosnia and Herzegovina took place in Zenica) and is considered the year of the beginning of electrification of Bosnia and Herzegovina. In 1895, Sarajevo received public lighting and an electric tram, which was the case in only a few metropolises at the time.



Fig. 6.1 Electric tram from 1895 (Manufacturer: Siemens-Schuckert)



Fig. 6.2 Thermal Power Plant Sarajevo, 1895

The electrification of Bosnia and Herzegovina (BH) began in the late 1890s. Its course had several characteristic periods:

a) Period of local electrification: 1888–1918

Two years after the BH fell under Austro-Hungarian rule, i.e. 1880 a private brown coal mine was opened in Zenica, which in 1886 became state property. In 1888, the first steam-powered power plant was built in this mine and a one-way dynamo steam engine was installed, which is used to illuminate the mine's management building. This is considered to be the first, officially recorded act of electrification in BH.
In 1894, the provincial government of Bosnia and Herzegovina under the Aus-

tro-Hungarian monarchy founded the company "Elektrana" (Bosnian term for power plant), which will supply electricity to consumers. In the same year, temporary regulations for the supply of electricity and the first tariff system for the sale of electricity were passed in Sarajevo, the capital of BH. The power plant building was completed in early 1895.

The thermal power plant had three steam boilers, 3 stable steam piston machines of 150 HP each. Each of these machines was powered by a rope drive of 2 DC generators of 60 kW each, all DC voltage, 110 V for lighting and smaller electric motors and 310 V for driving trams.

Simultaneously with the construction of the power plant, work was done on setting up installations for lighting the main streets and the most important buildings in the city, while the first electric lanterns were tested in April of the same year. Thus, on May 1, 1895, Sarajevo received electric lighting. Soon electric lanterns completely replaced old oil lanterns. The first public building to receive electric lighting was the Provincial Government building.

Consumption in Sarajevo grew rapidly, so the power of TPP "Sarajevo" was increased several times by reconstructions of existing and procurement of new boilers and machines, in 1897, 1904, 1912, 1928, when it had 2890 kW of installed power, 2130 kW on AC and 750 kW on DC voltage. The consumer zone did not extend beyond the narrower part of the city.

This thermal power plant has been declared a national monument of BH.

In 1894, in Jajce (municipality in the central part of Bosnia and Herzegovina), one of the first and largest hydroelectric power plants in Southeast Europe was put into operation, for the electrolysis plant in "Elektrobosna" company. This HPP used the natural accumulation basin of the Great Pliva Lake.

The hydroelectric power plant was equipped with eight Schukert's AC generators, 800 kVA, 180 V and 3000 A.

After HPP in Jajce, other HPPs were built: HPP Delibašinoselo near Banja Luka in 1899 (with expansion in 1910), HPP Carbide Factory near Jajce in 1899, HPP Travnik in 1904, TPP RudnikaugljaKreka in 1906, TPP Brčko in 1908, HPP Una in Bihać in 1911, TPP Mostar in 1912, HPP Bileća in 1912, TPP Prijedor in 1917, HPP Hrid near Sarajevo in 1917 and others.

HPP Hrid was put into operation in 1918 and, with certain interruptions in the war-period (1992–1995) and post-war period, was in operation until 1999. The HPP Hrid still consists of two horizontal Pelton units with a power of 675 kW each, with other auxiliary turbine and generator devices.

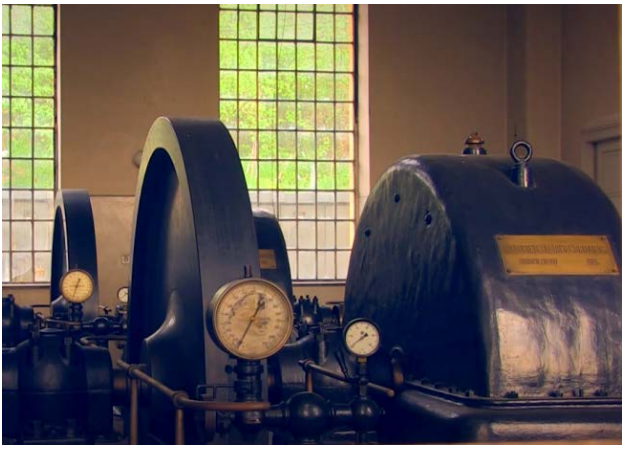


Fig. 6.3 Hydro Power Plant Hrid near Sarajevo, 1917



Fig. 6.4 Turbine circuitfrom 1937 (Installed in the HPP Pršljenica, Vesela Village Bugojno, B&H)

Thepowerplantswere unconnected, with the voltage level of these "networks" ranging from 3 to 5 kV, while the "network" for the distribution of electricity was the voltage level of 110 to 200 V. The lines were built on wooden poles. With copper conductors and modest protective and measuring equipment, with the rare installation of transformer stations.

The bearers of the construction of power plants and networks were city municipalities, companies, foreign and domestic concessionaires.

In all environments where power plants were built, electric lighting developed and spread rapidly. Due to economic underdevelopment and low level of technical development and equipment, electricity consumption in electric motor drives and technological processes developed much more slowly. The largest consumers of electricity at the time of local electrification in Bosnia and Herzegovina were: public lighting in cities, coal mines, carbide producers, sawmills, mills, breweries and tobacconists, larger craft and trade shops and public institutions. Given that the predominant use - electricity consumption for lighting, power plants worked more intensively at night. They generally had a low capacity utilization rate and high production costs. The staff of public power plants, in addition to production work and maintaining the operational readiness of power plants and electrical networks, sold electricity, light bulbs, electrical devices and appliances and electrical materials.

The development of local electrification in Bosnia and Herzegovina was slowed down by the Balkan wars, and then by the First World War, during which there was great damage to power plants and power grids.
At the end of the First World War, there were five hydropower plants and 44 small thermal power plants in operation in Bosnia and Herzegovina, with a total installed capacity of 22 MW. Only 1.1% of the settlements were electrified.

b) Period of regional electrification: 1919–1945

The dynamic flow of electrification and the growth of electricity needs in European countries after the end of the First World War, gave new impetus to the electrification of Bosnia and Herzegovina. Initiatives are being launched for the adoption of laws on electrification, the adoption of uniform technical regulations on the construction, maintenance and protection of power plants, the connection and better use of power plants. These professional initiatives had been implemented slowly due to the general lack of money, the inertia of the state administration, the disunity of the interests of power plant owners and the lack of professional staff, especially in the electrical engineering profession. The construction of power plants in Bosnia and Herzegovina in the period 1920–1945 is shown in the following table.

Table 6.1 Construction of power plants in Bosnia and Herzegovina (1920–1945)

Year	Total		HPP		TPP	
	Number	Capacity (MW)	Number	Capacity (MW)	Number	Capacity (MW)
1920	49	32.1	5	10.2	44	21.9
1930	71	44.3	7	10.3	64	34.0
1939	90	69.3	16	10.7	74	58.6
1945	48	48.7	13	7.1	35	41.6

During the Second World War, power plants and the associated grid were severely damaged. Of the 90 power plants built until 1939, after the end of the war, electricity could be produced in part in only 48 power plants. The transmission network of voltage levels of 30 and 36 kV was 305 km long. In 1945, the total realized production of electricity amounted to 62 million kWh, and the specific consumption per capita was 23 kWh. In total, about 16.2% of the settlements were electrified.



Fig. 6.5 30 kV and 35 kV transmission network built until 1940.



Fig. 6.6 35 kV transmission line from the regional electrification period

c) Period of general electrification and major construction: 1945–1990.

In the period from 1946 to 1990, there was an intensive development of production and consumption of electricity in Bosnia and Herzegovina. The increase in industrial consumption is especially evident, and in addition, Bosnia and Herzegovina had a surplus in electricity production for most of this period. The increase in the installed capacity of power plants, in the period of general electrification from 1946 to 1980, was at an average annual rate of 12%. The most intensive construction of power plants in Bosnia and Herzegovina was realized in the period from 1950 to 1960 when HPP Jablanica, HPP Jajce I and HPP Jajce II, TPP Kakanj, HPP Mesići, HPP Slapovina Uni, TE Banovići were built, including expansion of TPP Zenica, and construction of eight industrial power plants (Prijedor, Blažuj, Lukavac, BosanskiBrod, Maglaj, Foča, Banja Luka).

Later, significant generation facilities were built, HPP Trebinje 1 - 162 MW, 1968/75; HPP Rama - 160 MW, 1968; PHPP Capljina - 420 MW, 1979/80; TPP Tuzla - I stage, 64 MW, 1964, II stage, 100 MW, 1966, III stage, 200 MW, 1971, IV stage, 200 MW, 1974 and V stage, 215 MW, 1978; TPP Kakanj - III stage, 110 MW, 1969, IV stage, 110 MW, 1977, V stage, 230 MW, 1988; TPP Gacko - 300 MW, 1983; TPP Ugljevik - 300 MW, 1985; HPP Višegrad - 315 MW, 1989; HPP Bočac - 110 MW, 1981; HPP Grabovica - 114 MW, 1982; HPP Salakovac - 210 MW, 1981; HPP Mostar - 72 MW, 1987.

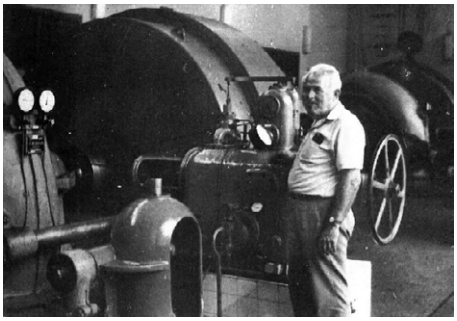


Fig. 6.7 HPP Bogatići, the first HPP in the former Yugoslavia builtafter World War II (in operation since 1947)

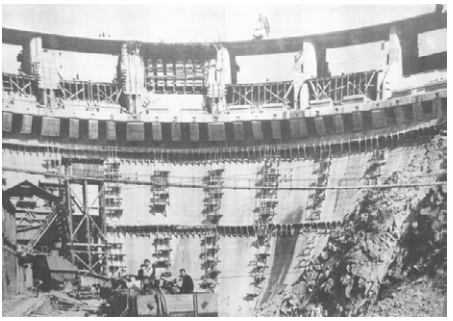


Fig. 6.8 Construction of HPP Jablanica, 1954

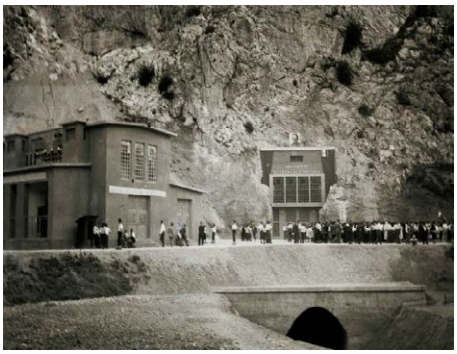


Fig. 6.9 HPP Mesići, built in 1950/51

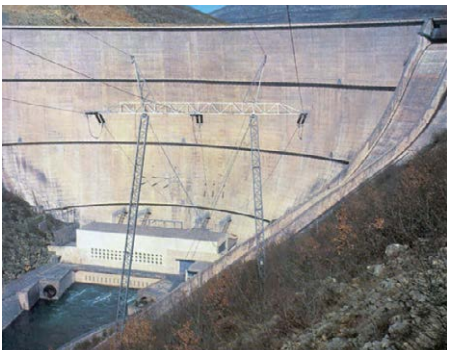


Fig. 6.10 HPP Trebinje I, 1968/75 The Dam Gračarevo,built on Lake Bileća, which is the largest accumulation in the Balkans

Simultaneously with the growth of production, the transmission grid in Bosnia and Herzegovina with voltage levels of 110, 220 and 400 kV with interconnections with neighboring systems of Serbia, Croatia and Montenegro was developed, and together with the SFRY system interconnection with European power system members UCTE was established.

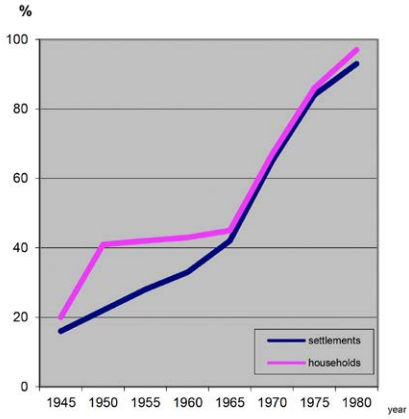


Fig. 6.11 The course of electrification of settlements and households in BiH, 1945–1980

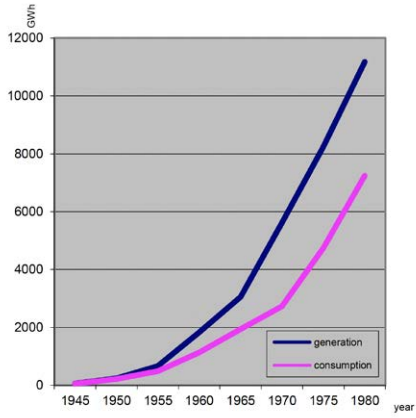


Fig. 6.12 Trends in electricity generation and consumption in BiH, 1945–1980



Fig. 6.13 Minimum oil circuit breaker, 36 kV (Manufacturer: Energoinvest Sarajevo, 1947)



Fig. 6.14 Low voltage switch(Manufacturer: Energoinvest Sarajevo, 1963)

In the period of general electrification, the construction and use of transmission grid facilities took place in three characteristic phases. In the first phase, from 1946 to 1957, 35 kV and 110 kV voltage facilities were built and used. From 1957 to 1976, the structure of the transmission grid consisted of transmission lines and transformer stations of 110 kV and 220 kV and transmission lines of 35 kV voltage, which were part of the transmission grid facilities. From 1976 to 1990,

the transmission network in Bosnia and Herzegovina consisted of facilities 4,457 km of 400 kV, 220 kV and 110 kV voltage level transmission lines as well as 59 transformer stations with a total installed capacity of 6,364 MVA.



Fig. 6.15 Very first 110 kV OHL in B&H

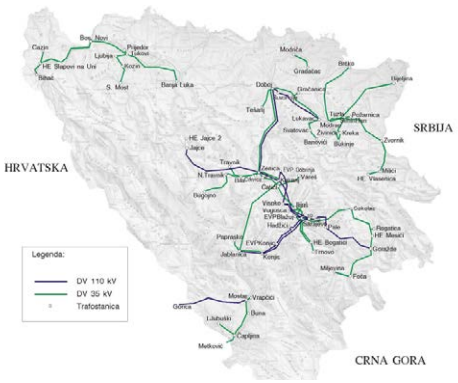


Fig. 6.16 110 kV and 35 kV transmission network built until 1954

Such a complex electric power system required unified management, so each electric power system had its own republic dispatch center, and according to the European interconnection, the joint center JUGEL was responsible for ensuring the balance and energy exchange.

d) Electricity sector of BH in the war period: 1992–1995

Until the beginning of the first war events in the former Yugoslavia, the electricity system in Bosnia and Herzegovina functioned within a single network of most European countries (UCTE), which enabled it to operate stably. In the middle of 1991, due to the war in Croatia, damage to the high-voltage transmission lines that connected the BH power system with the Croatian power system, and thus with the UCTE network, became more frequent. Due to the impossibility of repairing the faults, the transmission lines usually remained permanently out of operation, which in September 1991 resulted in the interruption of parallel operation with the UCTE network. Thus, the UCTE interconnection split into two zones, and the power system of Bosnia and Herzegovina was the central point of disintegration, so that part of the system was in synchronous operation with one UCTE zone, and the other part with another UCTE zone.

After that, the functioning of the BH Power System took place in a system consisting of the countries of Southeast Europe. The strength of this part of the system in relation to the total strength of the UCPTE network was only 6.4%, which was reflected in the deterioration of the stability of the system. However, the system continued to function without major problems.

Major disturbances began in April 1992, when a large number of transmission and production facilities in BH remained damaged because of the war. The total available power and the number of generators in the power system in BH has been decreasing, which, along with the damaged grid, has permanently left an increasing number of consumers without electricity supply. The transmission lines connecting the BH power system with neighboring countries also remain out of operation, so that the system has broken down into several isolated islands of low power and unstable operation, which has often led to system breakdowns. The system still survived, split and reconnected, but it always worked at least to a minimal extent.

In the following years, the system worked in very difficult conditions to a greater or lesser extent and in several islands. Although a significant part of consumers remained without electricity for long periods, production was still reflected to a lesser extent thanks to a large number of innovations and original solutions of workers in all segments of the electricity industry.

During that period, new facilities were built, such as a 35 kV cable, which enabled the delivery of electricity to Sarajevo via Igman (mountain located southwest of Sarajevo), and after that, a 25 km long 110 kV cable connection from Pazarić (settlement located 20 km southwest of Sarajevo) was built, supplaying basic humanitarian facilitiest of besieged Sarajevo (hospitals, refugee centers, the city's main bakery, etc.) with electricity generated in HPP Jablanica.The cables entered Sarajevo through the so-called Sarajevo Tunnel.

In addition to the 35 kV and 110 kV cables, towards Sarajevo, during this period the following transmission lines were built: 110 kV transmission line, Maglaj-Tešanj, which worked at a voltage of 35 kV during the war period; 110 kV transmission line, Jablanica towards Mostar (new route built from Salakovac to Opine); 110 kV transmission line Bosanski Petrovac-Ključ; 10 kV line for the purpose of supplying parts of Novi Travnik; part of the 220 kV line from Višegrad to Vardište, etc. All this time, the relocated republic dispatch center in the 220 kV Kakanj RP was successfully functioning.



Fig. 6.17 Sarajevo Tunnel, built in 1993, during the war

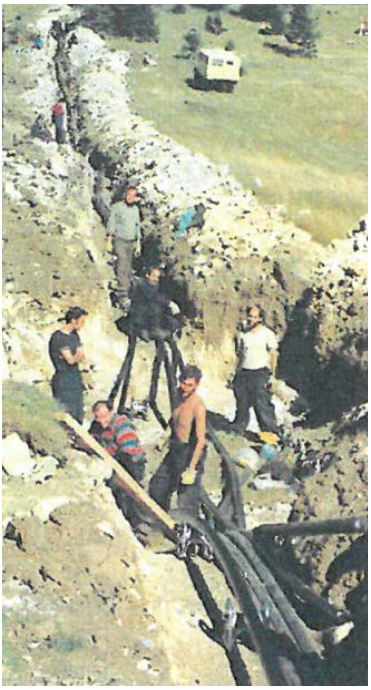


Fig. 6.18 110 kV cable jointing, during installing preparatory works, 1995, during the war

The Sarajevo War Tunnel also known as "Tunelspasa" (in English: Tunnel of Rescue) and Tunnel of Hope, was a tunnel constructed between March and June 1993 during the Siege of Sarajevo in the midst of the Bosnian War. It was built by the Bosnian Army in order to link the city of Sarajevo, which was entirely cut off by Serbian forces, with Bosnian-held territory on the other side of the Sarajevo Airport, an area controlled by the United Nations.

Since 1995, electricity conditions in BH have gradually become more favorable than in previous years. The volume of production was increased, which, along with the simultaneous rehabilitation of networks, enabled a larger volume and quality of supply to end consumers. The number of consumers without electricity was constantly decreasing and was reduced to a minimum by the end of that year.

e) Electricity sector after the Bosnian war

After 1995, therehabilitation and reconstruction of generation facilities, transmission, and distribution grids in BH was intensified. The World Bank started the rehabilitation of the 400 kV transmission network, which was completed on October 10, 2004, and after more than 12 years, the reconnection of the power system of Southeast with the rest of continental Europe was successfully reconnected. Of course, the reconnection has increased the stability and security of the power system. This was very important for Bosnia and Herzegovina, both because of the placement of surplus electricity, and because of the possibility of electricity transit. The reconnection resulted in significant effects in both technical and commercial terms, contributing to increased operational safety, frequency stability and reliability, improved voltage profile and quality of electricity supply, and the volume of electricity trade. The problem of elevated voltages in the transmission network (especially 400 kV) has remained a significant problem.
In addition to the rehabilitation and reconstruction of damaged power facilities, the modernization of the plant was carried out with the extension of the service life and increase of capacity, but also the construction of new facilities. In the last 20 years, several new power plants have been built Mostarskoblato, 60 MW, 2010; Peć-Mlini, 30.6 MW, 2004; TPP Stanari, 300 MW, 2016; WPP Mesihovina, 50.6 MW, 2018; WPP Jelovača, 36 MW, 2019, photovoltaic power plants near Stolac 22 MW and a significant number of small hydro powerplants.

The development of the transmission grid in the period from 1953 to 2015 is shown in the following figures.

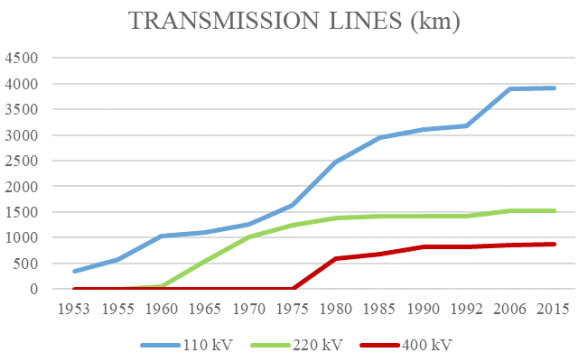


Fig. 6.19 Increase in km of transmission lines in the period from 1953 to 2015

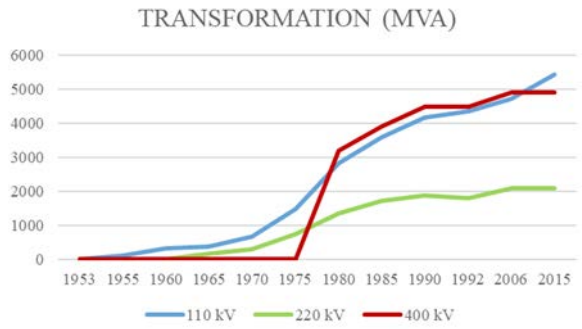


Fig. 6.20 Increase in installed transformation power in the period from 1953 to 2015

In addition to the Transmission System Operator, there are three electricity companies with majority state capital and legal entities that have a license for the generation and the activity of domestic and / or foreign trade of electricity.

6.2 History of CIGRE in BH

a) BH CIGRE activities in period 1951–1991

The history of CIGRE in BH began in former Socialist Federal Republic of Yugoslavia, which officially starts with establishment of JUNAKO CIGRE (Yugoslav National Committee, later changed its name to JUKO CIGRE) in 1951. The headquarters of JUKO CIGREwas in Zagreb all time from 1951 until 1991, when finished existing as association of consociationmembersfrom six former republics of Yugoslavia. First president of JUKO CIGRE was professor Milan Vidmar from Slovenia (up to 1960) and Secretary-general Herman Mattes from Croatia (up to 1976). Representative of BH in early time of JUKO CIGRE was Čedomir Miličević from Sarajevo, who was elected to the Management Board.
The first conference of JUKO CIGRE was held from in May 1953, in Ljubljana. About 100 power engineers attended this gathering from the power industry, electrical industry, faculties, scientific research institutes and other interested working organizations. Papers were distributed in five sections. The head of the first section - Construction of power plants, was Salom Šuica from Sarajevo.
In the first Management Board headed by professor Milan Vidmar were elected Salom Šuica and Emerik Blum from Sarajevo as one of vice presidents and member of Management Borad, respectively. ČedomirMiličević from Sarajevo was appointed in the Supervisory Board.
Unlike CIGRE mother from Paris, JUKO CIGRE also covered distribution net-

work issues. Thus, from beginning was established study committee for Distribution Networks.
Since its founding, JUKO CIGRE has been dealing with actual problems of the Yugoslav electricity supply industry and electrical manufacturing industry.

In the period from 1951 to 1991, JUKO CIGRE held 20 conferences, four of which were held in Bosnia and Herzegovina:

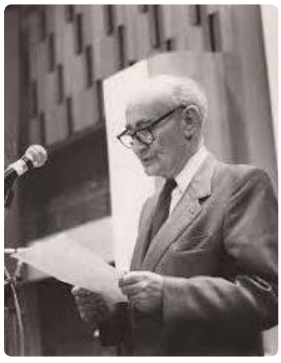
JUKO CIGRE Conferences in BH, in years	No. of papers	No. of participants
1954, Sarajevo	23	135
1966, Mostar	102	650
1979, Sarajevo	185	1058
1991, Neum (last conference)	216	Over 1000

The presidents of JUKO CIGRE from Bosnia and Herzegovina were Čedomir Miličević (1972–1975) and Jovo Mandić (1989–1991), who was the last president of JUKO CIGRE.

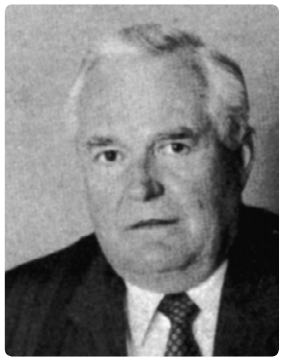
In 1989, two Study Committees of CIGRE Paris had meetings in the former Yugoslavia and both were held in Sarajevo:

- The meeting of SC 13 - "Switching Equipment" from May 22 to 25, 1989,
- The meeting of SC 22 - "Overhead lines and Transmission line open Conference", i.e. from October 8 to 13, 1989.

As part of JUKO CIGRE, two papers from Bosnia and Herzegovina were published at the sessions of CIGRE Paris, at the 29th session in 1982 and at the 32nd session in 1988.



Emerik Blum



Jovo Mandić



Čedomir Miličević



Fig. 6.21 8th Conference of JUKO CIGRE, Mostar 1966 - Sabaher, Wolf, Frančić, Sirotić, Jurković

b) History of the National Committee of CIGRE (BHK CIGRE)

BHK CIGRE was founded on August 23, 1992 in wartime Sarajevo. At the Provisional Founding Assembly, which consisted of the 33 so-called old Cigreans, the leadership of the BHK CIGRE and the chairmanship of the study committees were elected and a delegation to participate in the 34th session of CIGRE in Paris was appointed. For the first president was elected prof. Rusmir Mahmutčehajić. At the 34th session, the BHK CIGRE delegation, led by Edhem Bičakić was welcomed by the Secretary General, Mr. Yves Porcheron. Secretary General Porcheron gave strong support to BHK CIGRE and enabled our delegation to present the electricity situation in Bosnia and Herzegovina at the session of the CIGRE General Assembly. This resulted in the admission of BHK CIGRE to full membership in CIGRE at the Administrative Council in March 1993. Thus, BHK CIGRE became the first non-governmental organization in Bosnia and Herzegovina to achieve its full membership in an umbrella of international organization.

Today, BHK CIGRE is the largest professional, non-governmental, independent, and voluntary organization in Bosnia and Herzegovina.

Since 1993, BHK CIGRE has been a regular member of CIGRE Paris and its members participate in its work through administrative bodies, participate in Study Committees work, working groups and through reports at sessions

and colloquia. CIGRE President Michel Chamia visited BHK CIGRE in 1998. Secretary General Jean Kowal attended the 6th BHK CIGRE Conference in 2003 and President André Merlin attended the 9th BHK CIGRE Conference in 2009. Organization of technical work in BHK is similar like CIGRE mother, in Paris. National Study committees are organized as mirror of CIGRE Paris. BHK CIGREon local level has about 350 individual members and 21 collective members. Membership of BHK at international level as from 2020 is 51 individual and five collective members, which means 81 equivalentmemberswith CIGRE Paris.
In 2020 in Working Groupsof CIGRE Paris, there are six active members from BHK. In addition, BHK in 2020 has a significant number of Study Committee members (13 observers and 1 regular).
Authors from Bosnia and Herzegovina have published 12 papers at the CIGRE-Sessions in Paris since 2000.

Leaders of CIGRE BHK from 1992

Period	President of BHK
1992–2015	prof. dr. Rusmir Mahmutćehajić
2015–	Mr. Edhem Bičakčić



prof. dr. Rusmir Mahmutćehajić



Edhem Bičakčić

CIGRE International Awards - Distinguished Members:

- Mensur Hajro, 2006
- Mirsad Kapetanović, 2006
- Rusmir Mahmutćehajić, 2006

BHK will host the Administrative Council of CIGRE Paris, which will be held in 2023 in Sarajevo.

6.3 Activities of BHK of CIGRE and achievements

From 1993 to 2019, BHK CIGRE organized fourteen biennial conferences; in total 1718, professional and scientific papers were published, with the participation of over 4000 experts, scientists, and professionals.

Table 6.4 The list of conferences of BHK CIGRE from 1993 to 2019

BHK CIGRE Conferences	Location	Year	Number of authors / co-authors	Number of Papers
1	Sarajevo	1993	89	65
2	Tuzla	1995	110	86
3	Cazin	1997	149	94
4	Neum	1999	158	106
5	Neum	2001	226	142
6	Neum	2003	236	136
7	Neum	2005	216	121
8	Neum	2007	254	123
9	Neum	2009	196	114
10	Sarajevo	2011	267	114
11	Neum	2013	324	140
12	Neum	2015	411	155
13	Neum	2017	344	158
14	Neum	2019	337	164
TOTAL				1718



Fig. 6.22 1st Conference of BHK CIGRE, Sarajevo 1993, during the war time



Fig. 6.23 2nd Conference of BHK CIGRE, Tuzla 1995, during the war time



Fig. 6.24 Opening Ceremony of 13th Conference of BHK CIGRE, Neum 2017



Fig. 6.25 Opening Ceremony of 14th Conference of BHK CIGRE, Neum 2019

BHK CIGRE since 1998 has organized six international meetings:

1. CompositeInsulators: Why Yes - Why No/CompositeInsulators: Why Yes - Why Not, BHK CIGRE - STK 15 Materials for Electrical Technology, Sarajevo, 1998.
2. Tutorial "International School on High Voltage Circuit Breakers", BHK CIGRE, SC A3 of CIGRE Paris and Faculty of Electrical Engineering, University of Sarajevo, Sarajevo, June 2003.
3. International Colloquium "Asset Management of Switching Equipmentand New Trends in Switching Technologies", BHK CIGRE and SC A3 of CIGRE Paris, Sarajevo, Sep. 2003.
4. International Colloquium "Power FrequencyElectromagneticFields - ELF EMF", BHK CIGRE and CIGRE Paris SCs, B2, B1, B3, B4, C3 and C4, Sarajevo, June 2009.
5. International Colloquium "Power Quality and Lightning" BHK CIGRE and CIGRE Paris SC C4, Sarajevo, May 2012.
6. 1st SEERC Colloquium "Energy-climate National strategies 2030 and challenges for electric power sector", BHK CIGRE and CIGRE SEERC Sarajevo, October 2019.



Fig. 6.26 International Colloquium "Power Frequency Electromagnetic Fields - ELF EMF", CIGRE Sarajevo 2009.



Fig. 6.27 International Colloquium "Power Quality and Lightning" BHK CIGRE and CIGRE Paris SC C4, Sarajevo, 2012.

From 1994 until today, BHK CIGRE has organized over 30 round tables, panels, and lectures, with the participation of numerous local and regional experts, scientists and professionals.

Considering that the result of scientific research is an exceptional factor in the development of any social environment and that there is stagnation in the field of scientific research in Bosnia and Herzegovina due to well-known causes, BHK CIGRE in the last five year shas concluded several very important Agreements / Memoranda of Cooperation with several organizations and Academies of Science.



Fig. 6.28 1st SEERC Colloquium "Energy-climate National strategies 2030 and challenges for electric power sector", BHK CIGRE and CIGRE SEERC Sarajevo, October 2019.

BHK CIGRE is the publisher of the journal BH Electrical Engineering (https://bhee.ba/). The Journal publishes papers in the field of electrical engineering (power engineering, electronics, telecommunication, automatics, robotics, etc.), as well as in the field of computing engineering and information technology, in English, and has been indexed in IET Inspecand EBSCO.
BHK CIGRE has so far published three university books and one monograph.



Fig. 6.29 B&H Electrical Engineering, Volume 13, 2019

The awarding of recognitions and awards should be an ongoing process, so that it is regulated systematically, through the appropriate Rulebook adopted in BHK CIGRE in 2017. Recognitions and awards for their work can be given to members, honorary members, friends and sponsors of the BHK CIGRE. The awarding of recognitions and prizes according to this model started during the 13th conference of BHK CIGRE - Neum 17–21 September 2017.

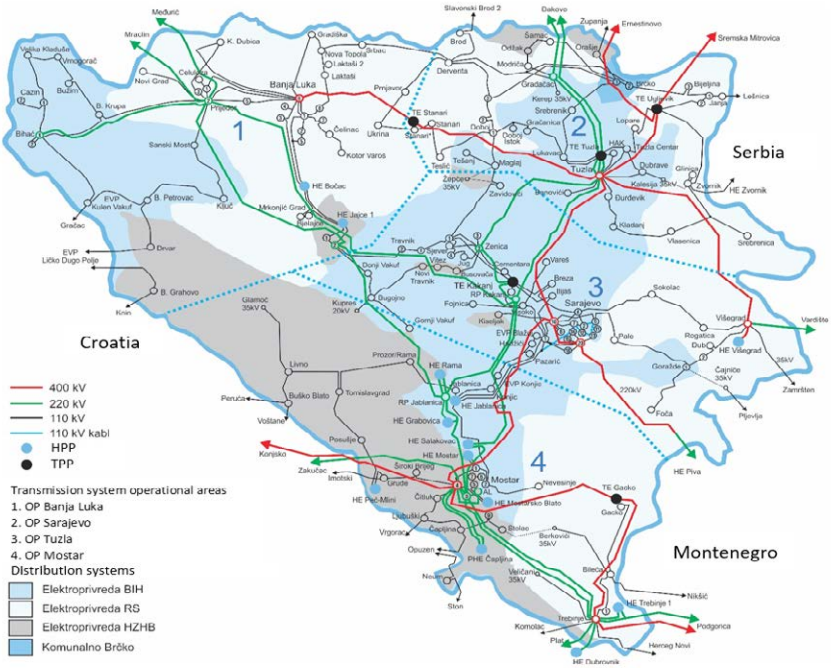
The following awards can be given for the development, contribution to the work and affirmation BHK CIGRE: Recognition for life time achievement (so far, received by Emerik Blum, prof. dr. Vefik Karabdić, prof. Franjo Božuta, dr. Jovo Mandić, Hakija Turajlić, Academician Božidar Matić and prof. Dane Maljković, posthumously, and Academicians Kemal Hanjalići and Branislava Peruničić-Draženović);



Fig. 6.30 Awarding plaques to individuals, as a special recognition for outstanding professional and scientific work in BH K CIGRE, 13th Conference of BHK CIGRE, Neum 2017

Within BHK CIGRE, during 2018, the Forum Women in Engineering was formed. The Next Generation Network Forum was formed in 2020.

6.4 Country electric power profile and RES vision



Population	3,511 million
Area	51,197 km²
GDP/capita	5400 EUR

Primary Energy (2019)	328 PJ
Final Energy (2019)	193 PJ

RES ENERGY	**%**
2020	40
2030	53.6

Transmission Grid		
Voltage Level	**HV lines**	**Length (km)**
400 kV	15	866
220 kV	42	1520
110 kV	241	3983
110 kV (cable)	9	33
TOTAL	**307**	**6402**
Distribution grid		
Voltage Level	**0.4–35 KV**	**Length (km)**
TOTAL		**97500**

Peak Load (2019)	1945 MW
Installed capacity Lignite (2019)	2156 MW
Installed capacity Hydro (2019)	2239 MW
Installed capacity Wind (2019)	87 MW
Installed capacity Solar (2019)	22.35 MW
Electricity generation (2019)	16 TWh
Electricity consumption (2019)	11.3 TWh

6.5 References

1. 100 godina električne energije u Bosni i Hercegovini, Izdavač: JP Elektroprivreda BiH, Sarajevo, 1988.
2. Monograph "25 years of work of the Bosnia and Herzegovina Committee of the International Council for Large Electrical Systems CIGRE", Sarajevo 2018.
3. MonografijaElektroprenos - Elektroprijenos BiH, Izdavači: Elektroprenos - Elektroprijenos BiH i Grafid d.o.o., Banja Luka 2016.
4. http://www.cigre.org/
5. V. Kh. Ishkin, International Council on Large Electric Systems, "CIGRE History activity 1921-2006", Orgengoservis, 2006.
6. The History of CIGRE (International Council on Large Electric Systems) - ImprimeriesConformes, 2011, ISBN: 972-285873-166-4.
7. 40 godinarada JUKO CIGRE: Izdavač JUKO CIGRE, Zagreb, 1991. godine.
8. PedesetgodinadjelovanjaCIGRE u Hrvatskoj 1951–2001./DesetgodinaHrvatskogkomiteta CIGRE 1991–2001, Izdavač: Hrvatskikomitet CIGRE, Zagreb, Berislavićeva 6, Zagreb, svibanj 2001., ISBN 953-6408-44-9.
9. 60 godinarada CIGRE: Antologijatekstovaizpriloga, monografijaidokumenata, Izdavač: SrpskinacionalnikomitetMeđunarodnogsaveta za velikeelektričnemreže - CIGRE Srbija, Beograd, maj 2011., ISBN 978-86-82317-70-8.
10. Dokumentisasavjetovanjairazličitihskupovaisastanaka u organizaciji JUKO CIGRE.
11. Dokumentisasavjetovanjairazličitihskupovaisastanaka u organizaciji BH K CIGRE.

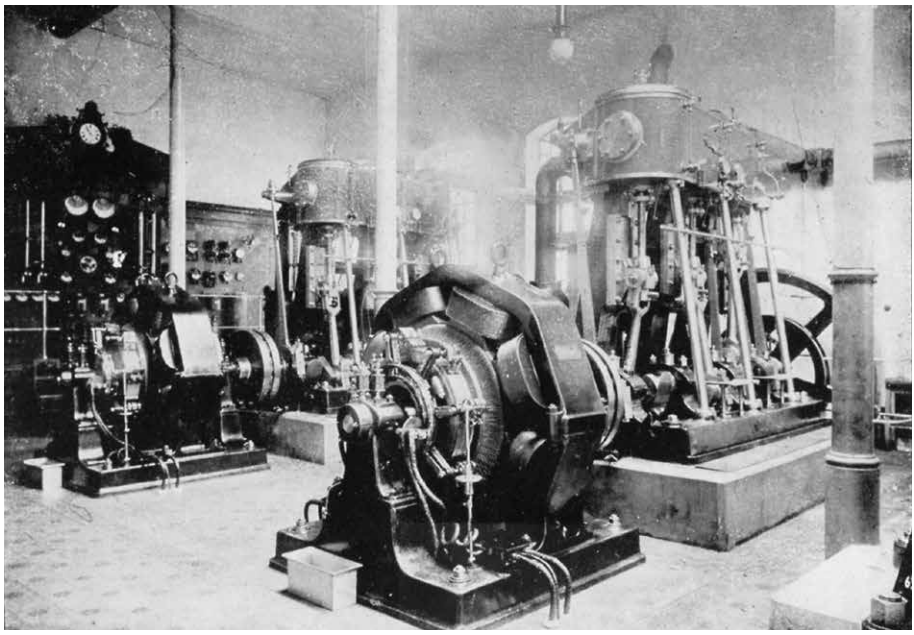
E-mail: contact@cigre.gr

7. NC CIGRE CZECH & SLOVAK REPUBLICS

7.1 History of the electric power sector

a) The beginnings of electrification in the Czech lands

The beginning of the use of electricity in the Czech lands dates back to the 1980s. People relied mainly on the use of direct current and small power plants, such as the power plant of the National Theater in Prague in 1882. Later power plants were built in factories, first exclusively for business needs but subsequently also for supply outside of the enterprises.
The year 1889 is considered the birth of the electric power industry in the Czech lands and marks the construction of the first public power plant in Prague-Žižkov by the Czech inventor and engineer František Křižík. The power plant supplied electricity for the needs of the public. It was the second public power plant to be built in the Austrian empire and was followed by others in Prague and elsewhere in Bohemia and Moravia.



The effort to provide electricity for the countryside was reflected in the establishment of agricultural power plants on a cooperative basis. This state of development of electrification existed in the Czech lands until the First World War. Overall, it was limited to the creation of small uneconomical works. This is evidenced by the following data: in 1918, there were 277 individual power plants with an installed capacity of 127 MW and 685 factory power plants with an installed capacity of 566 MW in Bohemia and Moravia.

At the beginning of the 20th century, renewable resources were used as fuel in a number of power plants. For example, the steam plant in Velká Meziříčí burned leached spruce bark from the local tannery or the power plants in Rychtářov and Mladkov and elsewhere used sawdust and waste wood. In 1905, the construction of the first municipal waste incinerator in the Czech lands was completed in Brno. The great importance of electrification consisted in the more rational use of all energy sources.

Until 1918, during the time of small local resources and larger resources for the use of one enterprise, the benefits of electricity were not notable. This was due to the fact that each plant was responsible for its own process of converting mechanical energy (in steam power plants chemical energy to mechanical energy), which was about demanding as building a steam engine. For some industries that needed steam as well as propulsion steam engines were more advantageous. Another disadvantage were the large fluctuations in electricity consumption, which meant that power plants had to be built for maximum consumption. This meant that especially small power plants remained unused for most of the day and were often insufficient during the peak. The exception was accumulation in small DC power plants.

The spontaneity in the establishment of power plants was reflected in various current systems.

Operating large new machines required qualified personnel that was unavailable. The stokers for power plant boilers and engineers were therefore retired sailors from the Austrian navy who became acquainted with this practice when operating machinery.

The first period of electrification is characterized in the Czech Electrical Engineering Association (Elektrotechnický svaz český) publication Electrical engineering in the construction of Czechoslovakia from 1945: *The first period of electrification is singular, creating unique electrified islands or oases in a non-electric desert. During this period, electricity was generated at or near the point of consumption, so geographically it was local electrification. The cities were electrified, namely the largest,*

large, smaller, gradually also small, and - rather exceptionally - individual settlements (near mills, sawmills, sugar factories). Electricity was used mainly for lighting and (in large cities) very soon to power (electrified) urban railways. During this period - the end of the 19th and the beginning of the 20th century until the end of the First World War - many power plants were built, often as part of factories (mills, sawmills, ironworks, mines, etc.). Electricity was produced and distributed mainly in the form of constant current from 110 V to 750 V. The energy efficiency of converting coal into electricity was only about 2% to 3%, later as much as 5%. This period of singular electrification is characterized by the names Edison and in the Czech lands Křižík.

As early as 1905–1910 various studies proved that it is possible to produce electricity up to 40% cheaper in power plants with an output of 3000–5000 kW and at the same time increase their use by 10%. Therefore, in the first decade of the 20th century, new power plants with ever higher outputs were built in all European countries and overseas. Electricity was becoming a sought-after commodity that paid relatively well. Practically overnight, small power plants expanded, new ones were built and ways to further expand and satisfy the demand for new energy were needed. Electricity had many advantages that no other type of energy had.
AC electrification began to develop in the early 20th century. It required new high-performance propulsion machines and the production of a considerable amount of steam at high temperature and high pressure. Electricity generation is closely connected with the development of energy engineering and the electrical engineering industry, the origin of which dates back to the 1880s in the Czech lands.

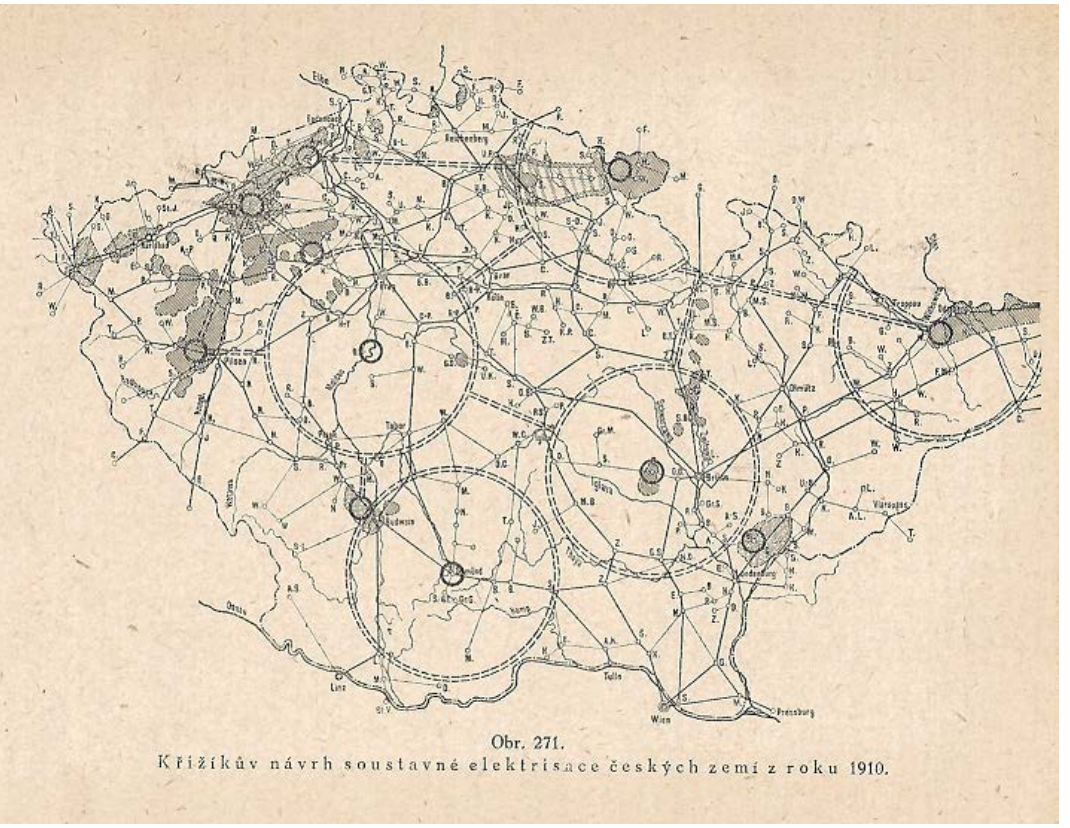


Fig. 7.1 Electrification concept by Fr. Křižík (1910)

b) The efforts to electrify railways in the Czech lands

František Křižík is best known as an enthusiastic promoter of the use of electricity and a successful businessman – Českomoravské elektrotechnické závody Fr. Křižík used to produce all electrical equipment for power plants. He is the creator of the so-called Křižík arc lamps and he built the first public power plant in Prague and a number of other public and factory power plants in the Czech Republic, Bosnia, Croatia and Poland. In 1905 he built the first electric car. That year he also authored a proposal for the systematic electrification of the Czech lands, which he submitted to Jiří of House Lobkowicz, the provincial marshal. In 1910, Křižík repeated his proposal for the project to the Austrian Railway Council.

Křižík built electric railways in Prague (1891), Pilsen and Pula, and the port railway from Dubrovnik to Gruž. As early as 1899, Křižík's factory conducted systematic experiments with a DC voltage of 750 V, despite the fact that at that time the DC system was considered unsuitable for railways and experiments with an alternating current took place in Germany, France and the United States.
In March 1899, Křižík's factories began trial runs with an electric car equipped with batteries. The next stage was the electrification of the Tábor-Bechyně line. The first motor car with a voltage of 2 x 700 V departed on the 1st of June 1903. The results with high DC voltage were so favorable that Křižík's factories took part in a competition for the electrification of the Vienna city railway presenting a similar solution. Their proposal was recognized as the most appropriate. During the trial runs, DC voltage was selected again, but this time an extraordinarily high 2 x 1500 V for the first time in history. With this Křižík proved the advantages of the Czech DC system, which was subsequently adopted in the United States, France and elsewhere. The electric locomotive for Vienna's city railway introduced several pioneering elements. The Czech DC system was thus a world leader.
In 1905, to make the electrification of railways possible, Křižík proposed the creation of a unified electrical network. The proposal was based on the use of inferior Czech fuel with power plants directly at the mines, which would bring many benefits for the development of industry in Bohemia, Moravia, and Silesia. It was rejected by the Austrian authorities.

The headquarters designed by Křižík had (as seen in the picture) a range of about 50 km and were interconnected, which would have created a fairly dense network of supporting power plants to not only cover the need for railways, but also supply electricity for other purposes. The interconnection of Křižík plants opposed the generally accepted idea of a separate railway network.
The central point of the design was to be the hydroelectric power plant in Štěchovice, the circuit of which was directly connected to the North Bohemian coal region, the Kladno and Plzeň basins as well as the South Bohemian and Moravian-Silesian circuits. Křižík's project was not realized because the preparatory work was interrupted by the war.

c) Research and Development

Research in the Austrian empire was ensured in the Czech lands by laboratories and institutes of universities or was organized, supported, and ensured, to the extent possible, by scientific societies, professional associations, and foundations. Steam engine production was a test of the technical sophistication of our engineering. In the 1870s and 1880s plants employed new technical staff with deeper theoretical knowledge of the construction of steam engines. The introduction of mechanical engineering as an independent field in 1863 at the Prague Polytechnical Institute and the teaching of machine construction theory under the guidance of professors Schmidt and Salaby paved the way for the research and development of new types of engines and improvements to the older designs. The practicality of the connection of technical education and technical practice in industrial production became fully apparent in the 1880s. An important field in terms of growth of the technical level of Czech engineering was the introduction of steam turbine production. At that time, the Czech steam engine school was rightly talked about around the world.

Research in electrical engineering was primarily focused on mastering the simplest principles of electricity production, distribution, and consumption technology, although in this period efforts to examine these problems in the broader context of the system arose. In addition to universities, the scientific and technical solutions to these issues were concentrated in the development and design offices of companies producing energy equipment.

Even the war could not stop progress in electricity generation. In thermal power plants, the focus was the better use of inferior fuels in large-scale power plants built directly at the mining sites. Efforts to recover the valuable by-products of coal and only burn other combustibles came to the forefront. The production process was modernized by replacing human labor with machines. Developments of hydroelectric power plants as well as steam power plants continued. Water turbines were improved. The Kaplan turbine significantly affected the construction of hydroelectric power plants, which enabled better use of small and medium gradients at large and medium water flow rates.



Fig. 7.3 Hydro power plant Hučák (est. 1912)

d) Systematic electrification

Other proposals for the systematic electrification of the Czech lands are associated with the name of professor Lista and were created after 1910 with the aim to ensure their further economic development. They consisted in private and public capital cooperation and the establishment of provincial power companies - one for Moravia and one for Bohemia. They were to focus on the construction of large power plants, power lines and networks appropriate to the given conditions.

These efforts resulted in a bill in 1914 centered around the electrification of Moravia. The basic idea of the bill was to replace the irrational fragmentation of the power business of the local governments with a concentrated, systematic, and unified business. In the history of technology, this was, according to the historical press, the first attempt at systematic electrification of the entire country. Unfortunately, the war interrupted its further implementation.

It should be noted that the Austrian government tried to enforce the electrification of the monarchy with the Imperial Electrification Act after unsuccessful attempts in 1908 and 1914. On the 24th of August 1917, a new proposal was submitted to the parliament with no avail.

e) The creation of territorial electrical grids

The basic conditions were created after the establishment of the Czechoslovak Republic by Act No. 438/1919 on State Aid for the Commencement of Systematic Electrification. The following was said during the discussion of the law in the National Assembly:

- Our country is lagging in the use of electricity. Switzerland, northern Italy, Belgium, and Prussia are almost entirely electrified. This can also be said about the Alpine countries. On the other hand, we only had one large Czech power plant in Prague until recently.
- We made a serious mistake by building a large number of small power plants with large overheads for often local or petty reasons. Thus, for example, according to the statistics of the provincial administrative commission, there were 205 power plants in Bohemia in 1915. And yet, with this number, only 1,000 municipalities with 2,750,000 inhabitants were supplied with electricity, while 6,780 municipalities with 4 million people were left without electricity.
- Hydropower flowed out of our lands unused. Now we must work tirelessly to make up for what has been lost.
- Only in this way will it be possible to eliminate the expensive use of small heat engines, which, in the interests of economy and in particular to save coal, must be replaced by concentrated electricity generation in power plants built on mines and water resources.
- The following comparison shows how uneconomical small power plants have been: In peacetime, a 100-horsepower plant produced one kilowatt-hour in about 40 hours, while a large steam power plant produced a kilowatt-hour in 5 hours and plants using waste coal in 2 hours.
- The fact that the current method of energy production by various engines uses almost half of all coal mined in today's coal industry is a warning phenomenon. It shows that we need to utilize hydropower, which would amount to about 800 000 horsepower and we would save 600 000 wagons of coal annually.
- Coal management is a basic requirement for the future proper management of power, and therefore electricity. It is our duty to take the utmost care examining our coal deposits since it is not possible to determine the future consumption of power, but we must assume that this consumption will increase as physical labor is reduced.

- The mechanical energy of the steam engine, which replaced human and animal labor, was a huge turning point in the last century. Electricity has become the most suitable form of auxiliary energy as it is the easiest way to transfer mechanical energy, to make the best use of hard-to-reach water resources and to concentrate energy production directly in the mines.
- Systematic electrification is of similar importance to our national economy as railways, and with its cash turnover it will be equal to railways in the foreseeable future, as it is not long before the total annual energy consumption in the Czech Republic will amount to 3–4 billion kilowatt-hours.

f) Characteristics of Act No. 438/1919

State Aid for the Commencement of Systematic Electrification had three sections and 33 paragraphs, and its quality is evidenced by the fact that it was valid with minor changes until 1957. The law offers interesting solutions for the creation of state aid in the energy sector and the protection of property rights even today.
The Ministry could order the owner of an inadequately used electrical work or hydroelectric resource to utilize it properly as a part of the systematic electrification in the public interest if this could be achieved without affecting its regular operation.
If the owner did not comply with the set deadline, the Ministry was entitled to take the necessary measures for the full use of the electric work or hydroelectric resource itself, in particular by entrusting the use to another enterprise. The owner would be compensated if he or she suffered property damage.
The law ordered the approval authority to take into account the needs of systematic electrification and the public interest when approving all power plants and lines, even those that were to only be used for the purposes of the entrepreneur, and to lay down the necessary conditions in concessions.
Electrical companies were obliged to submit the reports needed for systematic electrification and data for statistics to the Ministry free of charge.
The transmission of electricity across the borders of Czechoslovakia required a special permit issued by the Ministry.
Due to the creation of this law, the Ministry of Public Works in agreement with the participating ministries could declare enterprises, in which the state together with self-governing unions or cooperatives would take over 60% of the

share capital and would ensure permanent influence on their administration, to be so-called "non-profit enterprises".
It was assumed that the state and regions would build expensive hydroelectric power plants and non-profit enterprises would build thermal and distribution power plants and take electricity from state and regional hydroelectric power plants.

Based on the Electrification Act these non-profit power **companies were created:**
Ústřední elektrárny, stock company, Praha
Elektrické podniky hlavního města Prahy, Praha
Elektrárenský svaz okresů středočeských, private limited company, Praha
Elektrárenský svaz středolabských okresů, private limited company, Kolín
Východočeská elektrárna, stock company, Hradec Králové
Východočeský elektrárenský svaz, private limited company, Pardubice
Ploučnický elektrárenský svaz, private limited company, Česká Lípa
Jihočeské elektrárny, stock company, České Budějovice
Povltavský elektrárenský svaz, private limited company, České Budějovice
Lužnický elektrárenský svaz, private limited company, Tábor
Otavský elektrárenský svaz, private limited company, Písek
Posázavský elektrárenský svaz, private limited company, Německý (Havlíčkův) brod
Západočeské elektrárny, stock company, Plzeň
Elektrárenský svaz pošumavských okresů, private limited company, Stříbro
Družstevní závody, cooperative society, Dražice nad Jizerou
Přespolní elektrárna, stock company, Liberec
Západomoravské elektrárny, stock company, Brno
Moravskoslezské elektrárny, stock company, Moravská Ostrava
Severomoravské elektrárny, stock company, Zábřeh
Středomoravské elektrárny, stock company, Přerov
Západoslovenská elektrárne, private limited company, v Bratislava
Středoslovenské elektrárne, private limited company, Banská Bystrica
Južnoslovenské elektrárne, private limited company, Komárno
Spojené elektrárne severozápadního Slovenska, private limited company, Žilina
Východoslovenské elektrárne, private limited company, Košice

Conditions for systematic electrification were set for 25 non-profit power enterprises in Czechoslovakia by the Ministry of Public Works on the 13th of September 1920. A three-phase current system of 50 Hz and normal voltage was

set for the whole country. 3 x 380/220 V for local networks, 22 000 V for country networks and 100 000 V for long-distance networks. The voltage of 6000 V was determined for generators.

A Power Advisory Board was also established. It was set up within the Ministry and appointed representatives of regions, self-governing corporations, science, industry, agriculture, trades, trade unions, electricity companies and electricity consumers, as well as representatives of officials and workers of electricity companies.

It should be noted here that there were a number of power plants in Czechoslovakia that could not be non-profit. According to statistics from 1927, there were

Hydropower plants	62 with total power 15 960 kW
Steam power plants	34 with total power 114 482 kW
Steam and hydropower plants	45 with total power 35 344 kW
Diesel power plants	29 with total power 8467 kW
Gas power plants	6 with total power 587 kW
Mixed drive power plants	55 with total power 12 698 kW

Non-profit power plants were grouped in the Group of Non-profit Power Plants of the Czech Electrical Engineering Association, power plants without the right to be non-profit in the Czech Electrical Engineering Association, German power plants in the German Power Plants Association, which in 1926 had 75 members, including factory power plants with an output of 122,000 kW and a supply area of 1,000 towns and municipalities.

The increase in installed capacity in steam power plants in the interwar period was: non-profit enterprises with an output of 354.7 MW, of which 203 MW in coal districts, 151.7 MW outside of them; power plants in mines 180 MW; power plants without non-profit rights, both municipal and factory, with a total output of 186 MW. Output in larger power plants in 1939 was about 650 MW (with 91 turbines with an average unit output of 7.15 MW).

The development of new power plants brought losses of brake-specific heat consumption at the level of 26.5 MJ / kWh in 1937, i.e. lower consumption by 15% compared to 1930.

In 1930, the most modern heating plant in Europe was launched in Brno with pulverized coal-fired boilers of 6.4 MPa, 450° C and back-pressure turbogenerators with a steam pressure of 0.9 MPa. The leading position in the Czechoslovak Republic was maintained by the Holešovice heating plant.

During the 1920s and 1930s, steam engines and transmissions were gradually abandoned and replaced with steam turbines and electric motors. It was thus

possible to significantly increase labor productivity with lower fuel consumption. With the growth of consumption in industry and households, attention was paid to the operational efficiency of thermal power plants, especially peak and seasonal ones. For example, a state-of-the-art power plant with the necessary operation of 3 hours in the morning and 2 hours in the afternoon was in operation for up to 13 hours and thus took the load off the main power plants. The changes could be achieved by purposeful reconstruction of boilers and machines in old power plants, where the improvement in operating efficiency was particularly remarkable.

The waste incinerator in Vysočany was to become an economical source of energy in the 1930s in Prague. Provided that only 0.6 kg of steam is produced from 1 kg of waste, about 10,000,000 kWh was to be produced from 122,000 tons of waste in Prague, which was approximately one-seventh of all energy produced annually at the Prague Power Plants.

g) Electrification in industry, transport, and agriculture in 1919–1939

Industry

For some time after the war, the industry secured electricity by rebuilding plants. The growth of power plants only slowed down in the crisis years of 1930–1934. The share of power plants in the use of electricity decreased from 74% in 1919 to 61.2% in 1938. Nevertheless in 1936 the total number of power plants was 958 with an output of 1120 MW. Small power plants with an output of less than 0.1 MW produced 3% of the total production with an installed capacity of 80 MW. In 1936, power plants supplied 448 GWh of electricity to public networks. The high share of factory power plants is evidenced by comparisons with foreign countries from 1928: Germany 49%, USA 25%, Czechoslovakia 71%.

The slowdown had a number of reasons: neglect of development, little care for the power reserve, new equipment required more qualified staff, underestimation of the impact of lower energy prices, inconsistent approach of public power plants in obtaining industrial offtake, disruption of electricity supply or competition with fuel suppliers.

In addition, the share of electricity in production expenses of industrial enterprises was small (3–5%). It was the lowest in the clothing industry, higher in textiles, mining and in the metals and iron industry, and high in paper production (approx. 10%). This situation was not interesting for business, although the

links of industrial offtake to non-profit enterprises were mostly, especially in the second half of the period, more advantageous than the production expenses.

Electrification of transport
Very little was done in the electrification of railways compared to the period before the First World War. There was a shift in the Wilson station with battery-powered locomotives with 280 horsepower. A substation with convectors with a total output of 5 MW (for 17 service locomotives) was built for service in the Vinohrady tunnel.

Electrification of agriculture
The electrification of agriculture was also slow. The Ministry of Agriculture offered support action in the form of an annual subsidy of 15.25 million crowns, but it was only focused on a small number of municipalities in poorer areas, so it did not help much.
Improvement was brought about by the Act of the 1st of July 1926 No. 13 Coll. on Financial Support for Rural Electrification.
The original subsidy of 10 million crowns / year, provided to up to 50% of the cost of the secondary network and mainly the connection, increased to 35 million crowns / year from 1929 to 1933, and later decreased again to 25 million crowns / year. By 1940, 371 million crowns were available. Conditions were more favorable in Bohemia and Moravia.

h) Electrification of households

The high price of electricity per kilowatt-hour negatively affected the consumption of electricity in households throughout the time of the First Republic. At the end of 1928, the supplier organizations justified the price of the energy consumed to their customers with the fact that the lighting of the apartment, which consumes 1 kW at the highest power of light bulbs, consumes a total of 600 kWh in one year at 600 hours of lighting.
Only areas in the countryside where there was a guarantee of invested capital return with interest were given care. Therefore, there was a differentiation in the electrification of the country. Cities and prosperous communities were electrified while poor areas were not.

i) The economy

The development of electrification depended primarily on:

- the prices of coal, building materials and technological equipment,
- the economic level and size of the supply area,
- technical indicators of electricity production (power utilization, brake-specific fuel consumption, the number of employees per unit of output),
- the nature of the investment, i.e. the size of the enclosed space, the specific weight of the equipment, the unit power of sources and the concentration (density) of electricity consumption and related investments in electricity distribution.

These indicators led to a different level of investment per capita from a minimum of 129 crowns/capita to 495 crowns/capita.

In 1925, non-profit power plants produced over 285 million kWh, i.e. about 22% of all energy. In addition, these companies owned more than 85% of all country, interurban power lines, mainly overhead lines.

The progress of the electrification was estimated by the fact that from the coup until 1925 1 and a quarter million new light bulbs were connected, reducing kerosene imports by about 24 million crowns. In addition, 70 000 small engines with small outputs were connected, mostly for the needs of sole traders and agriculture.

There was a significant difference between non-profit, municipal and factory power plants in terms of profit generation. While in 1935, 13 out of 25 non-profit enterprises did not pay a dividend, the economic result of SEVČE (Severočeské elektrárny městské) shows the advantage of production, high dividends and a high ratio of sales and investments. This was made possible both by the high price of electricity and by objective conditions, such as the average consumption density per 1 km of the primary line, which was 4.5 times higher in 1929 and 2 times higher in 1936 than for non-profit enterprises.

The results of municipal power plants were however generally worse than the results of the non-profit power plants. This advantage was not reflected in lower electricity prices. Potential surpluses were sent to cities. The municipal power plant in Kadan, for example, was so indebted that the economic results were not enough for interest or loans. The utilization of the installed capacity was 1085 hours, i.e. half that of non-profit power plants.

After 1918, about 330 individual power plants were established in the Czechoslovak Republic. They however started ceasing to exist or merging with non-profit

enterprises. At the end of 1932 there were only 218 individual power plants with an average output of 766 kW, while the average output of large power plants was 6540 kW, i.e. 8.5 times greater with 40% better utilization. Electric current prices were often up to 1/3 higher than for non-profit enterprises.

Price and tariff policies

Price and tariff policies were inconsistent in 1919–1939. More than 300 enterprises were in the electricity trade without unified management based on the profit principle. Prices were related to the unequal degree and pace of electrification. For example, Prague had an annual consumption of 290 kWh / inhabitant and Přerov 125 kWh, but the countryside and poor areas only 26 kWh. The development of retail serves as a reflection of the standard of living. Compared to other countries we were in 9th place in terms of production per capita. While the average consumption in the Czechoslovak Republic was 100 kWh per household, the USA reached 850, England 500, the Netherlands 300 and France 180 kWh. This was not only caused by the price of electricity, which decreased by about 1/3 over the course of 20 years and did not differ much from the world average. Comparing the prices of electricity for light and small engines abroad with some wholesale prices according to the conversion of the currency ratio shows that the power plant cost as much in Czechoslovakia as abroad. The trend of secondary indices in 1918–1934 also shows that electricity for light, the price of which gradually decreased, had the lowest secondary index.

j) The results of the development of electricity generation

In 1919–1939, electricity production quadrupled with an annual increase of 5–15%. In Europe, the Czechoslovak Republic was overtaken by developed countries and countries rich in water resources. After 1938 there was a slowdown, the increase decreased to 3% year on year.

Of the total national assets, which were estimated at 500–600 billion crowns, individual power plants with distribution equipment had a value of approximately 4 billion crowns and electric railways, the electrical engineering industry, low-current equipment, the telegraph, and the telephone had a value of 10 billion crowns.

The use of power plants was about 40%. In Bohemia and Moravia about 70% of municipalities, in which about 90% of the population lived, were electrified, in Slovakia 23.5% of municipalities with 50.8% of the population.

Electricity costs accounted for about 1.5% of total national production and about 4% of the processed products cost.
The electrical engineering industry employed about 50,000 workers (mechanical engineering about 20,000 people). 5000 employees worked in the electrical appliances trade and in electrical installations. The number of employees in electrical companies ranged from 20–25 thousand. About 100,000 people found work in connection with electrification. In 1937, 600 million crowns worth of coal was burned in power plants. In costs, it represented about 1/3 (for big costumers). In 1936, the Czechoslovak Republic reached 200 kWh per capita per year, two years later 280 kWh/capita per year.

k) The results of areal electrification

In the beginning, the electrification of municipalities grew in proportion to the number of local power plants being built.
After 1920, when urban and private companies began to connect only those cities and towns where electrification promised profit, the pace slowed down. E.g. a secondary network with house connections and a transformation station cost about 150 to 200 thousand crowns in 1924. Citizens whose taxes contributed to systematic electrification had to renounce the benefits of electricity in these cases.
According to a statistical survey in 1929, electrification in the Czech lands was expected to end in 1935 and in Slovakia in 1945.
This was not achieved mainly due to the economic crisis. The first economic crisis occurred in Czechoslovakia as early as 1921. The index of total industrial production fell from 60.1% in 1921 (1929 = 100%) to 54.7% in 1922. The critical economic decline did not stop until 1923. However, in less than 6 years, a much greater economic crisis occurred, which devastated the economies of many countries including ours. This world crisis had a negative effect on the development of electricity and electricity consumption in Czechoslovakia.
During the First Republic, there was no unified energy distribution system. Individual areas, which were supplied by various power companies, from non-profit to municipal and commercial to private, developed separately without unified management and without a unifying master plan. The principles of standardization, especially for power plant machinery, were not followed and investment policy was often influenced by interests other than those of the

highest economic efficiency from a national perspective. Distribution networks were often built regardless of the possibility of their later interconnection, especially at the border. Centralization, whether by concentrating production for industrial purposes in large units using inferior fuels or even by concentrating electricity and heat consumption in advantageous energy areas, was a unique phenomenon.
Between 1920 and 1930, non-profit enterprises built up to 500 km of high-voltage networks a year. A qualitative change occurred with the construction of the 110 kV Ervěnice - Prague network in 1927 and then the Zábřeh - Handlová network. However, it was not possible to connect the regional non-profit enterprises and only 750 km of 110 kV lines were built as opposed to the original plan of 1400 km.

l) Technical development

Electrification had many other valuable economic results. For example, it gave a very effective impetus for the construction of huge turbines, generators, and transformers, and for the production of high-voltage electrical devices. It also stimulated the production of electricity meters in Czechoslovakia. It had an impact on the rationalization of boiler heating, the construction of new grates, the development of furnace inspection, the use of waste steam, and the development of heating with coal dust and inferior fuels. Regarding water turbines, it caused the introduction of very advantageous propeller (Kaplan) turbines, as well as improvements in water turbine regulators, mostly due to the activity of technicians and workers in Czechoslovak plants.
In the newly built steam power plants, the Czechoslovak Republic kept pace with state-of-the-art European technology in the development and construction of boilers with pressures of 40, 65 and 130 atm, as well as pulverized coal-fired boilers, steam and water turbines and electricity distribution. It is necessary to mention a Czechoslovak primacy in the field of water turbines – the construction of the Kaplan turbine in 1919 and pioneering deeds in thermal power plants. In 1927, the first boiler in the world with a pressure of 130 atm was built in Czechoslovakia and in 1931 a turbine of 21 MW, 125 atm, 490° C with steam interheating was put into operation. Teplárna Brno was at the forefront of Europe that same year with combined heat and power generation of 65 atm.
From 1919 to 1939, only 8 hydroelectric power plants over 10 MW with a total installed capacity of approximately 170 MW were built. Electricity consumption

for industry, agriculture and for the personal needs of the population was low in relation to the level of industrial production in the Czechoslovak Republic. In 1937, electricity production per capita was 270 kWh per year, while many industrial drives remained unelectrified.

Czechoslovak standardization

Developments in standardization began as early as the 18th century and World War II pushed standardization developments forward. Immediately after its founding in 1919, the Czechoslovak Electrical Engineering Association set to work on electrotechnical norms and regulations. In 1920 the first Czechoslovak electrotechnical regulations and norms for insulators, sockets, electrotechnical threads, transformers and so on were published. Soon, other technical fields also felt the need for standardization. A conference of industrial, economic, and technical experts at the beginning of 1921 spoke unanimously in favor of systematic standardization in Czechoslovakia. The Czechoslovak Standardization Society was founded in December 1922.

With the development of the energy industry, legal and technical regulations were created. The Czechoslovak Republic had regulations for the construction and operation of high-current equipment and a world class testing laboratory. However, standards and regulations were only recommendations without legal validity. Nevertheless, new uniform devices were introduced (e.g. the first 55 kV compressed air switches, 10 kV expansion switches, or illuminated dispatch schemes). Experience was gained with the parallel operation of several power plants. The frequency control was also very precise.

Research and Development

In the post-war period, there was an effort in all industrialized countries of Europe to rationalize the use of thermal energy and the need to create appropriate institutions for continuous research regarding these problems. In the Czechoslovak Republic, the initiator of the establishment of such an institution was the Ministry of Public Works. Due to its initiative the Institute for Fuel Efficiency was established in 1922. The institute's basic tasks included:

1. to consistently examine fuels and compile accurate statistics. Explore various ways of using fuels and find suitable constructions of consumer equipment and rules of correct operation.
2. to arouse general interest in the efficient use of fuels and to apply the principles of proper use of fuels in technical practice. In 1927, on the initi-

ative of the Association of Mine Owners, the Institute for Coal Scientific Research was established.

- Research institutes focused on individual technical fields were concentrated in Prague and Brno. 70% of them consisted of institutes and laboratories at universities and vocational schools in the field of electrical engineering and mechanical engineering. The mechanical laboratory of the Faculty of Mechanical and Electrical Engineering at the Czech Technical University in Prague, Institute of Theoretical and Experimental Electrical Engineering at the Czech Technical University in Prague, First Institute of General and Technical Physics of the Czech Technical University in Brno, Institute of Physics at the German Technical University in Prague. The beginnings of the connection between scientific research and industry appeared in the 1930s after the economic crisis and their main representatives were design laboratories and physical research at the Škoda factory in Pilsen.
- The Ministry of Industry and Trade established institutes, which mostly verified and tested electrical products and materials. For the same purpose, the Testing Electrical Engineering Institute at the ESČ was established in 1926, which later led the marking and calibration of electrical engineering products and materials.
- High-level research industrial activity was carried out by the so-called physical research of Škoda Factories and testing laboratories and laboratories of the Electrical Engineering Factory in Doudlevce, which were built in 1921–1922. They mainly carried out research of high-current devices focused on rotating electrical machines, transformers, and electrical devices. The physical research of Škoda›s factories was the only research institute that continued to operate during the Second World War and in which some professors and students from closed Czech universities found refuge.
- The broad base of research at universities and in interest and federal organizations was fragmented and not very economical, focusing on test, laboratory, expert, and hobby work rather than on important research, which lacked funding and technical equipment. The needs of the development of the Czechoslovak Republic (electrification of the territory, introduction of telegraph and telephone network and radio broadcasting, production of electrical equipment for power plants and industry) were only partly solved by research. The rest had to be provided by foreign licenses.
- Several institutes carried out electrical engineering research in ČKD in

Prague - Vysočany. These were the Centrally Authorized Testing Institute of ČKD, the Material Testing Laboratory of the ČKD Electrical Engineering Factory, the Testing Laboratory of the ČKD Electrical Engineering Factory, and the Testing Laboratory of Electrical Devices at the ČKD Electrical Machinery Factory. Research and industrial activities were carried out by the physical research of Škoda factories, associated with the Dolejšek Institute of Physics at Charles University and the testing laboratories and laboratories of the Electrical Engineering Factory in Doudlevce. According to the Czechoslovak National Research Council, the state's research base in the First Republic consisted of a total of 1,230 workplaces.

1938–1975

Electricity production in Czechoslovakia in 1937 was 3.682 GWh. The sources were as follows: 84.5% coal, 10% water, 4.4% gas (Vítkovice and Kladno) and 1% diesel. In the territories ceded in 1938 90 power plants were lost, of which 7 were large thermal power stations (Ervěnice 75,000 kW, Třinec 22,000 kW, Poříčí 35,000 kW, Trmice 60,000 kW, Třebovice 42,000 kW, Zbuch 15,000 kW, Nýřany 15,000 kW) and 4 were large hydroelectric power stations (Střekov 24,000 kW, Vranov 12,000 kW, Černé Jezero 1500 kW, Srní 6400 kW). The loss in Bohemia was 485 million kWh and in Moravia over 200 million kWh.



Fig. 7.3 Thermal power plant Ervěnice

Throughout the war industrial production grew and peaked in 1944. According to statistics, for example, our metalworking and engineering industries employed about 200,000 people in 1939, 253 998 in 1941, 302 897 in 1942, 373 634 in 1943, 451 703 in 1944 and 469 059 in March of 1945. About 29,000 people were employed in electrical engineering in 1941 and 47,500 people in 1944. This data does not include the border area. The growth of industrial production required more and more energy, which was taken from any available resources.
During the occupation there were four power companies in Bohemia and two in Moravia. According to the Order of the Protectorate Government No. 319/1941, the Reich industrial concern Elektrowerke was allowed decisive capital participation of these companies. In addition to non-profit power plants, urban and factory power plants remained. Electricity production in Bohemia and Moravia increased during the war. However, the equipment was not maintained and renovated.
Capital expenditures in energy sector was minimized. The increase in output was from the completed power plants that began construction before the occupation - Štěchovice, Kolín, Vydra, Kníničky and Svatoňovice. The construction of high voltage lines was small – only two lines were built (in 1941 the line from Lower Silesia Walbrzych to Poříčí and Všestar and in 1942 the Kolín-Všestary connection). At the same time efforts were made to subordinate and use our energy for German interests. A project for the construction of a 220 kV line from the Silesian districts through Moravia to Austria was prepared, with a promising connection to the Alpine water resources, which, however, was not implemented.
The development of areal electrification was also restricted. A total of 323 municipalities were connected during this period, i.e. an average of 56 municipalities per year. These were the consequences of not only the limited supply of electricity to small consumers, but also of the so-called "decopperization". During the war, the Germans began to promote the regular removal of copper from the lines because copper was scarce, and lines were not being repaired. Copper wires in the low-voltage networks were therefore replaced with iron wires.
A plant for the production of aviation gasoline and diesel fuel with an annual capacity of 660,000 tons of synthetic fuels was built in the Most brown coal district shortly after the occupation of the Sudetenland borderland. The production technology was based on the low-temperature carbonization production of tars and their further processing by high-temperature hydrogenation into motor fuels. The production of synthetic fuels peaked in 1943, when 400,000 tons

of gasoline were produced by processing 3,694,000 tons of coal. After the war, the hydrogenation plant was reconstructed and later rebuilt for oil processing because liquid fuels from coal were significantly more expensive than from oil. Part of the newly built plant for synthetic fuel was the construction of a large thermal plant with an electrical output of 200 MW. Stanislav Záhorský said at the congress of power plants in Zlín in May 1946:

The Germans understood the economic importance of the North Bohemian brown coal basin, which they intended to take full advantage of in the Reich's interests, and prepared, and for the most part already implemented, a plan to increase mining to such an extent that they would have depleted the entire basin in perhaps less than 50 years. They were mainly concerned with the production of motor fuels and electricity, and they planned accordingly. All mining companies were merged into a single coal concern, and in the vicinity of Most in the middle of the district, they built a huge factory for the production of synthetic gasoline at a cost of almost 6 billion on an area of about 4 km² - the current Stalin factory. The production capacity of the plants was to reach 650,000 tons per year in the first stage, and this output was actually achieved during the war for a short time. At the same time, the second stage planning was underway, so that production could be increased to 1,000,000 tons of motor fuels per year. For comparison, the entire consumption of petrol in the Czechoslovak Republic at the time of the greatest development of motorization before the occupation was about 300,000 tons. A heating plant for 200,000 installed kW was built for the first stage for steam and electricity consumption. A second heating plant for another 100,000 kW was under construction for the second stage.

However, the huge planned capacity of the company was supposed to correspond with a reasonably high consumption of coal. In the first stage 9 million tons and in the second stage 14 million tons, not counting the consumption of heating plants for the production of about 2 billion kWh in the first and 3 billion kWh in second stage, corresponding to another 2.5, resp. 3.8 million tons, and not counting the consumption of coal for long-distance gas production.

The mined coal was to be sorted in two central sorting plants in Komořany and at the Hercules mine. Three large-scale power plants were planned for the energy utilization of soot and inferior fuels, namely in Ervěnice at 140,000 kW, in Komořany at 270,000 kW and at Hercules at 300,000 kW, with a total of over 1,000,000 installed kW in two heating plants of today's Stalin factory. The electricity produced was to be supplied by high-voltage lines to aluminum plants in Linz and to steel mills.

In addition, extensive gas production for long-distance distribution with a capacity of half a billion m³ per year was planned.

1945–1970

Nationalization of the Czechoslovak industry in 1945 culminated in the issuance of Decree No. 100. On its basis, the Minister of Industry issued a decree in March 1946 establishing national enterprises. In total, around 1,350 different plants with a total electrical output of 1,481 MW were nationalized in the energy sector. Of these, 920 MW were in steam power plants and 180 MW were in hydroelectric power plants, 60 MW were in heating plants and about 320 MW were in factory power plants. However, this output could not be fully utilized due to the fact that about 55% of the power plants were over 20 years old and about 25% were over 10 years old, and therefore hadn't been properly maintained and repaired in several years. About 70 to 75% of the output was usable regardless of economic incentives. Over 13% of the machines had a brake-specific fuel consumption of over 7000 kcal for the production of 1 kWh and 62% had the lowest consumption from 4500 kcal up to 7000 kcal per 1 kWh. The delay in the construction of new power plants was estimated at 10 years at the time of nationalization and the loss of electrical power was estimated at 300 MW. In the factory power plants, which accounted for about 2/3 of all installed capacity and were mostly older than public power plants, the situation was even less favorable.

In addition to the poor technical condition of power plants, there were a number of small, self-operating systems with low outputs in the sources of unconnected distribution systems after the war. Every area had, in addition to small localities, its own individual system, which had high-voltage and very high-voltage lines built, to which larger sources located in the area supplied electricity.

The exceptions were Prague and Central Bohemia, which were connected to the Ervěnice power plant at the end of the 1920s, and some areas of Slovakia supplied from Moravia. Although the extra high voltage in all these isolated nodes was practically the same, which had a great advantage in the later interconnection of individual systems, the technical design and equipment were not uniform.

After the liberation, there were 7 main unconnected distribution systems in Czechoslovakia. The system in Bohemia operating in parallel in the 100 kV network had a maximum load of about 350 MW. The peripheral systems of western and north-eastern Bohemia and partly also southern Bohemia had an output of about 100 MW. The East Moravian 100 kV system connected to western Slovakia operated with a maximum of 130 MW, the West Moravian system with 80 MW and separate East Slovak networks about 40 MW. This regional

cooperation, with a total maximum of about 700 MW, saved about 50 MW due to the non-uniformity.
The situation was significantly worse in the taken over high and low voltage equipment. While the 22 kV system prevailed in the countryside, there were areas, for example in the North Bohemian borderland, which operated the 10 kV system, part of Central and Eastern Bohemia 15 kV, the Pardubice region 6 kV, etc. The situation was even worse in cities with cable networks. There was a whole range of voltages from 1.5 kV to 3, 5, 6 to 10 kV. In addition, several large cities introduced direct current, such as Liberec, Jablonec nad Nisou and others. In addition, until 1945, there was a different interpretation of technical standards, especially in border areas. Even with electrical installations not everything was right. So-called flat rates were also commonly used. One 25 W light bulb, which had a special thread so that it could not be replaced with a stronger one, cost 15 to 20 crowns per month, regardless of consumption. The installations were corded and on the wall on small insulators. Distribution boards with three-digit electricity meters, which showed a value as high as three nines, were placed in living rooms, regardless of the safety of people or things.
The situation was further exacerbated by the fact that large industrial enterprises producing and supplying electricity equipment were severely damaged during the war. This was negatively reflected in the supply of necessary material and repair capacities. And so only thanks to enormous efforts was it possible to restore the supply of electricity to most of Czechoslovakia shortly after the liberation.
It was a supply of considerably low quality with frequent outages due to malfunctions and due to lack of fuel or other materials necessary for operation. In some situations, consumption was turned off. At that time, all customers were affected as there was no choice and there were not enough funds for another solution. Thanks to the dedication of energy employees, in 1946, when the installed capacity of power plants was practically at the same level as in 1945, 15% more energy was supplied to households and industry. This was achieved by increasing the annual use of the standby output of power plants from 1796 to 2256 hours.

The technical development of electrical engineering

In the first post-war years, the technical development of the power industry in the Czechoslovak Republic was represented by steam generators with an output of 32 MW on steam of 80 atm and 480° C and boiler units with an output

of 100 t/h. At that time, small, technically obsolete power plants were being dismantled. The power industry was gradually concentrated and the operation was more economical through the reconstruction of old and the construction of new sources.

The first five-year plan (1949-1953) was a stage of technical development, after which units with an output of 50 MW were gradually put into operation in 1954 at the Třebovice and Hodonín power plants. Other power plants were gradually equipped with standardized turbines of 50-55 MW, steam of 90 atm and 500 ° C and boilers 125 t/h until 1960 (e.g. power plants Nováky I., Poříčí II, Tisová I, Opatovice, Mělník I). In 1947, 76.2% of all municipalities were connected to the electricity distribution network and 88.3% of all inhabitants were supplied with electricity.

The five-year plan also marked a milestone in the development of hydroelectric power plants. The water works being constructed had a predominantly multi-purpose character. In addition to their energy function, they also have a water management role. This period also includes the completion of the Slapy waterworks and power plant, the largest in the Czechoslovak Republic at the time. In the power plant put into operation in 1954, 3 sets with Kaplan turbines with a unit output of 48 MW were installed, the use of which presented a very advanced solution.

In 1950, power plants at mines (factory power plants) were transferred to the energy sector. In 1952, a unified nationwide 220 kV electricity system was created, connecting the existing three regional systems into one unit with unified dispatch control. The first international cooperation supplying electricity from the Czechoslovak Republic to the Hungarian People's Republic took place a year later with a 110 kV line.

From 1946 to 1954, electricity production increased by 142%, but the installed capacity of power plants only by 33%.

During the second five-year plan (1956-1960), electricity production increased by 62.9% in 1960 in comparison to 1955. The installed capacity did not correspond to this, which increased by only 43.6% at the same time. Delays in the commissioning of new units, especially in the years 1956-1958, were the cause of the difficult energy situation. The construction and gradual commissioning of new power plants with higher parameters also increased the overall efficiency of electricity generation. E.g. in steam power plants and heating plants in 1960, the brake-specific fuel consumption for the production of 1 kWh was 520 grams of specific fuel and was about 95 grams of specific fuel (15.4%) lower than in 1955.

This reduction in brake-specific consumption represented an annual saving of approximately 1.5 million tons of specific fuel in the production achieved in 1960. In 1960, there were 5 employees per 1 MW of installed capacity in steam power plants, i.e. 1.5 less than in 1955.
Since 1958, high-voltage lines connecting individual national energy systems of the CMEA countries had been built and put into operation. In 1960 it was a 220 kV line between Czechoslovakia - Polish People's Republic and Czechoslovakia - German Democratic Republic.
The construction of new power plants, heating plants and distribution facilities enabled the development of electricity consumption in the country, which increased by 60% in the first five-year plan alone. In 1960 the electrification of all municipalities in the Czechoslovak Socialist Republic was completed which accounted for 97.8% of the total population.
In the second five-year plan, final electricity consumption increased by 64.5% in industry and construction, by 116% in agriculture and by a full 370% in transport due to the advancing electrification of railway traction. The increase in consumption in the non-manufacturing sphere was 48.2%.
Between 1956 and 1957, discussions on the state of the economy and the focus of other economic policies intensified. The motto of the time was decentralization and the reduction of directives in economic governance. The main administrations in the ministries were abolished and replaced by supra-corporate bodies – the middle element of management – which existed in various forms until the 1980s. Enterprises were grouped into production and economic units. In 1958, the number of centrally managed departments decreased from 1,417 enterprises to 383 production and economic units with 929 enterprises (of which 67 were associations with 487 enterprises). Although the potential of the Czechoslovak Republic grew and the economy reached a higher level compared to the previous five-year plan, the efficiency of the economy faltered.
In December 1957, Act 79 Coll. on Electricity Generation, Distribution and Consumption (Electricity Act) was passed. The reason was the changed conditions in production and consumption, which had occurred since the adoption of Act No. 439 Coll. of July 22nd, 1919 on the Commencement of Systematic Electrification. The new law, together with the relevant decrees and regulations, formed a comprehensive arrangement of the matters raised by the issue and the position of electricity in our economy... and could form a single unit concentrated in the Ministry of Energy. The Ministry of Energy thus had the power to manage the output of all energy works for the production and distribution of electricity, to

manage long-term and operational production and distribution of electricity and to regulate its consumption, especially for large customers.
Let us look at some paragraphs. Management of Electricity generation, Distribution, and Consumption § 9: To ensure a balance between consumption and electricity generation, the Ministry of Energy and organizations determine the manner and extent of the use of all energy works (§ 2 para. 1) and their outputs and regulate electricity consumption. In doing so, it shall in particular ensure the supply of electricity of a specified quality to the national economy and the population, and that the most efficient electricity production and effective use is achieved, taking into account the energy situation and the best use of individual energy works and natural energy sources.
Energy Dispatching §10 para. 2: The Ministry of Energy and organizations authorized by it are entitled to order, according to the dispatching rules, operators of works and equipment referred to in the previous paragraph to increase, decrease or temporarily stop or resume electricity production and determine the method of distribution; for factory energy works, it also determines the scope and course of electricity supply to the common energy system. §11 paragraph 2: Operators of energy works and equipment ... are obliged to follow the operating rules issued by the Ministry of Energy in agreement with the participating central authorities.
Putting stopped factory energy works into operation § 13: The executive body of the regional national committee may order, if it is urgently needed in the supply of electricity to the national economy and population, a factory energy work, the operation of which has been stopped, to be put back into operation; in doing so, it shall determine, taking into account the economy, the owner (administrator) of the work, the technical and economic conditions and the manner of putting the work into operation.
Electricity management § 14 par. 1: Large-scale consumers of electricity and socialist sector organizations, even if they do not consume electricity in large, are obliged to adapt electricity consumption to the current energy situation, follow the supplier's instructions, use electricity economically and adjust their equipment and appliances accordingly. (paragraph 2) Large-scale electricity customers are also obliged to plan and implement measures that are technically and economically effective for better use of electricity, in particular they are obliged to create progressive standards of electricity consumption and adjust and register loads according to supplier instructions.

In **the third five-year plan (1961–1965)** there was a quality change in steam power plants due to the switching to unit 100-110 MW (el. Tisová II, Tušimice I, Nováky B) characterized by a block arrangement of boilers and turbines with steam parameters of 130 atm and 565/535° C. At the end of 1965, a total of 9 units of 100-110 MW operated in the electricity system of the Czechoslovak Socialist Republic, i.e. 14.5% of the total installed capacity of steam power plants in the Czechoslovak Socialist Republic and 21.3% of the installed capacity of steam power plants.
The transition to higher unit outputs increased the efficiency of 110 MW units by 9.6% compared to 55 MW units (from 30.4% to approx. 34.0%) and due to the changing structure of sources there was a further decrease in brake-specific consumption fuel from 520 grams of specific fuel / kWh in 1960 to 456 grams of specific fuel / kWh in 1965. There was also an increase in labor productivity in the steam power system as a whole. With the further construction of hydroelectric power plants, their output increased from 873.7 MW to 1491.5 MW in five years, and in 1962 the construction of the Orlík waterworks was completed. Developments in 1960/65 did not show any significant disproportion between the growth of consumption and sources of electricity. Nevertheless, in 1962 and 1963 there was a significant reduction in electricity consumption, mainly due to failure to meet the investment construction plan. E.g. in 1963, according to the plan, 719 MW of new outputs of public power plants and heating plants were to be put into trial operation, but the reality was only 449 MW. Other causes of the difficult energy situation were the increased failure rate of steam power plants with 100-110 MW units, which in 1963 reached 5% of the total achievable power (trial operation and period of adoption of this new power series), very low possibility of using hydropower plants due to reduced flows and, in part, difficulties in the supply of fuel to power plants in the winter of 1962-63 (frost calamities).
At this time Czechoslovakia became an importer of electricity, which reached 4% in 1965 and amounted to 761.8 GWh, despite the fact that the extremely favorable situation in hydropower plants allowed the five-year plan to meet the production plan of 170% and produce 4,3 billion kWh in its last year. Network losses increased from 7.26% in 1955 to 7.39% in 1960 and were just as high five years later. For context - the average losses in the distribution of electricity were about 18% after the war and by 1950 they were reduced to 14% with a tendency to further decline. A similar problem was the economical compensation of the power factor. With the development of more efficient capacitors and control technology, compensation saved 75 million kWh in 1954.

In connection with the electrification of the national economy, it is necessary to mention the electrification of the railways. In 1948, Czechoslovakia was one of the worst countries in Europe in terms of electrification of railways. This situation changed significantly in the years of the second and third five-year plan. This is evidenced by the following data. While in 1948 only 92 km of railway lines were electrified in Czechoslovakia, in 1965 1660 km were already fully electrified. In 1948, the share of electric traction in freight transport was practically zero (the electrified lines were Prague main railway station-Smíchov or Vršovice and some narrow-gauge railways). In 1965, 40.5% of all freight transported by rail was transported by electric traction. Electricity consumption on the railways rose from a negligible value in 1948 to 1,138 GWh in 1965.

At the beginning of the five-year plan, investment-intensive tasks of modernization and development nature accumulated to an unmanageable extent. Unrealistic plans, an unfulfilled assumption of material cost savings, which on the contrary rose, unfinished construction and excess supply led to economic stagnation. All this led to the disintegration of the five-year plan in 1961 and the economy was further guided by annual operational plans. The planning system of 1959 was abandoned, and the previous administratively directive forms of management were restored.

In **the fourth five-year plan (1966–1970),** the temporary surplus of resources in 1966 and 1967 was incorrectly valued and assessed as a permanent phenomenon in the energy industry and the coal industry. In both sectors, therefore, investment development slowed down, and the negative consequences began to manifest as early as the end of 1968. By 1969, this tension and the overall deterioration of the energy situation had culminated. It was caused by several phenomena:

- an insufficient fuel supply - the reduction in standby output in steam power plants due to fuel shortages averaged 263.81 MW in 1969 (i.e. 4.3% of their achievable output) and increased to 294.98 MW in 1970 (4.6% of achievable output). Power plants with units of 100-200 MW had a significant share in these outages of standby output.
- an increased failure rate of steam power plants with 100-200 MW units, which in comparison to 1966 doubled in 1969 (5.45%) and 1970 (5.77%)
- a significant reduction in flows on the Vltava (in 1966 the average flow was 121 m^3/sec, in 1969 only 53.2 m^3/sec.) and Váh (in 1966 124.6 m^3/sec, in 1969 only 76.8 m^3/sec.)
- insufficient growth in new capacity in 1969

The sum of all these unfavorable effects was the cause of growing disparities between sources and electricity demand in 1969 and 1970, and even with increased electricity imports (4082 and 4525 GWh) it was not possible to ensure continuity and sufficient supply of electricity to the national economy. The imbalance of the power balance and the electricity balance was solved by reducing consumption (limiting supplies, negotiating consumption diagrams, a regulation plan, switching off network sections).

The average annual value of consumption restrictions in 1969 and 1970 was about 1.5% of the total gross electricity consumption in the Czechoslovak Socialist Republic. Organized management of electricity supply had significantly mitigated the possible adverse impact on special-purpose generation for large electricity customers. This is evidenced, for example, by the development of year-on-year indices of growth in industrial production and electricity consumption in the years 1966-1970. At the same time, it was confirmed that organized management of electricity supply can also be an effective tool for rationalization in electricity consumption.

The economics of operation of steam power plants were improved by new construction and the gradual decommissioning of obsolete and uneconomical plants. The brake-specific fuel consumption, which in 1965 was 456 grams of specific fuel per 1 kWh produced, decreased in 1970 to 418 grams of specific fuel (index 91.7) and the number of employees per 1 installed MW from 4.02 in 1965 to 2.68 workers in 1970. The increase in labor productivity in new power plants was particularly significant.

Even with a permanent reduction in the brake-specific fuel consumption for electricity production, steam power plants in the Czechoslovak Socialist Republic lagged behind some European countries in terms of their technical and economic level.

The lower efficiency of steam power plants in the Czechoslovak Socialist Republic was mainly influenced by lower unit outputs of production and worse quality composition of the fuel used.

The economy of thermal power plants and thus of the entire electricity system was deteriorated by the growth of investment costs of new energy works. For example, the investment costs per 1 installed MW in the Prunéřov power plant (6 x 110 MW), which was completed in 1968, amounted to 2,042 crowns; in the Počerady power plant (4 x 200 MW), completed in 1971, they amounted to 2,384 crowns and in the Mělník II power plant, also completed in 1971 (4 x 110 MW), they increased to 2,736 crowns.

The outage rate in steam power plants also developed unfavorably, which significantly reduced their ready output. While in 1960-1962, when power plants with the highest unit outputs of 50-55 MW were in operation, the total waste output of steam power plants amounted to about 20% of their achievable output, the average annual outage increased in 1966-1971 to about 26%. The main cause of this undesirable growth was the failure rate of the new 100-200 MW units and partly the lack of fuel (1969-1970) reported in so-called "other influences". In summary, this meant that the new construction, which was increasingly investment- and financially demanding, did not have the necessary effect.
The installed capacity of hydroelectric power plants did not change during the years 1966-1970. However, their production was significantly different from year to year due to fluctuating flows. It was especially low in 1969.
Since 1966, the tendency of faster consumption growth in the category of small consumers (i.e. population, agriculture, and small consumption) began to be more pronounced in electricity consumption than in large electricity consumers. Electricity consumption per capita, which in 1970 amounted to 2,899 kWh / year, was to increase to approximately 7,250 kWh in 1985 due to higher household equipment with electrical appliances. In the case of small electricity consumption, it was also because consumption was not limited.
However, the analysis of the development of fuel and energy efficiency (FSÚ Reports and Analyzes - November 1972) stated that the growth of electricity consumption in the Czechoslovak Socialist Republic was also influenced by the uneconomical use of electricity. The level of brake-specific electricity consumption for selected products was higher in the Czechoslovak Socialist Republic than in other industrialized countries.
Industry played a significant role in electricity consumption; however, this share had been gradually declining since 1966 due to the faster growth rate of consumption in the housing and communal sphere and in agriculture. Similar tendencies were manifested in economically developed countries.
The plan for the fourth five-year plan contained a much smaller number of indicators than the previous ones and was essentially a summary of the main tasks. Negative results were brought about by a hasty reconstruction of wholesale prices, an increase of 30% on average. Companies thus obtained undeserved financial resources, which conflicted with the principle of pressure on their efficient management. Despite the invasion of the Warsaw Pact army and the political upheaval, the basic indicators of economic development were favorable, although phenomena of economic imbalance were emerging. Changes in

the governing sphere were forced by the federal organization of the state. The competence of the federal authorities included issues of national importance, including planning, scientific and technical development, management of the fuel and metallurgical engineering complex, communications, and most transport. As part of the "normalization", a consolidation economic program was announced.

In terms of brake-specific consumption of primary fuel energy resources per capita, the Czechoslovak Socialist Republic ranked among the most developed countries in the world in the 1960s (4.1 tons of specific fuel per capita in 1960, ten years later it was 5.6 tons of specific fuel, e.g. Belgium 4.9 and 5, 4, United Kingdom 3.6 and 5.2). However, the effectiveness of their evaluation was 20 to 30% lower than abroad. For example, in 1975, $ 450 of gross domestic product (in 1970 prices) was generated per 1 ton of specific fuel of primary fuel and energy consumed in the Czechoslovak Socialist Republic, while in the GDR with similar geographical, climatic and demographic conditions $ 619. The reasons for the development of high energy demands were:

- the high, albeit gradually decreasing, share of solid fuels, especially low-calorie brown coal in the Czechoslovakian fuel and energy base (Czechoslovakia in 1965 - 82.9%, 1970 - 75.3%, 1980 - 58.8%; in the GDR in 1975 only 29.7%)
- the structure of industrial production with a high share of materially and energy-intensive products (e.g. in the Czechoslovak Socialist Republic in 1976 the production of pig iron 635 kg / inhabitant, steel 985 kg / inhabitant; in the GDR pig iron 535 kg / inhabitant, steel 706 kg / inhabitant)
- the low energy efficiency of some obsolete machines, equipment, and technological processes
- the structure of foreign trade with a large share of export of high energy products with a low kilogram price and with a small share of highly skilled labor
- inadequate level of energy management in production and non-production areas, enabling the uneconomical use of fuels and energy
- the small interest in the economical use of fuels and energy, both by organizations and individuals, and in the insufficient effect of economic incentives, including the price of fuels and energy, inadequate socially necessary work to obtain them.

m) Government regulation on main power engineers

The solution to achieving efficient energy use in the post-war years were, in 1946, proposals to create energy departments to oversee energy production and use. First, the provisions of energy managers were approved by Decree No. 961/1947 Ú. 1., which soon proved to be unsuccessful. The following Decree No. 737/1948 Ú. 1., on raw material managers had even more shortcomings. Decree No. 10/1952 Ú. 1., repealed these regulations and at the end of 1952 government Decree No. 47/1952 Coll. established a state energy inspection. It was then referred to as essential in connection with measures to manage electricity in particular in the winter of 1952/1953. This was followed by the government decree of January 13th, 1953 on the main energy sectors. It was to be a crucial step in securing long term energy operation.

Operating rules for power plants and networks

Since the 1950s, one of the ways to improve and streamline the operation of power plants and the distribution of electricity and heat had been the Operating Rules for Power Plants and Networks (Decree of the Ministry of Energy No. 168/1955 Ú. l., which introduced uniform operating rules for power plants and networks). They were to enable quick orientation in the matter for energy workers and assist in the performance of the functions of operating personnel. By 1989, several updates had been prepared (the second edition of 1954 contained 1,361 paragraphs, which were gradually downsized), as over time there were a number of changes in legislation, standards and provisions changed, and with it the technical level of the equipment. The rules did not replace local operating and labor regulations and standards, "but only applied, deepened and explained them."

Establishment of a unified electricity system in 1949–1953

An electrical output of 3,143 MW was achieved in 1949–1953. A new installed capacity of 253.6 MW was built in hydropower plants. The period from 1949 to 1953 was of great importance for the development of the transmission system and for the construction of a unified nationwide electricity system. In 1950, the largest Czech and Moravian-Silesian radial transmission systems merged. It followed the original plans and partly also the original constructions of 220 kV lines, which were operated at a voltage of 110 kV. Additional sections of the 220 kV line were built, which connected the northwestern region of Bohemia

with southern Moravia, and later a section connecting the Ostrava region with central Slovakia. This gradually created a unified electricity system. The construction of the 220 kV transmission line and its commissioning created the basic conditions for future cooperation with Poland and Austria and for interconnection with Hungary.
The power plant in Komořany (210 MW) was completed and the Ervěnice (32 MW), May 1st (50 MW), Suchá (7 MW), Čs. Army (12 MW) and IX. sjezd (32 MW) power plants were expanded. The total increase in this period was 355.2 MW, of which 270 MW in steam power plants.

The first generation of new power plants

The increase in new output was in the units of 50 to 55 MW. The Hodonín (1954 to 1959), Poříčí II (1956–1959), Opatovice (1959–1960), Tisová (1958–1959) and Mělník (1960–1962) power plants were put into operation.
For these new outputs, a modern device concept, a block layout, was gradually adopted. With the launch of the last 55 MW unit in Mělník I (1962), the construction of power plants with individual units of 50 to 55 MW was completed. With this generation of new unit outputs, a modern device concept was gradually introduced. Until 1957, condensing power plants were built with a transverse connection of boilers on the steam and water side. This basic scheme on the steam side ensured greater operational reliability, especially in the case of increasing outputs, with a reserve in boiler output. The connection on the water side again made it possible to economically solve reserve power supplies for the entire power plant. Further increase in the output and parameters of power plant equipment caused an enlargement of the pipeline and its thickness and placed increased demands on the quality of the material.
All this was adversely reflected in the cost of pipes and fittings. The first power plant where the block arrangement was consistently carried out was Mělník I. In 1954–1960, there were various national economic pressures, especially regarding deteriorating investment efficiency. This was accompanied by a shortage of steel, interrupting the further development of the use of steel structures for the construction of production units. It was therefore necessary to switch to the use of heavy prefabrication, which for a long time became a basic element of construction of thermal power plants.
Detailed analyzes showed the advantage of boiler-turbine block arrangements. This solution had already begun to be implemented at some power plants with 50-55 MW units, the construction of which began later.

The structure of electricity generation was characterized by a significant predominance of electricity generation in thermal power plants over electricity generation in hydropower plants. This is due to limited natural energy resources and the constant growth of consumption, which was ensured, although not to the full extent, by the construction of new condensing power plants.
Electricity production in 1960 reached 24.45 TWh, brake-specific fuel consumption decreased by 15% (yet it was 28% higher than abroad). Although the planned tasks were not achieved, the achieved installed capacity was 5,715 MW. Annual increments from 1951 to 1960 ranged from 4.5 to 14.3%.
Due to the deficit in the construction of power plants, it was necessary to regulate consumption and the frequency of the system was not observed. The production equipment was used regardless of the economics of operation. The utilization of the installed capacity of the new power plants increased from 4880 hours to 5117 hours.

The completion of areal electrification
One of the most important economic tasks was the completion of the electrification of municipalities. While in Moravia more than 90% of municipalities and most settlements were electrified after 1945, there were significant differences in the Czech regions. The worst situation was in Slovakia where 1826 municipalities were not electrified. As the electrification of municipalities in the Czech lands was almost complete, the focus of work shifted to Slovakia where 30% of municipalities remained unelectrified. As the last municipality in Czechoslovakia, Zlatá Baňa in the Prešov region was connected to the distribution network at the beginning of September 1960. After 1960, the electrification of 600 small settlements remained to be completed, where the cost per customer was over 1,630 crowns.

n) The characteristics and main results of the period up to 1960

If we evaluate the past period in terms of the development of the electricity system, we can consider a number of results a success that significantly contributed to the consolidation of the national economy.
In terms of securing new power plant capacities, there was a transition from the construction of power plants with 32 MW units to 50–55 MW units, which meant the outputs of the new power plants increased 2–3 times to 300-330 MW.

The development of 100 MW and 200 MW units commenced. For the 100 MW unit, specific work had already begun on its production, as well as preparatory work on the construction of a new power plant with these units.
The construction of the Vltava and Vážská cascades continued.
In 1958, the construction of the first nuclear power plant began in Jaslovské Bohunice.
In 1960, the electrification of municipalities and most of the settlements was completed.
The construction of the 220 kV transmission network and the interconnection of individual parts of the republic created a unified energy system in Czechoslovakia.
The construction of the 400 kV transmission system, an important link for energy cooperation with neighboring countries, had begun.
State and regional dispatch centers for energy system management were set up.
In 1954, energy tariffs were unified throughout the country. Among the negatives is the non-fulfillment of the GE60 plan in the construction of new power plants, where the deficit increased to almost 900 MW, and the start-up of new capacities was not possible without lengthy downtimes.

The construction of large thermal power plants in 1960–1980

During these years, the construction of steam power plants with 110 MW units was fully developed. The first three 110 MW units were built at the Tisová power plant (1960 to 1962), six 110 MW units were built at Tušimice (1960 to 1964), six units at Prunéřov I (1963 to 1968), four units at the Ledvice power plant (1966–1969) and four units at the Mělník II power plant (1966 to 1972).
The first 200 MW unit was built at the Ledvice power plant and was put into operation in 1967. This was followed by 4 units at the Počerady I power plant, two units at the Počerady II power plant, four units at the Tušimice II, Dětmarovice and Chvaletice power plants, and five 210 MW units at power plant Prunéřov II (Polish delivery).
The first and last 500 MW unit was built at the Mělník III power plant. With the construction of the last 210 MW unit at the Prunéřov II power plant, the construction of conventional steam power plants in Czechoslovakia was completed.

The distribution system

While the development of the transmission electricity system had been developing successfully, the development of high and low voltage distribution

stagnated. New additions caused mainly by extensive housing construction drained material and construction and assembly capacities. There was a lack of construction and assembly capacities and finances for the renewal and maintenance of networks, which showed a high failure rate and did not provide customers with a quality electricity supply. The constant growth of electricity consumption forced a significant expansion of the 110 kV network to shorten the distance of the 22 and 35 kV supply lines.

Insufficient implementation of the renewal of old distribution networks, which was characteristic of all energy distribution companies, was particularly serious in Prague. 110/22 kV transformer stations were under construction - Chodov, Jinonice, Holešovice, Pražačka (the first encapsulated) and Zbraslav. The 400/110 kV transformer station in Řeporyje and 220/110 kV in Malešice with the total installed capacity 1230 MVA served to cover the outputs.

The development plans of the energy sector also influenced the technical development of energy engineering. It was necessary to develop new equipment especially for 400/220 kV transformer stations. The transformers used in the 400 kV network mostly consisted of three single-phase units supplemented by a control transformer connected at zero.

The outputs of single-phase transformers at the beginning of the construction of 400 kV networks were around 250 MVA. The chokes were single-phase, the switches were compressed air.

In the 1960s, areal electrification was completed, ensuring the continuity of electricity supply with a deterioration rate comparable to Western countries, although with frequency fluctuations, which was significantly affected by the former USSR in the interconnected MÍR system. The Dukovany Nuclear Power Plant was built and reliably operated, the Temelín Nuclear Power Plant was designed and the construction began, the Dalešice hydroelectric power plant was built and the Dlouhé Stráně pumped storage hydroelectric power plant construction was underway. It can be said without exaggeration that the 400 kV transmission system works reliably and is also able to ensure the international transit of electricity.



Fig. 7.4 Nuclear Power Plant Temelín

The privatization of energy management

The complexity of privatization was evident from the course of its implementation in 1992–1994 when the number of registered juridical persons increased by 76,519, i.e. by 134%, with a significant structural change in ownership. For example, the number of private owners increased by 214%, cooperative owners by 297%, communal owners by 239% and international (domestic and foreign) by 195%. The number of state-owned enterprises decreased by 7029, i.e. by 42%. As of December 31, 1994, there were 9,733 entities. The number of private entrepreneurs (not registered in the Commercial Register) increased by 56% in the same period and as of 31 December 1994 there were 980,709.

State-owned enterprises of the Department of Fuels and Energy were privatized. The transformation of 35 state-owned enterprises created 42 joint-stock companies. In the coal industry, eight joint-stock companies were established from 15 state-owned enterprises. In the gas industry, after the separation of eight regional gas companies from the Czech company, the same number of regional gas distribution joint-stock companies and one production joint-stock company were established. Plynárenský dispečink and Transgas were incorporated into the state-owned company ČPP and privatized later.

After the delimitation of eight energy distribution companies and three power plants, which mainly provided supply heat from ČEZ, nine energy joint-stock companies were established in the power industry. The ČEZ joint-stock company included nine power plants, a portable electricity system division and the Central Energy Dispatching Center. After the singling out of the heating plants,

the privatized regional energy joint-stock companies ensured the distribution and sale of electricity in the area of their competence.
The most extensive reorganization took place during the privatization in the heating industry. With the independence of the above-mentioned public heating plants, 16 joint-stock heating companies were established, providing heat production and supply through 53 local district heating systems.
The privatization of factory plant energy was carried out within its own entities. During the privatization process, there was no significant shift from this sphere to public energy.
By 2001, the following objectives were met:

- the Energy Charter Treaty was ratified in 1996 (the Czech Republic became a member of the OECD),
- Act No. 222/1994 Coll., On Business Conditions and State Administration in the Energy Sectors and on the State Energy Inspectorate, was adopted as the basis of energy legislation.
- the price regulation of solid fuels was abolished (in 1994), in 1998 subsidies for the prices of heat supplied to the population from central sources were abolished,
- in 1996, the Ingolstadt-Kralupy-Litvínov oil pipeline was put into operation, thus creating the preconditions for the diversification of oil supply,
- in 1997, Act No. 18/1997 Coll., (The Atomic Act) took effect, which regulates all the requirements for the operation of nuclear power plants, the management and storage of radioactive waste and the management of spent fuel,
- in 1997 a contract was concluded for the import of natural gas from Norway and in 1998 a similar contract was concluded with the Russian Federation,
- the electricity system of the Czech Republic was synchronously connected within the CENTREL system (CR, SR, PR, MR) to the Western European EU system for cooperation of electricity producers and electricity transit participants (ÚCTE),
- the share of coal consumption decreased significantly, especially its use in its final form, and it was replaced mainly by natural gas and in households also by electricity,
- coal power plants, the long-term operation of which is planned, were desulphurised and denitrified by the end of 1998, and their operation complies with the stricter emission limits pursuant to Act No. 309/1991 Coll., On Air Protection.

7.2 The electricity system of the Czech Republic - 2019

The electricity system of the Czech Republic is a set of all equipment needed for the production, transmission, transformation, and distribution of electricity, including electrical connections and direct lines. It also consists of measuring, protective, control, security, information, and telecommunication technology systems.

Installed capacity of ES sources in the Czech Republic 2019

nuclear power plants	4 290 MW	19 %
steam power plants	10 982 MW	50 %
steam-gas power plants	1 364 MW	6 %
steam-gas and combustion power plants	925 MW	4 %
hydroelectric power plants	1 091 MW	5 %
pumped storage hydropower plants	1 172 MW	5 %
wind power plant	319 MW	2 %
photovoltaic power plants	2 033 MW	9 %
total	22 176 MW	

Transformation output in PS

400/220 kV	2 000 MVA/4 units
400/110 kV	16 800 MVA/50 units
220/110 kV	4 000 MVA/20 units
220 kV/vn (LDS Sever)	88 MVA/2 units

Line lengths

	route length	line length
400 kV	3 128 km	3 782 km
220 kV	1 279 km	1 770 km
110 kV		14 591 km

The transmission system

Interconnected set of lines and equipment 400 kV, 220 kV and selected lines and equipment
110 kV, used to ensure the transmission of electricity for the entire territory of the Czech Republic and interconnection with the electricity systems of neighboring states, including measuring, protection, control, security, information,

and telecommunication technology. The transmission system is being set up and operated in the public interest.

a) The Energy Regulatory Office

In 2001, the Energy Regulatory Office was established by law. Its scope and authority include:

- Price regulation, more precisely regulated components of energy prices, for which price decisions are issued every year.
- Pricing decisions, by law, support for renewable energy sources is also provided.
- Promoting energy competition.
- The licensing of energy producers, traders and other energy participants and further supervision.
- The protection of consumers in the energy market. This is the office that the consumer can turn to when resolving disputes with his or her energy supplier or distributor.

b) International cooperation

The ERO is a member of the Council of European Energy Regulators (CEER). It aims to facilitate the creation of a single, competitive, efficient, and sustainable internal gas and electricity market in Europe. CEER acts as a platform for co-operation, exchange of information and assistance between European energy regulators and is their interface at an international and EU level. The ERO is actively involved in all CEER activities.
Pursuant to Regulation (EC) No 713/2009 establishing the Agency for the Co-operation of Energy Regulators (ACER), the ERO is involved in the activities of this European agency. In addition to participating in working groups, the ERO appoints a representative of the Czech Republic to the Board of Regulators, which oversees the exercise of the Agency's powers. ACER's mission is to promote, deepen and coordinate cooperation between energy regulators at the EU level and to work towards the completion of a single and competitive electricity and gas market.

In 2018, the ERO became a member of the Regional Association of Energy Regulators (ERRA), which brings together regulatory authorities from Central and Eastern Europe and some other countries. Nine EU countries are members, including the V4 countries and Austria, which share common regional energy interests and are interested in extending the EU's regulatory framework.

c) The electricity market operator

A state-based joint-stock company, the task of which is to organize the electricity market in the Czech Republic, to process balances of agreed and actual electricity supplies and consumptions for market participants, to ensure that differences between agreed and actual values of supply are settled and organize a short-term electricity market.

d) Czech Transmission System (ČEPS)

The ČEPS transmission system is a part of the electricity system of the Czech Republic, which consists of all transmission equipment with a voltage level of 400 kV, 220 kV and selected 110 kV equipment, including measuring, protection, control, security, information and telecommunication technology systems. The system ensures the transmission of electricity for the entire territory of the Czech Republic and interconnection with the electricity systems of neighboring states. The transmission system is connected to the distribution system via 400/110 kV and 220/110 kV transformers.

- The total volume of electricity at the output from the transmission system was 66,447 GWh last year.
- Of the total installed capacity of power plants in 2019 (21,966 MW), production facilities with an installed capacity of 11,868 MW were connected to the Czech transmission system.
- Of which 41% were steam power plants, 36% nuclear power plants, 13% hydro and pumped storage hydro power plants and 10% steam-gas and gas combustion power plants (including biogas).
- Steam power plants accounted for 48% of the total gross electricity production in the Czech Republic with a value of 86,981 GWh, followed by nuclear power plants (35%) and steam-gas power plants (6%).
- The largest year-on-year increase in production was recorded by steam-gas

power plants, namely by 50%, while the production of steam power plants decreased by 8% year-on-year.
- Almost 200 km of lines with a voltage level of 400 kV were built or modernized.

Total length of line routes in operation

400 kV line	3 780 km
220 kV line	1 737 km
110 kV line	84 km

When formulating strategic goals, an analysis of the external environment was performed and, in accordance with the expectations of the owner and key stakeholders / entities of interest, three main driving forces of ČEPS's strategic development until 2030 were identified:

3. Decentralized energy
4. Innovation and digitization
5. Energy market

The key strategic areas and tasks of the ČEPS perspective until 2030:

- Implementation of European legislation
- Active role in energy platforms
- Promoting the interests of the Czech Republic
- Key service provider of electricity services
- Reliable and safe operation of PS in a new decentralized environment
- Necessary development of the transmission system
- Support and participation in the drafting of legislation and national policies
- Development of decentralized resources
- Stability of the source base of the Czech Republic
- New trends (batteries, aggregation, flexibility, electromobility)

Important moments in the history of the ČEPS company

1950 - Isolated transmission systems on Czech territory were merged into one unit. The system was part of the centrally controlled energy sector until 1998.
1953 - The first parallel cooperation of the electricity systems of Czechoslovakia and Hungary took place.
1956 - The exchange of electricity between Czechoslovakia and Austria was started on a double line of 220 kV Sokolnice-Bisamberg.

1961 - Parallel cooperation of the electricity systems of Czechoslovakia, the former GDR and Poland was started.
1962 - An agreement was signed on the establishment of the Central Dispatching Organization (CDO) of the interconnected electricity systems of the European CMEA member countries based in Prague.
1976 - A 220 kV line between the Rybnik substations (Poland) and Albrechtice and Dobrá (Czechoslovakia) was put into operation. In 1977 at a voltage of 400 kV.
1979 - An agreement was concluded for the construction of a 400 kV line and the establishment of a DC link Slavětice-Dürnrohr, which was put into operation in 1983.
1988 - An agreement was signed on the interconnection of Czechoslovak electricity system with the German system through Bayernwerk Munich.
1995 - The interconnection of CENTREL and UCTE transmission systems.
1997 - ČEZ joined a consortium of some UCPTE companies with the aim of participating in the European Community's PHARE / TACIS project.
2000 - The Central Dispatching Office at the ČEPS headquarters was put into operation.
2001 - ČEPS was accepted as an associate member of ETSO and became a founding member of UCTE.
2002 - As part of the liberalization of the electricity market, Czech market participants were allowed cross-border electricity import and export for the first time. The volume of cross-border electricity exchanges has increased significantly since then.
2005 - The company began to act as an auction office for the allocation of cross-border transmission capacities for electricity trading.
2007 - A complete modernization of the control room at the company's headquarters took place, which included the installation of a new unified TRIS dispatch control system.
2008 - ČEPS is a founding member of the Central European Coordination Operations Center TSC based in Munich.
2009 - The short-term electricity market between the Czech Republic and Slovakia was interconnected ("market coupling").
2010 - An extensive process of modernization and development of the Czech transmission system was launched.
2012 - The short-term electricity market between the Czech Republic, the Slovak Republic and Hungary was interconnected.
2013 - The representatives of ČEPS and 50 Hertz agreed on a joint solution to the issue of unplanned electricity flows through transformers with controlled phase shift (PST transformers) in the Hradec and Röhrsdorf substations.

2014 – The interconnection of the daily markets in the Czech Republic, Slovakia, Hungary, and Romania ("4M market coupling").
2015 – The construction of an independent telecommunication network, including data transmission of dispatch control (TELCO).
2019 - The company continued to meet the requirements of the CACM Regulation to create a single intraday market interconnection, the so-called Single Intraday Coupling, which is the target solution for the internal electricity market, in cooperation with European transmission system operators and nominated electricity market operators.



Fig. 7.5 ČEPS dispatch center

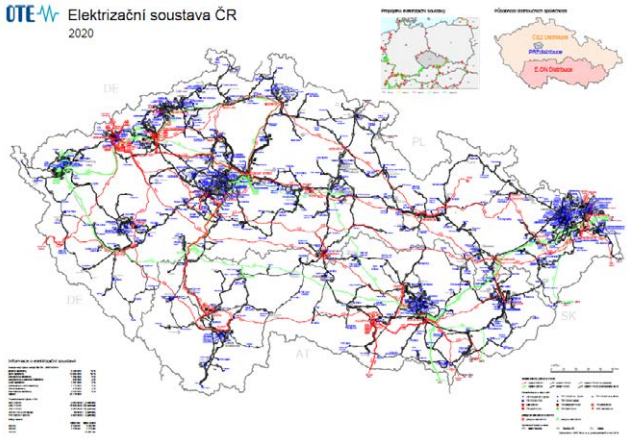


Fig. 7.6 Czech Electrical Power Grid

e) The distribution system

An interconnected set of 110 kV lines and equipment with the exception of selected 110 kV lines and equipment, which are part of the transmission system and lines and equipment with a voltage of 0.4/0.23 kV, 3 kV, 6 kV, 10 kV, 22 kV and 35 kV used to ensure the distribution of electricity in a defined territory of the Czech Republic, including measuring systems, protection, control, security, information and telecommunications technology.

Electricity distributors

PREdistribuce, a.s.
PREdi is a subsidiary of the parent company Pražská energetika, a. s. It operates a distribution network in Prague, Roztoky and Žalov in accordance with the Energy Act based on a license issued by the Energy Regulatory Office (ERO). As the operator of the distribution network in the capital, PREdi occupies a specific position within the Czech energy sector and faces extraordinary challenges and demands for quality and security of supply. From a security point of view, selected parts of its network and operating equipment are part of the critical infrastructure of Prague and the entire Czech Republic.

- The distribution system consists of a system of outdoor and cable lines 110 kV, 22 kV and 0.4 kV with a total length of 12,372 km.
- 25 substations with 110/22 kV transformation and 4,906 22/0.4 kV network transformation stations.
- At the end of 2019, more than 809,000 consumption points were connected to the distribution network.
- On 24th of January 2019, the annual load on the distribution network reached a maximum of 1,162 MW.
- The volume of distributed electricity in the PREdi network amounted to 6,296 GWh in 2019. In the future it can be assumed that the values of distributed electricity will increase with greater investor interest in connecting new buildings in brownfields, undeveloped and peripheral parts of Prague.
- A higher load of hundreds of MW on the distribution network in Prague can be expected especially with an increase in electromobility, for which PREdi is intensively preparing.
- In 2019, the company invested 1,643 million crowns (including capitalization) in the renewal and development of the distribution network. Another

226 million crowns were invested from operating funds in repairs. The total volume of funds spent on the distribution system is reflected in the high reliability and quality of electricity supplies in Prague.
- The company succeeds in fulfilling a new concept in the field of smart grid development, within which 22 kV, 1 kV cable networks and distribution transformer stations are built as smart grid ready.

ČEZ Distribuce, a. s.

ČEZ Distribuce, a. s., a member of the ČEZ Group, holds a license for electricity distribution and, in accordance with the Energy Act No. 458/2000 Coll., is the operator of the distribution system. The company operates in the Pilsen, Karlovy Vary, Ústí, Central Bohemian, Liberec, Hradec Králové, Pardubice, Olomouc, Moravian-Silesian regions and partly in the Zlín and Vysočina regions. The main mission of the company is the distribution of electricity to natural and juridical persons and a constant increase in the quality and reliability of supply to all customers.

The company's goal is to ensure the fully functional role of the executive manager of the distribution system's assets in the area of its competence. A prerequisite for fulfilling the business plan and mission of the company is a rich tradition and know-how taken over from former regional energy companies and supported by appropriate technical and personnel facilities.

- The supplied area of the company in 2019 was 52,001 square kilometers with 3,698,220 consumption points.
- ČEZ Distribuce, a. s. sells electricity distribution services to customers through electricity traders or direct sales. In 2019, the company had a framework agreement with 129 active traders.
- The composition of customers was as follows: extra-high voltage, high voltage - large customers (14,846), low voltage - small customers-entrepreneurs (437,932), low voltage - small customers-households (3,245,442).
- In 2019, 24,000 new supply points and 2,342 new plants with a total installed capacity of 167.5 MW were connected.
- The developed length of the line was 165,835 kilometers, of which EHV 10,002 km, HV 51,006 km, LV 104,827 km.
- The number of high voltage / low voltage transformer stations is 59 552, of which: 46 636 local, 2 916 foreign, the number of extra-high voltage / extra-high voltage, extra-high voltage / high voltage, high voltage / high voltage transformer stations is 287.

- Investments in the distribution system amounted to approximately 11 billion crowns. One of the most important constructions is the 110 kV Hlinsko – Polička line. Furthermore, the construction of new transformer stations in Třebovice and Hněvotín was completed as well as the reconstruction of transformer stations in Krásný Březno, Kolín, Polička and others.
- In 2019, ČEZ Distribuce a. s. announced 27 topics for diploma and bachelor's theses focused on the solution of thematic areas regarding the production and distribution of electricity for university students with an electrical engineering specialization. Three topics are currently being processed.
- In 2019, the National Competence Center program, which aims to support long-term cooperation between the research and application spheres and strengthen the institutional base of applied research, started projects of new elements and technologies of energy networks and research of secure communication technologies for smart communication networks in energy.
- ČEZ Distribuce carried out the following studies, analyzes and pilot projects of new technologies of high and low voltage networks:
  - InterFlex, co-financed by the EU Horizon 2020 Framework Program for Research and Innovation, where during 2019 implementation work took place on the installation of charging stands and testing of inverters in photovoltaic plants with and without accumulation to verify the effect of the fast charging of electric vehicles on possible deterioration of electricity quality and solving the problem of voltage stabilization in high and low voltage distribution networks with a high share of renewable energy sources and distributed generation,
  - implementation and practical testing of communication via BPL on a 22 kV cable line,
  - testing of technologies with the Internet of Things application that have been selected as suitable for distribution purposes, such as icing and wind identification, detection of seal violations, basic data collection and setting up a calculation methodology to assess the reliability of individual distribution system elements (element reliability), testing resources with controllers for management / use of surplus production from renewable energy resources, which according to previous experience may cause deterioration of some parameters of electricity quality or affect the measurement,
  - Aerial monitoring of power lines, studies.

E.ON Distribuce, a.s.

E.ON Distribuce, a.s. is part of the structure of the E.ON energy group in the Czech Republic. The main subject of its business is licensed activities in the distribution of electricity and gas. The company is fully owned by E.ON Beteiligungen GmbH, registered in the Federal Republic of Germany.

- The company's supply area is 26,499 square kilometers with 1,528,249 supply points.
- The company operates distribution networks in the voltage level of extra-high voltage (EHV) - 110 kV, high voltage (HV) - 22 kV and low voltage (LV) - 0.4 kV.
- E.ON Distribuce owns 14 km of EHV (route) cable, 2402 km outdoors, 3,867 km of HV (route) cable, 17,992 km outdoors, 24,309 km LV (route) cable, 15,164 km outdoors.
- The company owns 90 EHV / LV transformer substations with 5847 MVA installed EHV / LV transformer output, 172 transformers, 19,742 HV / LV distribution stations, 19,695 HV / LV distribution transformers and 5 912 MVA installed transformation capacity VN / NN.
- As of the 31st of December 2018, 11,676 generation sources with an installed capacity of 2,187 MW were connected to the company's distribution network, of which 11,311 were renewable sources with a total installed capacity of 1,672 MW. Photovoltaic power plants accounted for 10,533 units with an installed capacity of 987 MW.

7.3 History of NC CIGRE Czech Republic and the Slovak Republic

Czechoslovakia began operating in CIGRE very soon after its founding in 1921. The National Committee was established shortly after 1923 and the leading figure from the beginning was professor List who attended almost all CIGRE meetings in Paris. Professor List was very active in CIGRE and in 1931 he was elected vice president of CIGRE and became the chairman of the SC "Overhead lines" for the period 1931–1939.

Professor List was a scientist and pedagogue at the Brno University of technology. He participated significantly in the development of the Czech electrical industry and he was a key organizer of the technical normalization process and development in Czechoslovakia. His most important activities included establishing contacts with foreign professionals and very important informa-

tion and experience exchanges. His work and activities were appreciated and in 1946 he was awarded the CIGRE commemorative medal. In 1949 he was elected honorary vice-president of CIGRE.

After the war, the power companies in Czechoslovakia were restoring and developing power plants with low powers and efficiencies. It was evident that new sources with higher unit powers were necessary. Therefore the 110 kV transmission system was developed but it proved to be insufficient. A transmission system with a higher voltage level was required. This requirement was supported by the construction of new power plants in the North-west Bohemia near brown coal mines together with a need for interconnection with neighbor countries. Until 1950 the main Czechoslovak transmission system was formed by 110 kV lines. The transmission system development had to be realized in different conditions than before the war.

This led to collaboration of Czechoslovak experts with CIGRE Study committees (SC) and the organization of some SCs meeting in Czechoslovakia.

The collaboration with CIGRE was developed in the next years mainly within Study committees. SCs handled different tasks in the electrical power engineering. Some of them were very successful and contributed to important problems solving. The Czech Republic but also some parts of the Slovak Republic are areas sensitive to inverse weather condition occurrences. CIGRE solved the overhead line (OHL) endurance at the seaside where water includes higher mineral substance (salt) concentration in comparison with river water. A group from EGÚ Prague Běchovice lead by Ing. Dana Kohoutová handled a similar task in Czechoslovakia. It was the insulation endurance against dust and chemical substances deposed on the insulation during inversion states. The research resulted in using long rod insulators instead of disc-type insulators. The next perspective way was to reduce sulfur oxides exhalations gradually mainly from classical coal-fired power plants or from chemical factories.

The results of this research were presented in CIGRE Sessions based on the long-term collaboration of EGÚ Brno with experts from other companies, e.g. with Ing. Hrabánek from the ČEZ company in the field of icing and with Ing. Lago from Slovakia in the field of conductors loading capacity.

One of the very active CIGRE promoters in this field was also professor Veverka from Prague who actively participated in CIGRE Paris sessions for many years.

The collaboration with SC 22 was also beneficial for Czechoslovakia when the transmission system was formed and during operational problems solving. Mainly regarding tower constructions types, basement solving or conductor hanging types.

The other solved field was the HV transformers aging and reliability task. The SC 12 Transformers knowledge used long-term can be divided into two sections: transformer state diagnostics and partial discharges diagnostics.
The partial discharges diagnostics should find partial discharge occurrence during HV transformers testing. SC 12 information was very useful for operational failures analysis and failure reason identification in system transformers 250 MVA.
The task of cable insulation systems was also solved in the framework of CIGRE. The collaboration between VUKI Bratislava research and CIGRE knowledge in the field of dendritic discharges was beneficial here.
After 1990 research followed the modern trends and new surge arrestors implementing based on metal oxides (ZnO), similarly as in CIGRE. The collaboration of research in EGÚ Brno or in Prague Běchovice mainly in the field of insulation coordination in HV systems and overvoltage protection was also beneficial. Dr. Richard Gert from EGÚ Prague and Brno took part in these works in CIGRE SC 33 as a secretary of the SC. In the field of protection against flashes were in particular involved Ing. F. Popolanský, Ing. J. Jirků, Ing. V. Vyskočil and Ing. D. Kohoutová. The study committee SC 33 and working group WG 33.04.11 meeting took place in 2000 when overvoltage limiters and powerlines endurance against overvoltage fields were discussed.
The results of SC 23 HV substations activities were useful for Czechoslovakia mainly in connection with the implementation of enclosed substations and quenching gases SF6 applications for improving short-circuit currents switching-off. Air pressure circuit-breakers were in operation at that time which required high pressure compressor station operation. They needed a high amount of energy for circuit-breaker functions. Also, the old circuit-breaker reliability was worse as it was shown by a questionnaire carried out in terms of SC 23. Another important area in which the information from CIGRE SC 23 was appreciated concerned HV substation transition to the unattended state. Czechoslovakia was represented by Eng. D. Kopejtková from ČEPS in SC 23 or its working groups and by Professor Z. Vostracký from Pilsen University in SC 13. The study committee SC 23 meeting was held in 1992 and 1998 with the topic Enclosed Substations and in 2003 with the topic Conventional Substations.
Czechoslovak experts have participated in activities of the SC 14 "HVDC Links" since 1972 and later on also in the SC B 4 "HVDC and Power Electronics". It should be mentioned that Professor Milan Kubát, the regular member of SC 14, was the minister of Electrical engineering industry of Czechoslovakia. Subsequently he was replaced by Mr. Pavlinec who was the chairman of the NC at

the same time. The activities were utilized in the interconnection of electric power transmission grids of West and East Europe via Back-to-back HVDC transmission links in Düernrohr (connecting Austrian and Czechoslovak 400 kV networks in 1982) and further on in Etzenricht (connecting German and Czechoslovak 400 kV transmission systems).

The SC 36 up to SC 39 workload regards the topics of transmission systems operation and control and voltage and reactive power control. There was extensive collaboration in this field. These contacts enabled better orientation in prepared changes in specified conditions after 1989. This field can include a parallel synchronous interconnection preparation of several power systems in Central Europe to UCPTE. They were namely sufficient power back up ensuring failure coverage and a quick response of frequency and powers primary control to rapid load changes. The preparation was positive as it has been shown by the real collaboration longer than 15 years. The next transmission system's operation quality changes implement voltage and reactive power secondary control according to chosen regions and on the base of the system program instructions. This field also includes preventions and actions to the transmission system against system disintegration accompanied with long times without electricity supply. This problem is also connected with transmission system transient events computational method improving. SC 36 organized several CIGRE colloquiums during its meeting in Prague, e.g. in 1983 and 2001.

The Czech Republic and the Slovak Republic national committee has always taken care of the national committee representation either directly in professional Study committees or in Working groups of particular SCs. This was not easy because the number of SC members was always limited. The situation in WG was similar. Therefore, the national committee supported WG membership.

During the years, there have been many national committee chairmen in office. In the last fifty years, these have been the chairmen in chronological order: Eng. P. Erban, professor L.Reiss, Eng. V. Vyskočil, Eng. Z. Špaček, Eng. P. Pavlinec, Eng. J. Procházka and currently docent Z. Muller. There have only been two secretaries, Eng. B. Willmann until 2000 and professor J. Tlustý from 2000 to present.

A number of members of the national committee received Distinguished Member awards upon proposal from their National Committees.

The National Committee in the Czech Republic and the Slovak Republic has organized around 30 meetings of various SCs over the years.

In 2020 CIGRE has 78 individual members, 9 collective members and 2 student members in the Czech Republic and the Slovak Republic.



Fig. 7.7 NC Czech and Slovak Plenary Session 2019

8. NC CIGRE CROATIA

8.1 History of the power system

a) Very early period of electrification

According to available literature, electricity in Croatia was first used as lighting on 19th March 1873 in the Croatian National Theatre in Zagreb for the theatre show Margareta directed by the noble Ivan Zajc. In the same year, electricity was used for public lighting in the Croatian towns of Dubrovnik and Zadar at the Adriatic coast. That was during the visit of the emperor Franz Joseph, and the power supply of streetlights came from war ships accompanying the emperor of Austro-Hungary. During that period, small generators were set up in some factories generating electricity for the lighting of factories, and the surplus was used for the lighting of near streets. The first lightened public building in Croatia was the theatre in the town of Rijeka (a city on the northern coast of the Adriatic Sea). Upon opening the theatre on 5th October 1888, during a command performance of the opera Aida by Giuseppe Verdi, there was some light from the theatre's own generator, but due to malfunction it turned off soon. The performance took place one day later, and there was functional lighting. The first hydropower plant was built in Croatia in 1884 on the Mrežnica river, and in the DC generator produced electricity for lighting and other use of textile factory near Duga Resa, a place near the town of Karlovac.



Fig. 8.1 Gas lighting in Zagreb at the beginning of 20th century

The idea on electric lighting in Zagreb occurred simultaneously with the idea in other European towns. The committee for electric lighting raised two questions on 5 September 1888: "Are there any objections regarding the system? Regarding security, are we supposed to lay the cable above or under the ground?" It was also concluded to acquire the contract signed between the City of Vienna and F. Fischer, to compare them with the contracts from the cities of Salzburg and Timisoara. After examining the documentations, Fischer was invited to

Zagreb to make an agreement. The city council discusses as early as in 1888 on the offers that arrived. F. Fischer from Vienna made the first offer, who planned to make DC generator. The second offer came from E. F. Bothe from Zagreb, and it was for the AC generator. The city council opted for the offer of E. F. Bothe but the project never started.

The mayor of Zagreb, Milan Maruš invited Nikola Tesla (1856, Smiljan, Croatia), who was at the height of his fame at that time, to visit his homeland. On that occasion, Nikola Tesla held his famous lecture on 24th May 1892 in the City Council and suggested the electrification of Zagreb, as a route to economic and cultural development. He advised the application of alternating current for mass consumption, and direct current for tram operation. He ended his lecture by saying: "I believe it is my duty, as an own son of his own country to help the city of Zagreb in any way I can, by advice and action." These words have been engraved in the memorial plaque of the old City council building in Zagreb. The lecture was illustrated in a detailed article published in the newspapers *Narodne novine* and *Obzor* on 25th May 1892 entitled *Nikola Tesla on electric lighting in Zagreb.* The journal, Agramer Zeitung published a short piece of news on 24th May about a "famous electrician and former Edison's colleague" who held a lecture on electric lighting in the office of mayor Milan Amruš in front of a few municipal advisors, councillors and officers.



Fig. 8.2 Nikola Tesla in his laboratory

The entry from 24th May 1892 is more interesting: "Tesla's session with the municipal council recommends high-voltage AC." It was about a competition on the construction of a hydropower plant and the use of waterpower of the Kupa river near Karlovac (40 km away from Zagreb). The Karlovac daily paper, Glasonoša wrote at that time that Zagreb wanted to take away 8,000 HP from Karlovac. The competition failed and the hydropower plant was not constructed. After almost six years of discussion on electrification, a piece of information was accidentally published in the journal *Elektrotechnische Zeitschrift* on 3rd November 1893. It was published that the former Croatian Member of Parliament, E. F. Bothe obtained a concession in 1891 from the town of Zagreb to construct the power plant, under condition that he should pay a deposit and start with the works within the period of one year. The shareholders of gas society opposed it strongly; they were in various camps."We spoke up openly and some town councillors who had shares of the Zagreb Gas Company were ready to do whatever it took to avoid damage". Mayor Milan Amruš did not actually have any financial interest, but he protected capitalists' interests from the point of view of the party and politics.



Fig. 8.3 Oton Kučera – a great advocate of electrical engineering in Croatia

At that time, Oton Kučera was one of the biggest advocates of electricity use. He studied physics, mathematics and astronomy in Vienna. He wrote several books on electricity, magnetism and new inventions of the time. All his books were scanned and published on the web sites of Croatian National Committee CIGRE.

As early as in 1891 in Zadar (a town on the Adriatic coast) Eugenio Godnig analysed electric facilities in Venice, Udine, Milan, Trento and Salzburg and concluded that both the DC and AC systems work well. The city got two offers, Edison from Milan offered AC system, whereas Kremenezky and Mayer from Vienna offered DC. The town opted for the second offer, so two generators were constructed, one with 75 HP and another with 40 HP, which generated DC electricity for 1,900 light bulbs. So, on 20th April 1895 Zadar got public lighting, much earlier than other towns in Croatia.

b) The first power system in Croatia

In Croatia, it is considered that the first power system with generation, transmission and distribution happened on the Krka river Falls. The first public hydropower plant using an AC was commissioned on 28th August 1895 around 8 p.m., as was written in the daily paper, *Il Dalmata*. After the power plant declared that the machines were working well, they asked about lighting in the town of Šibenik? The answer was: "Fantastic, the power was not late." The

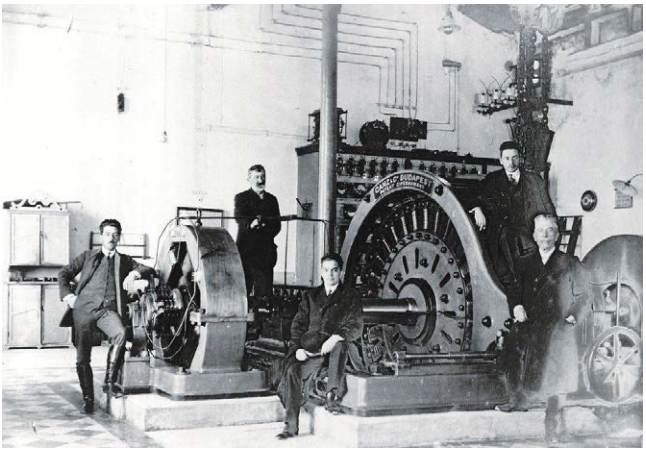


Fig. 8.4 Members of the Šupuk family next to the generator of Jaruga HPP

builders were knight Ante Šupuk, the mayor of Šibenik and the Dalmatian councillor in the Imperial Council in Vienna, his son Marko and the noble Vjekoslav Meichsner, the town councillor from Šibenik.
It is also of historical importance because of the two-phase system installed by the Hungarian company Ganz with electrically shifted phases of 90 degrees. It had Girard water turbine of vertical type, and generator was Zypernowsky patent type A2, 320 HP, 315 rpm, 42 Hz, with exciter on the same shaft made by the same manufacturer. That was one of the first experiment of that kind because at that time cities like Frankfurt, London, Rome and others preferred single-phase generators and they found the poly-phase system much more unreliable and unsafe. Electricity generated in Krka (later Jaruga HPP) transmitted power by an 11 km overhead line at 3 kV of to the town of Šibenik and by a distribution grid to the consumers. The line from Krka to Šibenik was erected on wooden pylons with steel U-beam cross arms 'supporting' glass insulators. For transmission at the 3 kV level, each pylon was provided with three cross arms with conductor cross sections of 35 mm^2 and 50 mm^2 (Cu). The lowest bracket was for telephone wires and it was used for a telephone link from Jaruga HEPP to Villa Meichsner Almost 360 pylons were erected on the 11 km route from Lozovac to Šibenik. The distribution network 3,000/110 V was built in the city with 2 switching stations and 6 substations installed on roofs of houses. Some private properties had to be bypassed because the owners feared the value of their land would decrease due to the pylons.
Following that, the hydropower plant Jaruga II was constructed, with the power of 5250 kVA, yearly production of 15 GWh, using Ganz equipment. Generator's voltage of 15 kV was transmitted by a 12 km long air cable with four copper wires (double two-phase) with a 9 mm diameter and a 64 mm^2 cross section. At the beginning of WWI, Austro-Hungarian army expensed the hydropower plant Jaruga I with the landline to Šibenik. Copper and iron were used for military purposes. Hydropower plant Jaruga II remained in operation because it supplied a carbide factory, which was strategic war material.

c) The state of construction of generation capacities after WWI

Generation capacities were constructed for the needs of various factories. So, middle parts of Croatia were the area with the most thermal power plants, in eastern Croatia there were the most timber factories, and in Dalmatia there

were the most hydropower plants. All of them, only 7 power plants had installed capacity over 1,000 kVA. After WWI, the areas of Istria, the Coast and parts of Dalmatia were allotted to Italy, and the electrification there was poor. Apart from bigger towns, like Pula and Rijeka, very few small places had electricity. Pula had a public diesel-fired power plant with the power of 640 kW, and Rijeka had a coal-fired power plant with the power of 300 kW. These areas developed separately from the rest of Croatia until the end of WWI. In the aftermath of WWI, there was the era of conjuncture, which reflected on power plant construction. At the beginning of 1930ies in Croatia, there were 196 generation facilities of different capacities and technologies, with the total power of 143 MW. Hydropower plants had the greatest share, 63 percent, followed by thermal power plants with 29 percent. Until 1931 the trend of abandoning DC was obvious, as it took up only 4 percent of the total installed capacity. According to sources, the total electricity generation without the areas of Istria and Rijeka amounted to 300 GWh, which was 56 kWh on average per capita, whereby in Zagreb that generation amounted to 128 kWh per capita.

d) The first interconnections for a larger (at that time) consumer area



Fig. 8.5 Column 10/0.4 kV transformer station during the period of mass electrification of Slavonia (eastern Croatia)

The first outline of the huge power system in the territory of the present-day Croatia, Istria and Rijeka excluded, could be seen after WWI when the construction of high voltage networks began around electrification centres. An important step forward was made in 1930 when the Power Plant in Zagreb (18,750 kW), the Power plant in the town of Karlovac the hydropower plant Ozalj (2,690 kW) and Diesel power plant in Dubovac (720 kW) were interconnected.

This allowed the exchange of electricity and allowed electrification of the area on that stretch. The 30 kV transmission line (55 km, 3 x 50 mm^2 Cu + 24 mm^2

Fe) was put in operation on 16th March 1930. It was constructed on reinforced concrete pylons with the conductor clearance allowing later switching to a higher voltage of 60 kV. In that year, 1930, Croatia got its first connected power system, which supplied power to a larger consumption area from the three power stations mentioned above. The unique power system of interconnected power plants allowed Zagreb to get four to five thousand MWh/y of surplus electricity generated from Karlovac at night in the power plant in Ozalj, and at the same time, Karlovac received from Zagreb one to two thousand MWh/y of the so-called supplementary peak power. The efficiency of the power plants' operation and power supply reliability were considerably enhanced. Even today, 30 kV transmission lines are used partly at 30 kV and partly at 10 kV. In that period, distribution network began to expand out of the borders of the town of Karlovac. So the 20 kV line was built and it connected the town of Metlika in Slovenia with the hydropower plant Ozalj. Even though this line can be seen as the first interconnection although at the distribution level, the interconnection on the transmission level will ensue much later.
Electrification of Istria and Rijeka during that period was very slow, until 1924 when the 50 kV line with the frequency of 42 Hz and the length of 103 km was put into operation between two transformer stations 132/50 kV Opicina (Italy) to the town of Pula (Croatia).

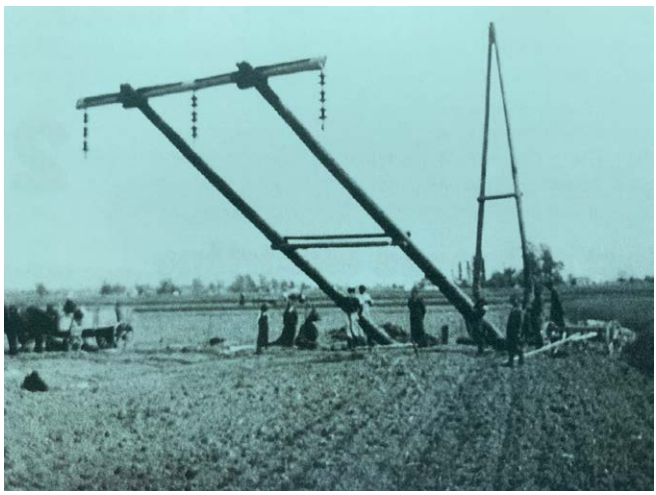


Fig. 8.6 Construction of the first 110 kV interconnection Zagreb (Croatia) – Brestanica (Slovenia)

Two TS 50/10 kV were installed into the route of the line, which significantly contributed to the electrification of the area. Later, in 1940 the 132 kV line was put into operation between Opicina and Matulji (Croatia), as well as TS Matulji 132/50 kV, which is considered the beginning of application of transmission voltage level in Croatia.
During WWII, the 110 kV line between Brestanica (Slovenia) and Zagreb was constructed. It was first operational under 30 kV to Zagreb's power plant, then it was operational under 80 kV and in 1949 it was operational under 110 kV. This line has been considered as the first interconnection of the Croatian power system.

e) Development and construction of the Croatian power system

In the post bellum period in Croatia, there were smaller isolated thermal- and hydropower systems with the local consumption. Only in the area of Dalmatia, Zagreb and Rijeka could one speak of organized micro power system. The total installed capacity of power plants amounted to 178 MW and the annual consumption in 1945 totalled at 224 GWh. The renovation of destroyed facilities until 1948 led to the same electricity consumption level as prior to 2WW, i.e. 543 GWh. There were only 13 percent of electrified settlements and around 20 percent of electrified households. Until the beginning of 1950ies, electrification had such an intensity that in 1953 reductions of electricity consumption were imposed, since it reached 3.2 percent of the total consumption. The beginning of 1960ies marks the era of intensive construction of generation facilities. The construction of hydropower plants was continuous until the end of 1980ies. The construction of thermal power plants began only in the 1970ies and continued by 2015 with interruptions.



Fig. 8.7 HPP Ozalj, one of the oldest HPP in Croatia built in 1908.

All major islands in the Adriatic Sea were electrified between 1955 and 1968, mostly with 30 kV submarine cables, whereby the 110 kV submarine cable with the length of 7.5 km was laid for the island of Brač.



Fig. 8.8 TE-TO cogeneration units in Zagreb

Along with the construction of generation capacities, the 220 kV network was constructed and the connection with the neighbouring power system of Bosnia and Herzegovina was established. Analogous machine for the regulation of frequencies and the power exchange was put into operation in 1972. This regulation was a precondition for the parallel work with UCPTE, which was achieved on 10th September 1974. That significantly increased the security of supply. Electrification of settlements reached 98 percent at that time, and of households 97 percent. Installed capacity totalled at 1922 MW, and the consumption at 8225 GWh.



Fig. 8.9 TS 400/220/110 kV Žerjavinec (left) and National dispatch centre (right)

In 1981 Croatia and Slovenia constructed Nuclear power plant Krško together, at the threshold of 644 MW (the power increased later). At the end of 1985, the electrification of households and neighbourhoods was actually completed, installed capacity then amounted to 4130 MW and the annual consumption 13759 GWh. In the part dealing with the management of the power system, the system of remote control was introduced, which was conducted by the National dispatch centre and four regional dispatch centres.

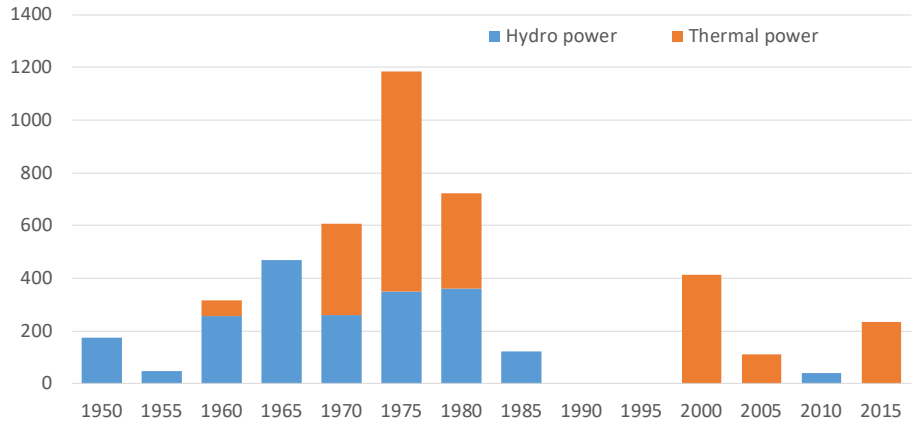


Fig. 8.10 Dynamics of building Hydro and thermal power plant

A special chapter in the development of power system is the Croatian Homeland War from 1991 to 1995. Political crisis affecting Yugoslavia at the time culminated with the Croatian Homeland War. The experts gathered in HK CIGRE were shown to have succeeded in solving technical problems with power supply to cities and neighbourhoods in the areas affected by Homeland war. Due to the Homeland war conditions, power system of Croatia disintegrated into two parts, northern and southern, which would reconnect into a unique power system later. Apart from the problems with the supply of cities and neighbourhoods, there were great challenges in the systems of managing power systems, both the ones connected to UCTE and those on the islands. Along with generation facilities, TS 400, 220 and 110 kV lines were also destroyed, as well as distribution network. Electricity consumption fell by almost 30 percent. One of the consequences of the Homeland war was the breakdown of UCTE synchronous zone into two parts, but it would be reconnected in 2004. This project was successfully managed by Hrvatska elektroprivreda. The biggest challenge after the Homeland War was the renovation of destroyed plants and Croatian NC CIGRE played an important role by discussing important technological problems on conferences, symposia and colloquiums.



Fig. 8.11 Destroyed TS 400/110 kV Ernestinovo command room (left) and transformer (right)

Transformer station Ernestinovo 400/110 kV (eastern Croatia) was commissioned in 1977, as the node point when it comes to electricity supply of eastern Croatia. It was completely destroyed in 1991, during the Croatian Homeland War. After its reconstruction, which meant almost complete construction for the second time, it was put into operation in 2003. TS Ernestinovo is interconnected on the level of 400 kV interconnections to the neighbouring power systems, Hungary, Serbia and Bosnia and Herzegovina.



Fig. 8.12 Destroyed HPP Peruča Dam (left) and Machinery compartment (right)

A similar happened with generation facilities. Such an example is hydro power plant Peruča in the south of Croatia, shown here. HPP Peruča is a hydro power plant with the biggest accumulation in Croatia (565 hm^3) constructed and commissioned in 1960. With installed capacity of 2 x 25.5 MW. During the Croatian Homeland War the dam of the hydro power plant was mined, but fortunately it was only partially destroyed. The engine room of the hydro power plant was destroyed. During the reconstructions, new aggregates were installed, as well as the turbine with installed capacity of 2 x 30.5, and it was put into operation for the second time in 2008.

The reconstruction of the distribution network lasted significantly longer, as the damage level was much bigger, so electricity supply normalized during 2000. In the period, which ensued, new cogeneration plants were constructed in Zagreb, as well as hydro power plant Lešće (42 MW). The end of 2000 marks the beginning of renewable energy sources period, especially that of windfarms. Taking into consideration the lack of experience and procedures of managing power system with a higher share of wind farms, the beginning was rather conservative, so that installed capacity was first limited to 400 MW and the feed-in tariff model was formed along with that. Today, installed capacity of wind farms is 738 MW, and of solar power plants 68 MW, as well as other technologies. The development of generation part of power system is defined by the Energy Development Strategy of Croatia until 2030 with an outlook to 2050, as well as Integrated National Energy and Climate Plan of Croatia for the period from 2021 to 2030. These documents determine the future structure of generation facilities of renewable energy sources, whose generation would be subsidised. 1075 MW solar power plants and 1050 MW wind farms dominate the structure.

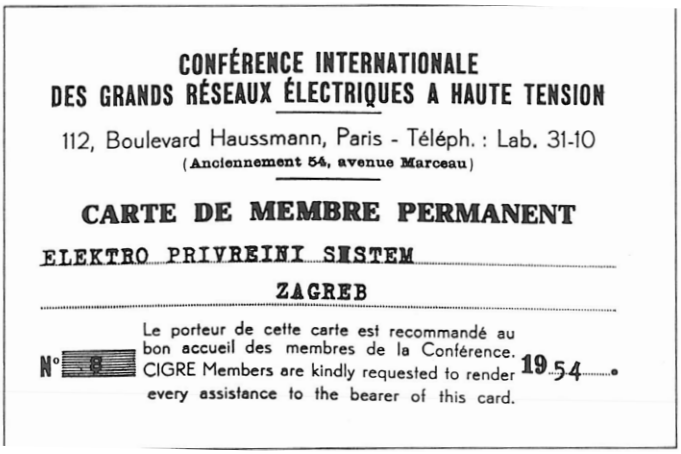
8.2 History of CIGRE in Croatia

It is not known, whether there have been contacts between Croatian experts and the international CIGRE before WWII. The contacts may have existed, since some prominent experts from Croatia, for instance Josip Horvat, Miroslav Plohl and E. Montana had intensive contact with Austrian and German experts, who were known for sure as members of CIGRE.
The first known contacts between CIGRE and the newly established Yugoslavia occurred in 1948. One of the participants at the 12th CIGRE conference in Paris

was the university professor, Milan Vidmar from Slovenia, who was an eminent expert for transformers and transmission networks. His meeting with the leading people of CIGRE resulted with a letter sent on 7th December 1948 by the then President of CIGRE, Jean Tribot-Laspiere to Milan Vidmar, in which he suggested establishing of the national CIGRE of the country at the time. By then 28 countries had national committees. So, the establishment of the National Committee of Yugoslavia (JUKO or YUKO CIGRE) was initiated by Milan Vidmar and his letter sent to the then Minister of electrical industry. The decision was then left to a very significant organization, the Association of Societies of engineers and technicians of Yugoslavia, with the headquarters in Belgrade (Serbia). The task to establish the national committee was given to the engineer Herman Mattes from Zagreb, who was also the vice president of the Association of Societies of engineers of Yugoslavia.

It is interesting that CIGRE from Paris sent a letter to Herman Mattes on 15th October 1949 addressed to the National Committee, although it still was not established. It was a circular letter sent by the Parisian CIGRE to Herman Mattes as a piece of information on the amount of annual membership (USD 150.00), proscribed for JUKO CIGRE, even though it was going to be established only in 1951. Initiative committee for the establishment of JUKO CIGRE was made up of the university professor Milan Vidmar from Ljubljana (Slovenia), the university professor Pavle Miljanić and the university professor Ilija Obradović from Belgrade (Serbia), the university professor Vladimir Žepić and the engineer Herman Mattes, both from Zagreb, Croatia.

It is interesting that the Governing board of the Association of Societies of en-



CONFÉRENCE INTERNATIONALE
DES GRANDS RÉSEAUX ÉLECTRIQUES A HAUTE TENSION

112, Boulevard Haussmann, Paris - Téléph. : Lab. 31-10
(Anciennement 54, avenue Marceau)

CARTE DE MEMBRE PERMANENT

ELEKTRO PRIVREDNI SISTEM

ZAGREB

N° 8

Le porteur de cette carte est recommandé au bon accueil des membres de la Conférence.
CIGRE Members are kindly requested to render every assistance to the bearer of this card.

19 54

Fig. 8.13 Membership card of a permanent member of CIGRE

gineers and technicians of Yugoslavia was given the task to prepare the participation of JUKO CIGRE on the 13th CIGRE Conference in Paris from 29th June to 8th July, 1950, although it was not formally established. The national committee will be established only on 3rd December 1951 in Zagreb at a private address of the Herman Mattes in Zagreb. The first president was the university professor Milan Vidmar, and the secretary general was the engineer Herman Mattes. The final instance regarding the acceptance of organization, such as JUKO CIGRE was the Ministry of Internal Affairs, so the secretary general, Herman Mattes was invited to the hearing upon filing the request for legalization. At that time, the hearing was not an innocent talk. as it might be today. However, after the hearing, the association was allowed to work, so on 6th March 1954 JUKO CIGRE became a legal organization.

Only in the following years will the significance of establishing the national committee in Zagreb be visible, as it gave an important momentum to the development of professional thought in Croatia. Apart from individual membership, and most of individual members were from Croatia, collective membership was numerous as well. For instance, out of the first 13 collective members, nine came from Croatia. At the first Conference of JUKO CIGRE, held in Ljubljana (Slovenia), 31 out of 100 participants were from Croatia.

Out of the total of 20 Conferences of JUKO CIGRE, two were held in the town of Opatija and one in the town of Dubrovnik. There were also 12 symposiums on computer science organized in the town of Cavtat near Dubrovnik.



Fig. 8.14 Prof. Hrvoje Požar, Herman Mattes and Vesna Velebir

Parisian CIGRE accepted 5 papers from Croatian authors between 1950 and 1992. Actually, until 1990 the total of 4 papers was accepted, and the fifth applied for the conference in 1992, when the Croatian national committee of CIGRE had already been established.
The first paper from Croatia was on the CIGRE conference in Paris in 1964 entitled "Mechanical Computer for the Computation of Sag and Stresses in the group 23/24 Overhead Lines, Vibrations" R204 by university professor Božidar Stefanini.



Fig. 8.15 Prof. Božidar Stefanini, Boris Markovčić (general secretary of JUCO CIGRE)

The presidents of JUKO CIGRE from Croatia were the university professor Hrvoje Požar between 1978 and 1982 as well as the university professor Božidar Frančić between 1985 and 1989. The secretaries general of JUKO CIGRE were always from Croatia. After the first secretary general, Herman Mattes between 1951 and 1976, General secretary was engineer Boris Markovčić between 1976 and 1989 and Zorko Cvetković, PhD. between 1989 and 1992, when JUKO CIGRE was fading away. The headquarters of JUKO CIGRE was always in Zagreb (which was unique at that time, since all organizations on the level of previous state had their headquarters in Belgrade) and that was the most significant for the promotion of the idea of CIGRE in Croatia. The biggest credit for that achievement goes to Herman Mattes. After WWII, he was the director of a power plant in Zagreb, the president of the Association of electrical engineers and technicians of Croatia, the head of construction of Ruđer Bošković institute in Zagreb and the director of the Institute for electrical and energy in Zagreb etc.

8.3 History of the Croatian National Committee of CIGRE

During the 20th JUKO CIGRE Conference held in Neum (Bosnia and Herzegovina) in April 1991, one could feel the climate of political and economic crisis and forthcoming events connected to the breakup of Yugoslavia. One could also sense this to be the last JUKO CIGRE conference. In autumn and winter of 1991, the war escalated, and at the same time, efforts were put in to establish the independent Republic of Croatia. That was the beginning of the Croatian Homeland War, which would eventually lead to the international acknowledgement of the Republic of Croatia. The thought on setting up the Croatian National Committee of CIGRE (Croatian NC CIGRE) was imposed in such circumstances.

Upon certain preparations, the constituent assembly of the Croatian NC CIGRE was held on 18 February 1992 in Zagreb, at the location of the Association of engineers and technicians of Croatia at number 6 Petar Berislavić Street. Today's Croatian NC CIGRE headquarters are still at the same address. More than 110 individual members and 15 collective members from all over Croatia attended the Assembly, as they were able to come to Zagreb under those war circumstances. The Assembly was chaired by engineer Mirko Majić, as the oldest member of the Initiating Council and of the international CIGRE. Ivan Putanec, M.Sc., (the then President of HEP's d. d. Management Board) was appointed President of the Croatian NC CIGRE, the Vice-president was Josip Moser and the Secretary general was Zorko Cvetković, Ph.D. (who continued to act as the Secretary general, but in HK CIGRE), and the administrative secretary was Vesna Velebir. Temporary heads of the total of 16 study committees were also appointed, modelled by the Parisian CIGRE. That was not a big problem because many experts from Croatia actively participated in the work of all study committees. Along with the establishment, activities were conducted for the Parisian CIGRE to acknowledge Croatian



Fig. 8.16 First president of Croatian NC CIGRE Ivan Putanec

NC CIGRE. Finally, on 30th August 1992, at the session of the Parisian CIGRE, Croatian NC CIGRE became a full member of CIGRE world family. Thus, the number of countries with national committees reached 44.

At the first Assembly it was concluded that the first conference should be held in 1993. Also, the first Symposium on the management of electric power system was held in 1994. Since then, the conferences, the total of 14 so far, have been held every odd year, and the symposia on the management of power system, the total of 13 so far, have been held every even year. Also, in 1996 the Symposium on electricity distribution started, and the total of 6 would be held, but after 2006 there was a division of the part dealing with electricity distribution, and Croatian National Committee CIRED was established, as part of the CIRED world organization.

Croatian NC CIGRE recognized the importance of collaboration on the international level, so apart from national conferences and symposia, it organized a lot of international colloquiums, the total of 11 on various issues of power system, with the participation of a huge number of foreign participants. It also organized 34 round tables on numerous topics interesting for power engineering, 34 seminars on various specialist issues for the purpose of expert education and there were also numerous professional discussions, workshops etc. All these meetings contributed significantly to the affirmation of CIGRE idea in Croatia and the affirmation of Croatian NC CIGRE in the world. Today Croatian NC CIGRE gathers around 900 individual members and 26 collective members.

Special attention has been paid to women in engineering sector, which is reflected in 90 female members. Croatian NC CIGRE based on the Parisian CIGRE set up the section Women in engineering, which started working in 2019, and other sections were established as well: Young engineers, Cooperation with scientific institutions, Cooperation with economy and councils for renewable energy sources. Huge attention has been paid to students, who make up 66 individual members.

One of the basic principles of Croatian NC CIGRE was to be independent in its work, as much as possible. Through history, from its establishment until today it always relied on Hrvatska Elektroprivreda d.d. (Croatian Electricity Utility) and Končar Electrical Industries d.d. (world famous producer components of power system and engineering) and Dalekovod d.d. (world famous engineering and construction company) as three pillars of power engineering. The next component belonged to the scientific academic community on universities and colleges. They were the source of the highest number of experts who have acted

in Croatian NC CIGRE, which is the guarantee that what has been achieved will be maintained. In addition, Croatian NC CIGRE achieved an important cooperation with other companies in the field of power engineering in Croatia, whose support to professional meetings is very important. Further below is the overview of the leading people in Croatian NC CIGRE, from its establishment until today.

Table 8.1 Leading people in Croatian NC CIGRE

Year	President	Vice-president	General Secretary
1992–1996	Ivan Putanec	Josip Moser	Zorko Cvetković
1996–2000	Milan Bobetko	Marijan Kalea Tomislav Kelemen	
2000–2008	Ivica Toljan	Juraj Šimunić	
2008–2012	Krešimir Meštrović	Ante Marušić	Božidar Filipović Grčić
2012–2014	Tomislav Šerić	Mladen Zeljko	
2014–2018	Miroslav Mesić		
2018–2019	Mario Gudelj		
2019–	Goran Slipac	Goran Majstrović	

8.4 Activities and achievements of the Croatian National Committee CIGRE

Regarding the fact that Croatia had good and rich experiences in CIGRE's work, it was not difficult to continue with activities, but also to expand them and enrich them with new content. All experts of different profiles joined the work of Croatian NC CIGRE. They were divided into 16 study committees on the basis of the Parisian CIGRE. The links Croatian experts shared with colleagues around the world enabled the development of the idea and mission of CIGRE in Croatia. The most important professional meeting of Croatian NC CIGRE in Croatia is the Conference held every second (odd) year. The last meeting of the kind, 14th in line, was held in November 2019 in Šibenik, and it there were 1,125 participants, 80 of which from foreign countries. There were more than 240 papers from all 16 study committees. There were also 27 exhibitors and Conference sponsors, so numerous sponsor and expert lectures were held. There were many representatives of CIGRE national committees from neighbouring countries.

Croatian NC CIGRE organizes a Symposium on the management of power system held every second (even) year, organized by five study committees SC B5, C1, C2, C5, and D2. The Symposium is the continuation of the tradition of Parisian CIGRE, established to discuss the problem of managing power system. The last meeting of the kind, 13th in line, was held in 2018 in Rovinj. There were 107 papers presented at the Symposium, with more than 600 participants, along with 24 sponsors and exhibitors. The 14th Symposium on managing the power system will be held in 2020 in Opatija.
The President of the Parisian CIGRE as well as the Secretary General visited



Fig. 8.17 Opening of the International SC33 conference, 1998 (left) and president of CIGRE Michael Chamia visiting Croatian NC CIGRE, 1998 (right)

Croatian NC CIGRE several times. One of the visits was in 1998, when Michael Chamia visited Croatian NC CIGRE. That year important international meeting of CIGRE working groups was organised, so after the third symposium in 1998 in Cavtat (Dubrovnik, Croatia), there was a WG SC 33 meeting followed by the international conference on "Insulation coordination for electricity development in central European countries".

Colloquia are temporarily organized seminars, devoted to specialist problems in power system. As a rule, Croatian NC CIGRE organizes only international colloquia, either independently or in cooperation, and seeks the approval of its parent institution, SC CIGRE. The papers are reviewed, and expert rapporteurs, apart from the paper report ask authors questions, which they are obliged to answer during the presentation. Apart from papers, invited lectures, sponsored lectures, exhibits of equipment producers, technical visits to electromagnetic facilities and sightseeing tours are also organized. The organization is very similar to colloquia of CIGRE Paris.

One of the most important colloquium is The International Colloquium supported by Croatian NC CIGRE with CIGRE Study Committee A2 - Transformers, the Faculty of Electrical Engineering and Computing, University of Zagreb and the Centre of Excellence for Transformers in Zagreb. This international conference and exhibition is recognized as an event of great interest for researchers and scientists from all over the world. Traditionally chosen topics offer some answers to R&D and technology trends as well as to Transformer Maintenance Life Cycle.

The 5th International Colloquium was organized by the Croatian CIGRE National Committee in cooperation with the Faculty of Electrical Engineering and Computing in Zagreb and the Centre of Excellence for Transformers in Zagreb with support from CIGRE A2 Study committee (Transformers). The goal of the Colloquium was to share latest research in the in the areas of distribution, power and instrument transformers. The Colloquium extended over three days. Participants from manufacturers, utilities and universities took part in discussions. All the papers were divided into three sessions; Numerical Modeling, Materials, Components and New Technologies and Transformer Life Management. There has been more than 200 participants from 25 countries from all over the World. In line with the Colloquium, there were organized meetings of working groups A2.56 Power Transformer Efficiency, A2.63 Transformer Impulse Testing and A2.64 Condition of Cellulose Insulation in Oil-Immersed Transformers After Factory Acceptance Test.



Fig. 8.18 The 5th international colloquium transformer research and asset management held in Opatija, 2019.

From the very beginnings of the organization Croatian NC CIGRE has been very active in SEERC, so it was a host of RWG 01 in September 2016, as well as the host of the meeting TC SEERC, which was held in March 2019 in Split. After

discussions on the organization of SEERC, the members of TC SEERC made a tour of hydro power plant Zakučac, the biggest hydro power plant in Croatia. Croatian NC CIGRE is active as the co-organizer of various national symposia. One of those is the History and philosophy of technology. The significant purpose of the symposium is documenting memories and gathering documents scattered across personal records. The history is important because it describes our identity, and the Philosophy of technology examines the interaction between a man and artefacts. Each symposium had a journal published in the end in digital form, which can be found on the websites of Croatian NC CIGRE. Together with the Science Council for Oil and Gas Economy and Energy of Croatian Academy Of Science and Art, Croatian NC CIGRE organizes round tables with various topics interesting for professional public. In addition, together with experts from universities it organizes seminars for experts with an aim of distributing the latest information and cognitions on some professional topics. Historical dimension has been recognized as very important, so Croatian NC CIGRE launched a project within which historical monographs, old university textbooks and other professional and historical literature is converted into electronic form and published as such on web sites of Croatian NC CIGRE. In such a way historical information and other materials are saved from oblivion and offered to the professional public.



Fig. 8.19 The 5th TAC SEERC meeting held in Split, 2019.

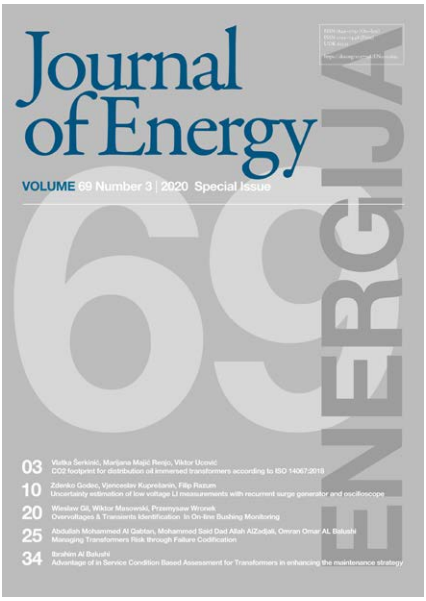


Fig. 8.20 Front page of Journal of Energy

Croatian NC CIGRE in cooperation with Hrvatska elektroprivreda (HEP) publishes a scientific magazine The Journal of Energy. The first issue was published in 1957, under the title Energy. There are not many journals with such a long tradition of publishing, so in it one can find not only historical data on the development of electrical engineering in Croatia, but also various theoretical considerations of electrical engineering. Croatian NC CIGRE recommends that The Journal of Energy becomes the journal in which SEERC would publish professional and scientific papers from its conferences.

Croatian NC CIGRE in cooperation with the Faculty of electrical engineering at the University of Zagreb and the Faculty of electrical engineering, mechanical engineering and naval architecture at the University of Split has organized the third international colloquium Smargrimet, which comprises a wide technological issue of smart networks. This experimental cooperation of CIGRE with the university community has proven to be very successful and promising.

Croatian NC CIGRE keeps close contacts with the representatives of other NC CIGRE, so Croatian NC CIGRE together with Croatian Transmission System Operator and Končar - Power Transformers Ltd. hosted a visit of NC Georgia in October 2019. The representatives of NC Georgia, Giorgi Amuzashvili, Chairman of NC Georgia, Giorgi Arziani Secretary of NC Georgia and Giorgi Khorbaladze from GSE had a tour of National Dispatch Centre, TS 400/220/110 kV Žerjavinec and the factory of energy transformers Končar - Power Transformers Ltd..



Fig. 8.21 NC Georgia visiting National dispatch centre of Croatian transmission system operator

8.5 CIGRE Awards

CIGRE central office granted following awards to the members of Croatian NC CIGRE

CIGRE Fellow Award
2018 - Ivo Uglešić

CIGRE Technical Council Award
2011 - Ante Sekso
2012 - Ivo Uglešić

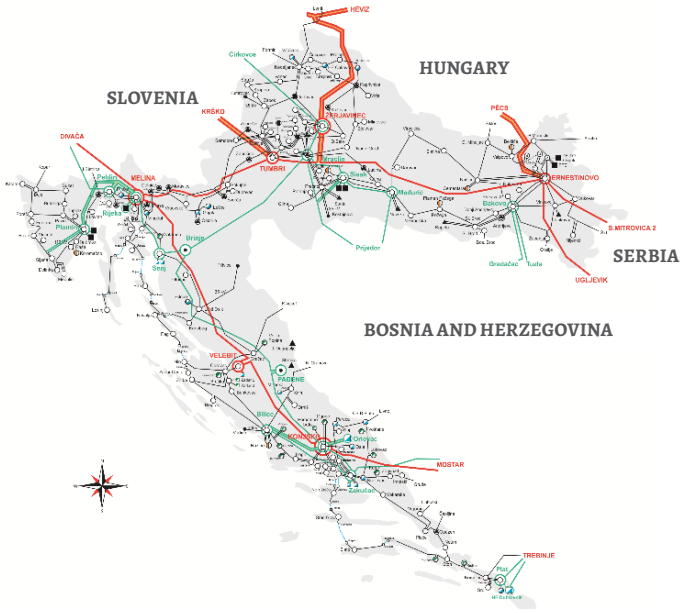
CIGRE Distinguished Member
2000 - Zorko Cvetković
2000 - Ante Miliša

2002 - Zdenko Tonković
2004 - Zlatko Maljković
2004 - Ante Sekso
2006 - Krešimir Meštrović
2008 - Josip Moser
2008 - Gordan Mirošević
2012 - Ivo Uglešić
2014 - Josip Študir
2020 - Antun Mikulecky



Fig. 8.22 President of CIGRE Rob Stephen presenting the award to Prof. Ivo Uglešić, 2018

8.6 Country power system and energy profile



Voltage level	OHL (km)	Cables (km)	Undersee cables (km)	Total (km)
35 (30) kV	2981	1365	142	4488
20 kV	4521	5218		9738
10 kV	15968	11289	247	27505
0,4 kV	44142	17443		61586
House-hold con.	22796	12676		35472
Total	90408	47991	389	138789

Voltage level	Lenght (km)
400 kV	1247
220 kV	1246
110 kV	5298
Submarine cable	73
Underground cable.	83

Indicative nationals target for RES share by 2030	
In total primary energy supply	36.40%
In electricity consumption	63.80%
In heating and cooling	35.30%
In transport	13.20%

Peak Load (2019)	3038 MW
Electricity consumption (2019)	18214
Max daily consumption (2020)	60,588 GWh
Installed capacity Wind (2020)	738 MW
Installed capacity Solar (2020)	68 MW

Primary energy production	221.21 PJ
Total primary energy supply	408.85 PJ
Final energy demand	286.28 PJ

Population	4,086 million
Area	56594 km^2
Teritorial see	31067 km^2
BDP/capita	13270 EUR

8.7 References

1. The History of CIGRE (International Council on Large Electric Systems), A key player in the development of electric power systems since 1921, Paris, 2011.
2. The History of CIGRE National Committees, A major contribution to the International history of CIGRE: Creation and Development of National Committees since the 1920s. Paris, 2013.
3. Pedeset godina djelovanja CIGRE u Hrvatskoj ("50 years of CIGRE in Croatia"), 1951–2001, Deset godina Hrvatskog Komiteta CIGRE ("10 years of NC CIGRE Croatia"), 1991 – 2001, Zagreb, 2001.
4. Povijest javne rasvjete i elektrifikacije grada Zadra (The history of public lighting and electrification of the City of Zadar), Hrvatska elektroprivreda, Distribucijsko područje Zadar, Zadar, 1994.
5. A Century of Hrvatska elektroprivreda, Hrvatska elektroprivreda d.d., Zagreb, 1995.
6. 50 godina organiziranog prijenosa električne energije u Hrvatskoj (50 Years of Organised Transmission System in Croatia), Kigen d.o.o., Zagreb, 2008.
7. Još dalje … Dalekovod - 60 godina Dalekovoda, (Even Further – 60 years of Dalekovod), Dalekovod d.d., Zagreb, 2009.
8. 110 godina elektrifikacije Zadra, (110 Years of Electrification of the City of Zadar), HEP Distribucija d.o.o. Distribucijsko područje Zadar, Zadar, 2004.
9. Annual Energy report – Energija u Hrvatskoj - Energy in Croatia, Ministry of environment and energy of the Republic of Croatia, Zagreb, Ulica grada Vukovara 78, 2019.
10. Razvoj elektrifikacije Hrvatske (The Development of the electrification of Croatia), Hrvatska elektroprivreda d.d., Ulica grada Vukovara 37, Zagreb, I i II dio, 1984.
11. 8.11Arhiv Hrvatskog ogranka CIGRE, (Archives of Croatian National Committee CIGRE) Berislavićeva 6, Zagreb

9. NC CIGRE GEORGIA

9.1 History of the electric power sector of Georgia

a) Before and during the first republic

The history of electricity in Georgia dates back to the 80s of the 19th century. Ilia Chavchavadze, a great public figure, paid great attention to the issue of electricity use. This was related to the opening of the renovated theater building. The population of Tbilisi saw electronic lighting at the Georgian Theater on December 15, 1887. By the end of the 19th century, there were eight small public and private power plants in Georgia.

In 1897, at the behest of Mikhail Romanov, the head of the Borjomi Mineral Waters Chemical Laboratory and a member of its management - Mr. Moldengauer, has been tasked with resolving the issue of electricity supply to the Likani Palace. Construction of the first HPP with 216 kW capacity began in 1897 in the Borjomi Valley, near Borjomi Park, and in 1898 was completed. In 1908 Batumi HPP with installed capacity of 97 kW had been commissioned. Then in 1909, 448 kW Sukhumi HPP was built. By 1913, in total 7 HPPs with a capacity of 1300 kW were already operating in Georgia.

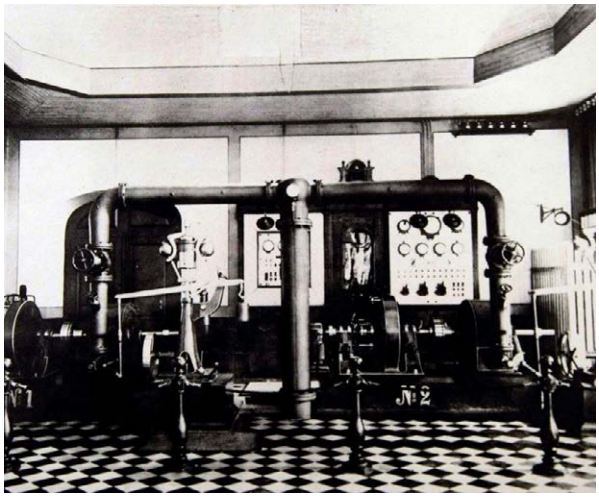


Fig. 9.1 Borjomi HPP

Until 1917, the most powerful power plant in Tbilisi and throughout Georgia was the city's tram thermal power plant, built in 1905 with a capacity of 1,430 kW. By this time, 70 small power plants were already operating in Georgia, with a total installed capacity of 8000 kW.

The first electricity lightning network was commissioned in 1897.

b) From 1921 to 1990 (During soviet era)

Hydro Power Plants

On June 16, 1921, the Soviet government nationalized all power plants in Georgia. On April 3, 1927, Tbilisi received electricity generated by Zahesi HPP. The project was designed by the engineer Mr. Melik-Pashaev. Special attention has been paid to the planning and construction of the main dam. The team of specialists from the German construction company "Siemens Baunion" has been invited to contribute into the consultation.

It was the first hydro power plant with reservoir in Georgia. The HPP was completed in 1934. The final capacity of the station was 36.8 MW, and the annual electricity production - 210 million kWh.

At the same time, discussions were underway on the master plans for the Rioni River. From 1932 to 1934, complex master plans for the Rioni River were developed. In particular, Gumati HPPs, Lajanuri HPP and Vartsikhe HPPs, according to which the four-stage cascade HPPs of Rioni, Gumati-1, Gumati-2, Lajanuri and Vartsikhe have been built.

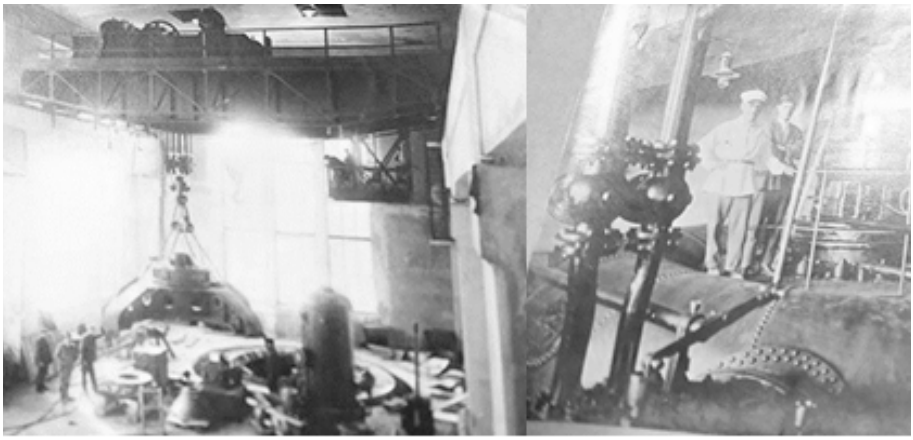


Fig. 9.2 Zahesi HPP

Construction of the Rioni HPP began in May 1927, the first unit was opened on September 30, 1933, and the last on June 30, 1934. Construction of the Zahesi - Rionhesi transmission line was completed by the end of 1932, laying the foundation for Georgia's power system.

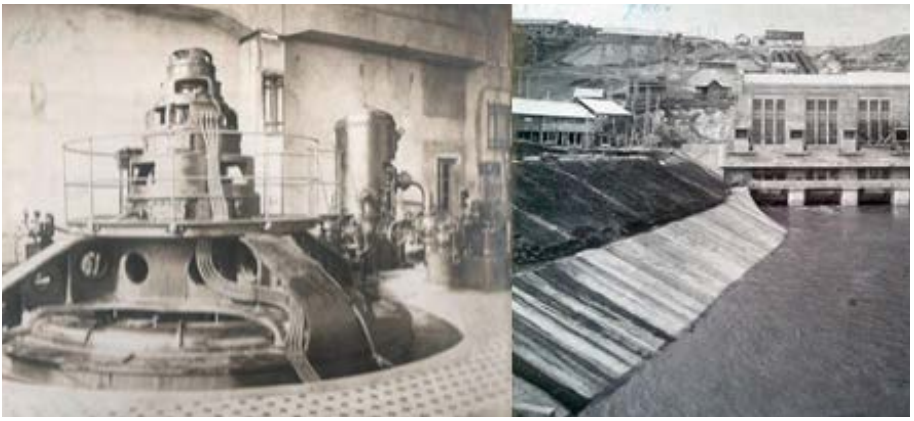


Fig. 9.3 Rioni HPP

From 1940 to 1970 several HPPs were launched into Georgian Power System, given in Table 1 below.

Table 9.1 HPPs launched in 1940–1970 period

HPP	Installed Capacity, MW	Year of commissioning
Alazani	6	1942
Chitakhevi	21	1949
Tkibuli	80	1956
Shaori	40	1959
Samgori Cascade	27	1964
Khrami 1	111	1948
Khrami 2	110	1963
Sokhumi	19	1948
Adjaratskali	16	1941
Ortachala	18	1954
Bjuja	12	1957
Gumati 1	44	1958
Gumati 2	23	1960
Lajanuri HPP	111	1960

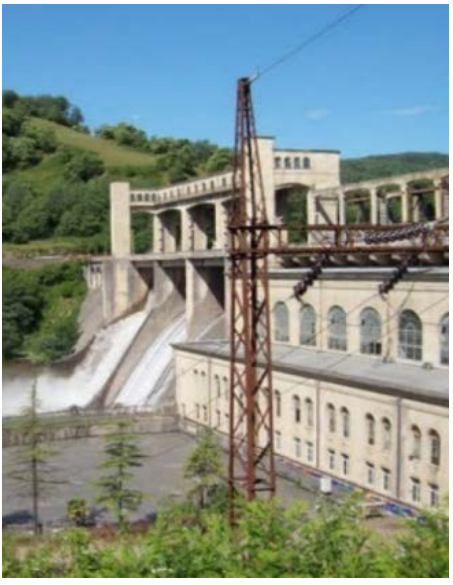


Fig. 9.4 Gumati HPP

Building of small hydro power plants were intensively taken into consideration in the years of 1940–1960, mainly for agricultural purposes. Until 1970, more than 400 small hydro power plants have been put into operation.

Reflecting the construction of small HPPs at almost each village, the funny song was created in the folklore of 50th, with the following text *"A small mill embedded in the swamp, please listen to us and listen to us well. Perhaps this news has broken your heart, but our collective has decided: you will be dismantled because you are old and small, and we will build a dynamo-machine instead of you".*

In 1977 one of the biggest HPP of Georgia Vartsikhe HPP was launched with an installed capacity of 184 MW. Construction project for Zhinvali HPP had been developed in 1963–1969. Its purpose was not only to generate electricity but also to provide Tbilisi with secured water supply. The construction started in 1971 and the HPP was put in operation in 1983. Zhinvali's reservoir capacity is 500 mln. m^3.



Fig. 9.5 Arch Dam of Lajanuri HPP

Enguri, the largest hydro power plant in the Caucasus region

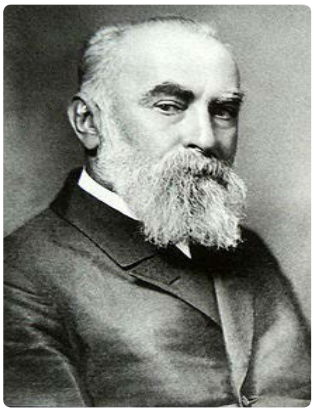


Fig. 9.6 Niko Nikoladze

Great publicist and public figure Niko Nikoladze started thinking about using the rich hydropower resources of Georgia. He invited his son from St. Petersburg in order to conduct a professional analysis over the rivers of Georgia, eventually turning his attention to Enguri and decided to study it. Famous Petersburg engineers Fyodor Rapp and Boris Bakhmetev, also have been invited by Niko Nikoladze. On his advice, Enguri river was chosen for constructing a big power plant with large reservoir.

Due to the several reasons, such as the high construction cost, World War I and the hesitation of

the invited investors, the effort to raise the money for the issue has been failed. Niko Nikoladze has been fighting for the use of the Enguri hydro resources for 20 years, but it was impossible to implement his idea at that time. Finally, the large electricity shortage existing in Georgia and the growing demand on electricity, enabled Georgian scientists and engineers, by operating together with the foreign specialists, to design and construct the unique hydropower plant, such as the Enguri HPP, launched in 1978. The largest hydropower plant in the Transcaucasia is located on the Enguri River. The installed capacity of Enguri HPP is 1300 MW and Enguri Cascade (including Vardnili HPP) is 1520 MW. Enguri dam is unique, the first largest and highest arch type dam in the world up to 21st century. The height is 271.5 m and the volume is 1100 million cubic meters. It has given status of immovable cultural monuments of national significance by Georgian governance.



Fig. 9.7 Enguri Dam

Thermal Power Plants (TPP)

Large-scale processing of coal mines in Georgia and the increase in demand for electricity have created a precondition for the construction of thermal power plants.

In 1938, the first units of Tkvarcheli thermal power plant and Tbilisi thermal power plant were commissioned, with initial capacity of 25 MW. Operation of the TPP was oriented to ensure local coal mining.

In 1945 the capacity of Tkvarcheli TPP achieved 50 MW. In 1956–1958 years this TPP expanded and total capacity achieved 125 MW. The first two units of Tbilisi CHP with installed capacity of 8 MW started operation since 1942. Since 1954, heating system was developed having silk weaving factory as the first customer. Later the residents of the central part of Tbilisi were connected to the thermal supply as well. Batumi CHP was built and put into operation in 1929 with 19 MW capacity. It mainly served for Batumi oil refinery factory. The Kutaisi auto factory and CHP started operation in 1954. Initially the installed capacity was 4 MW, and later increased up to 5.7 MW. One of the major energy facilities, which should serve Rustavi Metallurgical Complex, was Rustavi CHP. The first 12 MW unit launched in 1949. Total installed capacity of CHP was 130 MW. In 1959 construction of the largest Tbilisi State district thermal power station began. The Installed capacity was 1250 MW. The first unit started operation in 1963, and the last eighth unit in 1972. In 1983 decision on re-designing of the TPP was made. The project was envisioning dismantlement of four old units and installation of two new N9 and N10, 300 MW units. Installation of those two new 300 MW units began in 1988 and ended in 1994.

c] Transmission Network of Georgia

35 kV OHL Zahesi – Tbilisi is the first high voltage OHL in Georgia, with length of up to 15 km. 35 kV electric infrastructure was created in Tbilisi, which consisted of four step-down substations and 35 kV transmission lines. Thus, 1927 year is an inception of constructing power grid of the country and which served as a milestone for the rapid growth of industry (clothing factory, railway mechanic shops of Transcaucasia, water – pipes, etc.). However, the next level of high voltage OHL system development served to the creation of the country's high voltage transmission system.

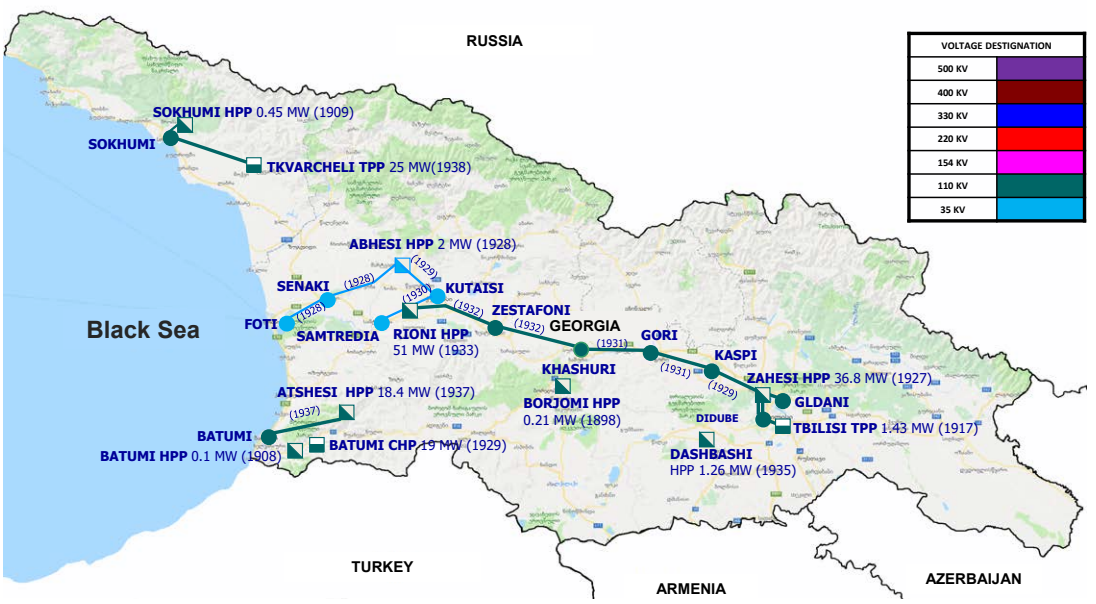


Fig. 9.8 First Transmission System of Georgia

In 1929, 110 kV OHL started operation, which was built to supply the Kaspi cement factory. In 1928, soon after "Abhesi HPP" started to operate, electricity was provided to Poti, Senaki, Bandza and to Martvili. The following year, in 1929 Kutaisi was supplied and in 1930 Samtredia as well. In 1931, during the construction process of transmission lines connecting Zahesi-Rioni HPP, Kaspi – Gori, Gori – Khashuri, Khashuri – Tsifa and Tsifa – Moliti were isolated as a separate districts and in 1932, districts of Moliti – Zestaponi and Zestaponi – Rioni HPP operated in an isolated mode as well.

In 1932 From Zahesi HPP, four 110 kV OHLs were commissioned: one in direction of Rioni HPP, two to Tbilisi (Didube substation), and the rest in direction of Gldani. At the same time, one more substation was built in Tbilisi on the left side of the Mtkvari (now near the old Tetsi). In addition, substations were built in Didube and Navtlugi, creating a new network for the capital city. Hence, this 110 kV network already covered most part of Georgia. Thus, in 1932 there was established the first TSO of Georgia - GeoMainEnergo or GeoEnergo [SakEnergo or SakMtavarEnergo in Georgian], with three synchronously operating power plants Zahesi HPP, Rioni HPP and Abhesi HPP.

In the following years, the transmission network was expended by constructing

Hydro power plants and generation units. Hence, it became necessary to develop 220 kV network. The first of them was built in 1957, connecting Tkvarcheli and Kutaisi. Firstly it was loaded by 110 kV voltage, but in 1959 after construction of "Big Kutaisi" substation, 220 kV part of substation was energized as well. In 1959, "Big Kutaisi" – "Tbilisi (Navtlughi)" 220 kV transmission line was built. At the end of construction of Enguri HPP, 500 kV voltage transmission lines were launched, connecting to each other Enguri HPP – Zestaponi – Gldani – and Tbilisi regional heating station – Akstafa.

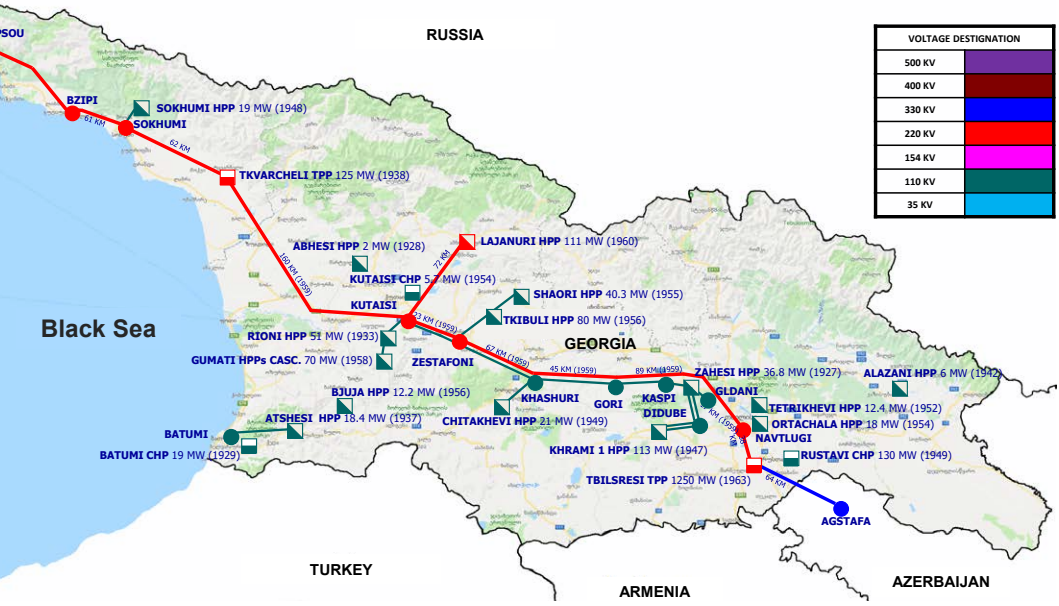


Fig. 9.9 Transmission system of Georgia for 1960

Interconnection lines were developed as well: 220 KV OHL Alaverdi (Gardabani-Alaverdi) with Armenia; 330 kV OHL Gardabani (Gardabani-Aghstafa) with Azerbaijan, 500 kV OHL Kavkasioni (Enguri-Centralnaia) with Russia and 220 kV OHL Adjara (Batumi-Hopa) with Turkey.



Fig. 9.10 Transmission system of Georgia for 1990

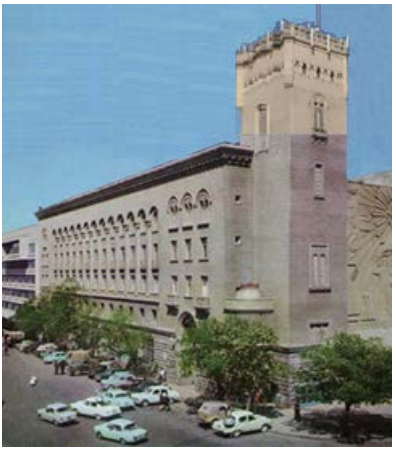


Fig. 9.11 Head office of SakMtavarEenergo (GeoMainEnergo)

By 1990 in the power system of Georgia there were already 500 kV voltage transmission lines, with the total length of up to 580 km; 330 kV – 21 km; 220 kV – 1558 km; 110 kV – 4172 km, 35 kV – 3331 km; 6–10 kV – 23 351 km. As the capacities of the power systems of Soviet Republics of South Caucasus increased, the need of coordination of the planning and operation of these systems raised. Therefore in 1966 the Unified Dispatching Governance [ODU Zakavkazia in Russian] of the Caucasus was established.

The control center of Caucasus UDG was situated in the same building and floor as the existing NCC of Georgia (GSE). Caucasus UDG existed until 1991.

GeoMainEnergo was a vertically integrated company, covering the functions of electricity Generation, Transmission and distribution. The head office of GeoMainEnergo was situated near to the existing head office of GSE. This building is structured with monumental Georgian architectural style of "Lavrenti Beria period" and has a bomb-resistant walls. At the end of the building stands a bastion and there is a logo of GeoMainEnergo. The logo shows a man, bringing the fire (light) to the people. So, even today the motto of GSE (legal successor of GeoMainEnergo) is *"We Bring the Light to You!"*.

Electrical Transport

In 1904, the construction of an electric tram by the Belgian company was began. On December 25, 1904, an electric tram with a rail width of 1000 millimeters was put into operation.

In July 1900 Tbilisi self-government signed an agreement on the withdrawal of the funicular in the city and approved the project of Robbie. The agreement included the following: the Belgian anonymous community of Funicular would have operated for 45 years and then transferred to the city free of charge. The construction of the funicular began in September 1903 and opened on 27 March 1905. During the independence of Georgia (1918–1921) Georgian railway was partly electrified and Electric Trains of Ferrel were operated.

On August 16, 1932 for **the first time in the USSR, the electric traction train ran in the Surami (Georgia) pass (Khashuri-Zestafoni).** In honor of Surami's place, the first Soviet elves were awarded the Surami (S) class. The General Electric Company produced the initial eight electric locomotives of Class S for the service, then USSR bought the license on this locomotives and further produced several locomotives of Surami Class.

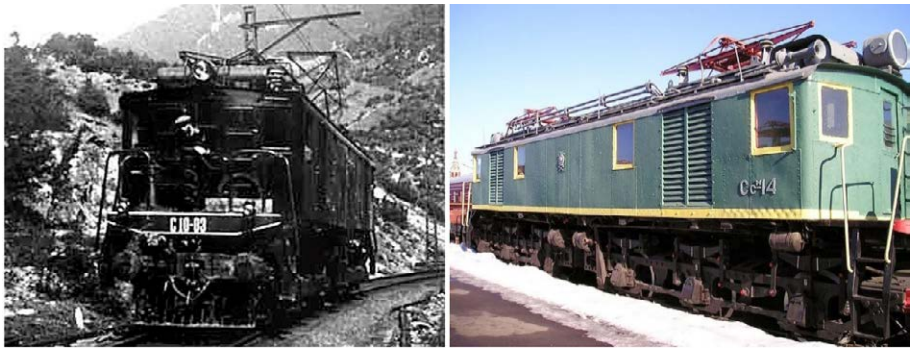


Fig. 9.12 The first electric trains in USSR - S10 (Suramian) and Ss14 classes



Fig. 9.13 Georgian electric locomotive VL 11

In 1956, Tbilisi Locomotive Repair Plant started construction of electric locomotives. In 1961 was developed T8 (then renamed as VL10), direct current, eight-axle trunk electric locomotive. From this date up to now Tbilisi Electric Locomotive Factory (TELF) have been constructing the models of electric locomotives 4E1, 4E10, 4E10I, VL10-УУ, VL11, VL11-M5, VL11-M6, ЭК14, ЭК15, VL15, VL40, VL-8B. TELF was on of the biggest supplier of electric locomotives in USSR. Nowadays many electric locomotives of TELF are in service in the railways of post-soviet countries.

d] The power system of Georgia, after the independence and before 2003

The electricity transmission system of Georgia was planned for the stable operation with the giant united system of USSR and Eastern Europe. Sizes of big units and power stations were fitted for this system as well. Enguri cascade – 1500 MW - The biggest HPP is situated in Western Georgia and was designed not for resident power system but for the peak sheaving of south Russia. For supply of Tbilisi-Rustavi consumption centers 2000 MW TPP was built. Georgia does not have enough sources of oil and gas, however for the operation of this TPP gas and oil was imported from Russia and Azerbaijan, almost at zero price, as these all countries treated as one state.

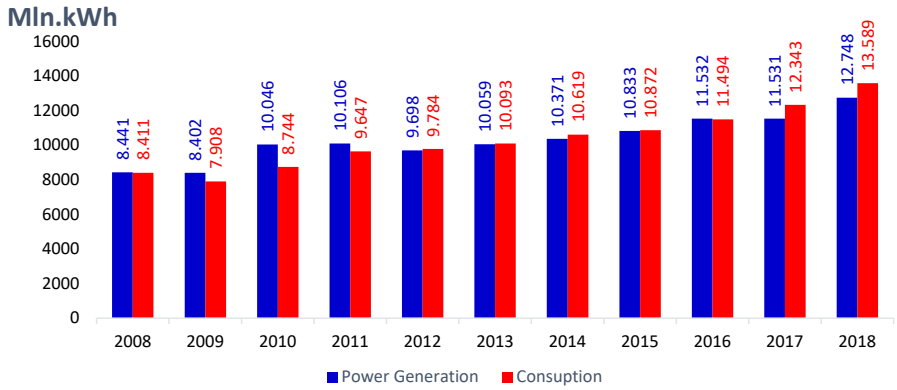


Fig. 9.14 Power generation and consumption growth in Georgia

Soon, After the recovery of independence of Georgia in 1991, civil war began and the electricity system had to withstand hard times. Much equipment, including conductors of the transmission lines had been stolen. Because of absence of fuel, TPPs were unable to operate, HPPs had to cover the full electricity consumption of the country. Industrial consumption decreased but civil consumption increased. Beside the scheduled power supply restrictions, around 4–6 hours/day, real time electricity supply was not enough and recently power system was operating at 45 Hz frequency. It resulted in additional damages of electrical equipment. Most disappointing was the fact that the construction of Khudoni HPP with 700 MW installed capacity (the biggest storage HPP after Enguri) was stopped and even today it has not finished. Because of difficult operational situation, the 300 MW TPP units N9 and N10 at Gardabani were hardly damaged. N10 TPP unit is still not able to operate.

The situation, in electricity supply, gradually improved after 2003, it was caused mainly by improvement of metering, tax deductions and overall criminogenic situation in the country.

e) Transmission network reinforcement from 2003–up to now

The construction of 500 kV OHLs Zestafoni-Akhaltsikhe "Zekari" and Akhaltsikhe-Gardabani "Vardzia" closed 500 kV ring from Zestafoni around Tbilisi and increased the stability of Georgian power system. In 2012, 500/400 kV HVDC at the border of Georgia-Turkey (Akhaltsikhe) and corresponding 400 kV OHL Akhaltsikhe-Borshkha (Meskheti) from commissioned. These elements make possible 700 MW power exchange between the power systems of Caucasus and Turkey. Afterwards, the reconstruction of the double-circuit 220 kV OHL Tskaltubo-Menji "Senaki 1,2" was done. This element increased the reliability of 220 kV western grid. In parallel, all 220/110 kV substations (s/s) had been refurbished. 500 kV substation Marneuli was commissioned which was connected to s/s Ksani via existing OHL "Asureti". Thus, new "smaller" 500 kV ring closed around Tbilisi. In s/s Marneuli existing OHL Akhaltsikhe-Gardabani looped as well and new sections Akhaltsikhe-Marneuli "Vardzia" and "Marneuli-Gardabani" Gachiani had been established. S/s Marneuli solves two tasks:

1. reserves existing 500/220 autotransformers of Gardabani and Marneuli,
2. prepares support for north south corridor, Russia – Georgia – Armenia – Iran.

500/220 kV substation Jvari was commissioned to back-up of 500/220 kV substation of Enguri and 220 kV western grid. 220/110 kV substation Khorga and 2-Circuit 220 kV OHL Menji-Khorga was constructed for feeding the free industrial zone and planned port Anaklia. 500/220 kV substation Jvari was built to back-up of 500/220 kV s/s of Enguri and 220 kV western grid. Several new 220 kV and 500 kV OHLs were constructed to strengthen the connection between the different areas, interconnections and increase the reliability and security of supply of Georgian power grid. At the same time, the park of transformers had been renewed as well.

Generation expansion from 2003 up to now

From 2003 up to now several new power plants had been commissioned with total capacity of 725 MW. The list is given in the table

Table 9.2 The list of newly commissioned power plants

Type	Name	Installed capacity, MW	Commission year
HPP	Shuakhevi	175	2017
HPP	Dariali	108	2016
HPP	Paravani	86	2014
HPP	Kirnati	52	2017
HPP	Khelvachauri	48	2018
HPP	Mestiachala 1, 2	50	2019
HPP	Mkvari	50	2020
TPP	Gpower GT	110	2006

The evolution of generation capacities in Georgia is shown in the Fig 9.15 below.

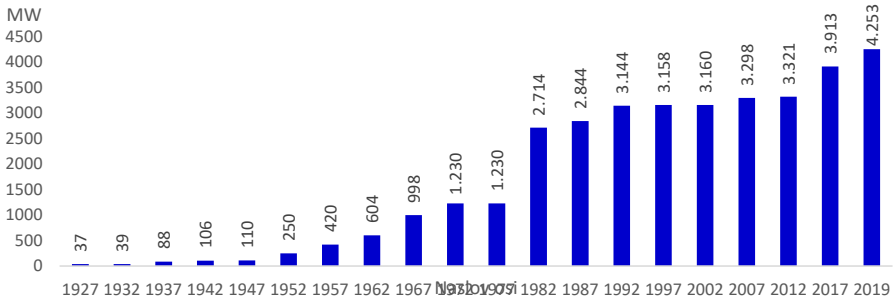


Fig. 9.15 Evolution of generation capacities of Georgian power system

9.2 CIGRE National Committee of Georgia

In 2018 the National Committee of CIGRE has been established in Georgia at the initiative and under guidance of **Georgian State Electrosystem. CIGRE Georgia** has become 59th NC of CIGRE. CIGRE Georgia is organized exclusively for scientific and educational purposes. It aims to facilitate and promote the interchange of technical knowledge and information as regards the field of electricity generation, transmission and distribution systems. CIGRE Georgia is the first national committee across the region. In addition, it should be noted that Georgia has already became an active member of **South East European Region of CIGRE (SEERC).**

CIGRE Georgia consists of 54 equivalent and 20 student members. Besides the experts of Georgian State Electrosystem, the representatives of Georgian Technical University, Parvus Group LLC, SEL Georgia, SIEMENS Georgia and GTS electronics LTD are supporting the Committee.

The objectives of Georgian National Committee are:

- To act as liaison between the CIGRE head office and the members in Georgia. To share the enhancements and modern technical know-how existing in the field of Power Systems
- To recommend persons to the CIGRE Central Office for membership of 16 Study Committees and Working Groups; their research efforts are anchored to assess current progress and challenges in the sector and joining forces to improve electric power systems of today and tomorrow
- Recruit CIGRE members to organize the studies regarding the most important issues of Georgian electrical power systems and to ensure national representation and contributions to CIGRE sessions
- To promote meetings of Study Committees and Working Groups, technical meetings or other events in Georgia, either separately or in conjunction with other appropriate organizations.



Fig. 9.16 CIGRE SEERC management board meeting in Tbilisi

In July, 2019 the management board meeting of CIGRE SEERC was held for the first time in Tbilisi, Georgia. For this reason, representatives of South East European countries have been visited Georgian State Electrosystem.



Fig. 9.17 CIGRE SEERC management board meeting in Tbilis

CIGRE Georgia has an ambitious plan to invite and help the companies and individuals on becoming the active members of CIGRE family.

9.3 Current Situation in Georgian power system

Generation and consumption

Currently, Georgian power system has installed capacity of 4250 MW and an annual output of 13,200 GWh. Electricity consumption in Georgia is seasonal: the maximum consumption is in winter, indicating that during this period electricity is mainly used for domestic purposes. Demand is being filled by electricity generated by HPPs, thermal power plants and import. However, the ratio of electricity generated by hydropower plants and thermal power plants is 80/20. Accordingly, water is the main source of electricity generation in Georgia. However, in the rivers, the water flow is also seasonal: in summer they have abundant water, and in winter the water level drops down significantly. That is why there is an electricity shortage. The maximum utilization of existing abundant hydro resources is one of Georgia's priority areas, alternative energy sources (wind and solar) are also being worked on. The long-term policy objective of the energy sector is to attract investment for building the new power plants. Part of this policy is to fully meet the country's demand for its own resources step by step: first by replacing imports and then by replacing the thermal power plant.

Current achievements

Training Center – Since 2005, GSE started the training program for students and young engineers. Due to the increased demand of high class professionals, the program transformed to the training center. The training center of such a scale is the first in the South Caucasus region. The center has two main directions:

1. to recruit students of technical direction from the universities and to improve their skills for their future employment at GSE.
2. to maintain and to increase the qualification of GSE employees, especially - operational personnel of national control center and substations. Emergency exercises are held several times a year, with involvement not only GSE, but DSOs and even the neighboring TSO staff as well. Many students from GSE training center are now working on the managerial positions at GSE.

RAS system – The power system of Georgia was planned to be a part of a big united system of Eastern Europe and USSR. After the independence, Georgian power system was separated and the only one 500 kV line was connecting the

main center of generation (Enguri cascade) with the main centers of consumption. In case of outage of each section of this line, the full or partial blackouts were quite frequent in the eastern part of Georgia. Tenth of blackouts might occurred a year. In order to eliminate this emergency situation, in 2011, the first RAS system was implemented in Georgian power system. In case of outage of 500 kV lines from Enguri to Tbilisi, the RAS system was tripping some portion of loads in eastern Georgia and several units at Enguri HPP, in a way to maintain the power flows on weak 220 kV East-West network at permissible ranges and to ensure the unity and stability of Georgian power system. This system almost eliminated the blackout risks of east Georgia. From 2014 up to now and in the future the RAS system expands following to the expansion of the of Georgian transmission network.

Ten Year Network Development Plan (TYNDP) – At first time in the south Caucasus, in April of 2015 the first TYNDP of Georgia was proved by the Ministry of Energy of Georgia with the agreement of Government of the country. The TYNDP was developed by the planning team of GSE. This document was prepared according to the guidelines and the best practices of ENTSO/e, with the consultation of Portuguese TSO REN. It shows in a transparent way the weak points of the system and the future network development to eliminate these points.

Grid Code – The first grid code in the south Caucasus was prepared by GSE and on April of 2014 was approved by the regulatory commission of Georgia (CNERC). It reflects the technical requirements for generation, consumption side as well as for TSO and DSOs, which allow the stability and reliability of power system and high level of transparency. In 2019 with active involvement of GSE and support of the Energy Community, GNERC proved the European (ENTSO/e) connection codes (RfG, DCC and HVDC). The further harmonization works to the other network codes (operational and balancing) are in progress.

NCC – GSE was the first system operator in south Caucasus region which installed the SCADA/EMS system for the NCC. Nowadays this SCADA system is upgrading and the installation of new SCADA/EMS system is in progress.

Akhaltsikhe B2B HVDC station – the first B2B HVDC substation in the region was installed in Georgia near the border of Turkey in order to make possible the power exchange between the countries of south Caucasus (IPS/UPS and AM/IR synchronous zones) and Turkey (CE synchronous zone). The capacity of HVDC is 700 MW.

Main Goals of Georgian Power System Development

The current energy sector can be assessed as a transitional sector. Whose technical capabilities as well as the legal framework are being modernized. The point is that Georgia's energy system was planned as part of a larger unified energy system, so as not to jeopardize the sustainability of this large unified system. Energy legislation and standards were tailored to this system.



Fig. 9.18 Existing and planned Georgian Transmission System 2020–2030

Strengthening and developing technical capabilities is aimed at ensuring security of supply and energy independence. In particular, power plants are being built in this direction, including hydropower plants, wind and solar power plants, so that at any time it is possible to meet the country's electricity consumption with its own sources (this does not exclude the possibility of disconnecting a number of thermal power plants in a given period). In the same direction, the construction of transmission infrastructure is being carried out in order to ensure high reliability of electricity supply from generation sources (including imports) to consumption centers (including exports).

So Georgian power system development has following goals:

- To increase the security of supply and the flexibility
- To achieve the energy independence
- To utilize the transit potential of the country, from east to west (AZ-GE-TR) and North to South (RU-GE-AM-IR)

As for the legislative changes in this area, they are aimed at ensuring the reliability of the country's energy system, as well as harmonization with European legislation.



Fig. 9.19 Generation mix

For the achieving of these plans, there are scheduled to increase the installed capacity of the country from 4245 to 9740 MWs. And to build 1600 km lines and 5000 MW substations.

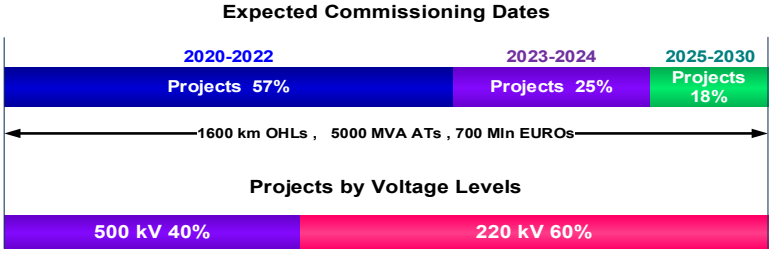


Fig. 9.20 Planned projects by voltage levels

Georgian State Electro-system - GSE

After Georgia gained sovereignty, the process of energy sector rehabilitation started, system was decentralized and several units were separated from Georgian Main Energo. Firstly, it was distribution grid of Tbilisi. Later on, the gen-

eration plants were formed as independent electric power plants. Also, number of energy companies have been established: "Electric Dispatching 2000" LLC, "Electric Transmission" JSC, "Georgian-Russian-Energy 2000" LLC, "Energy Generation" LEPL, "Sakenergo".



Fig. 9.21 GSE Office today

Since 2000, a new phase of the energy sector rehabilitation started, this time with the participation of a foreign company. In 2002, Georgian State Electrosystem Ltd was founded as a result of merge of JSC Electrogadatsema and JSC Electrodispetcherizatsia. During 2003–2007, management rights over Georgian State Electrosystem Ltd were transferred to International Company ESBI INTERNATIONAL. In 2011, Georgian State Electrosystem Ltd was turned into a joint stock company, and state-owned partnership fund became its 100% shareholder.

Nowadays GSE is the only TSO of Georgia. There are two DSOs – Telasi, which serves for Tbilisi distribution and Energo-Pro Georgia – for the rest regions of the country.

GSE is responsible for the planning, operation and maintenance of transmission system of the country. In 2020 GSE got the license of the Balancing Market operator, which allow the country to have enough balancing products, in a transparent and economic way to increase the reliability of the power system.

9.4 References

1. http://energy.gov.ge/energy.php?lang=eng&id_pages=54
2. https://en.wikipedia.org/wiki/Trams_in_Tbilisi
3. http://www.gse.com.ge/sw/static/file/TYNDP_GE-2020–2030_GEO.pdf

10. NC CIGRE GREECE

10.1 History of electric power sector

Electric phenomena have been observed and studied by several philosophers of ancient Greece. They tried to understand and explain many different natural phenomena proposing significant theories by following scientific methods. Among them the ancient Greek philosopher Thales of Miletus (c. 624/623 BC – c. 548/545 BC) observed that a piece of electron (fossilized resin, commonly amber) rubbed on a dry cloth attracts small pieces of straw, introducing the concept of static electricity. Hence, from this historical observation, the term electricity originated.

a) First years: 1880–1920.

Referring to the history of Electricity in Greece, during the period 1889–1920 the first steps were taken to develop public electricity installations and applications. The first laws concerning electricity, such as the establishment and operation of 'electricity or power generation laboratories' and the definition of technical rules for the construction and operation of electrical installations, were published in 1889, 1890 and 1912. In late 1889 the first electricity production unit for public distribution in Aristidou Street, in the center of Athens, was put into operation by the 'General Contracting Company' and the supply of electricity and power for the area enclosed between Omonia Square, Panepistimiou Street, Syntagma Square, Ermou and Athena Streets was undertaken. The palace was the first building to be illuminated. Thus, Athens took the first steps towards electrification, in comparison to the first public power stations in London and New York (Pearl Street Station) which started operating in 1882.

In 1899 the 'Hellenic Electric Company' (HEC) started the development of a central power plant at **Faliro** near Athens and the electrification of Athens and Piraeus railways and trains. In 1901 HEC signed a cooperation agreement with the 'Hellenic Gas Company of Athens', where HEC undertook the development of electricity production and distribution and the Gas Company the commercial exploitation and promotion of electricity. Thus, **in 1915 Athens was one of the**

best illuminated cities in the world. HEC also expanded its activities to provincial cities. Argostoli (Kefalonia) was electrified in 1898, Ermoupoli (Syros) in 1899, Chalkida, Kalamata and some other cities in 1900. Also, by other companies, Lavrio was electrified in 1895 and Zakynthos in 1900. By 1914, 12 cities had been electrified.



Fig. 10.1 Faliro Substation, 1927

During this first period the use of electricity was initially for illumination purposes, which was far superior to gas light. Soon, however, electric consumption was growing with use of electric motion devices, both in electric traction vehicles in cities and generally in industry. All the plants in that period were thermal, while primary energy was supplied by coal, imported from abroad. The wars between 1911–22 i.e. the Balkan wars, World War I and their consequences, limited the rate of electricity growth. Specifically, only 9 new cities were electrified by 1922, resulting to a total number of electrified cities from 1889 to 1922 to 21.

b) Regional electrification: 1920–1950.

After 1922 and until 1929, all cities with a population of more than 5,000 were electrified, while the number of power stations, mostly small power stations with a few tens of kilowatts, amounted to 250 in 1929 and exceeded 380 in 1939. Due to significant technological advances enabled by the development of diesel engines, steam engines were replaced, especially in small installations. Great efforts were made by the laws of 1918 and 1923 to exploit domestic sources of energy, particularly hydropower, and for the first time the concept of 'services of general interest' for electricity activities was introduced. Efforts to promote and organize electricity applications were implemented by law in 1922. In 1932 'rules of indoor electrical installation' were issued, introducing rules of good and safe construction of installations inside buildings.

In 1922 the first hydroelectric power plant on the homonymous river **'Glafkos'** near Patra was put into operation. After renovation by PPC, it is still operating today.

The Attica Region attracted interest of Greek and foreign investors, due to the rapid increase in demand after 1922. In 1925 the State granted the newly established 'General Greek Company', majority owned by British Power and Traction, the exclusive right to produce, distribute and sell electricity, as well as the privilege of installing and operating trams, within a 20 km radius of Omonia Square, and the Athens-Kifissia and Athens-Piraeus railways. The company immediately proceeded with the development of technologically advanced facilities i.e. the construction of a new central power plant in **Keratsini,** close to Athens, and replacement of the old distribution networks. So, while electricity sales in 1926 were 19,345 MWh, in 1930 they amounted to 57,535 MWh. In 1930, as demand continued to grow and new investments were needed, a new company was created, the 'Athens-Piraeus Electric Company' (HEAP), which successfully continued to meet the needs and took measures to expand the use of electricity, especially in the residential sector, thus electricity sales in 1939 reached 188,569 MWh, a 230% increase in nine (9) years.
The Greek province was dominated by HEC, which during the period 1925–1930 undertook the electrification of 11 large provincial cities, acquiring many of the existing small electric companies.

During World War II (1940–1944) the electric companies suffered serious disasters. In 1944 only 120 electric companies were operating, from around 340 in 1939. The re-operation of businesses was slow and in 1949 only 240 companies were in operation. Studies were made during this period on the future power supply of the country by utilizing domestic sources and in particular the use of waterfalls and secondary lignite. In 1948 the country's four-year economic recovery program, with the prospect of funding it from the Marshall Plan, was submitted to the Organization for European Economic Cooperation, which approved it. Subsequently the US Company EBASCO commissioned a study for the first Construction Program 1950–55, which included hydroelectric and thermoelectric projects and the initial construction of a unique 150 kV network to connect all the above-mentioned stations.

c) System Development: 1950–2020

Initial development period 1950–1962

The need to utilize domestic energy resources to electrify the country and create a single interconnected Transmission System led to the creation of a fully state-owned company, the **'Public Power Corporation'** (PPC). The founding law of 1950 stated that PPC should ensure financial self-sufficiency, provide electricity at the lowest possible price, avoid unjustified discrimination between different regions of the country, allocate revenue, in addition to reserves, for the refinement of facilities, improving consumer service and reducing electricity prices. PPC was granted the exclusive privilege of Electricity Generation, Transmission and Distribution throughout the country, with the restriction that the Distribution privilege would not be exercised in areas where it had previously been granted to private or community owned companies. PPC proceeded rapidly with the organization of the company and at the same time with projects execution. In 1955 all major Production and Transmission projects and most of the Distribution projects had been completed. In addition, a second five year Development Program 1956–61 was developed, which included hydroelectric and thermoelectric projects and construction of high voltage and medium voltage lines.



Fig. 10.2 Local Distribution, 1950

The most important event of the period 1956–62 was the law of 1956, by which the State declared the expiry of the licenses of existing electricity companies and extended the privilege of PPC throughout the country. Friendly acquisition of municipal companies and the setting of a single electricity sale price throughout the country were followed. These tariffs were similar to those of HEAP, but significantly lower than tariffs applied in other cities. PPC, following unbiased procedures, quickly organized the inventory and valuation of the facilities of all companies and their gradual acquisition was followed. Thus, by 1962, 379 companies were acquired. In addition to that, PPC organized the distribution units throughout the country by supplying the existing networks from the National System and by the gradual closure of the local power stations. After the takeover, PPC replaced the existing distribution networks with new ones. Finally, a long-term plan was followed for the development of long-distance district networks and the locations of new high-voltage substations were fixed. The significant increase in consumption in the province is a characteristic of PPC's contribution to regional development in the country, enabling industry, craft, small and medium sized enterprises and agriculture to operate on equal terms

and at low prices throughout Greece. Specifically, the per capita consumption (kWh / inhabitant) in Attica and the province was 350 and 16 in 1950, while in 1962 it was 783 and 129, increasing by 124% and 706% respectively.

The period of development 1962–2000

Serious efforts were made to modernize the business throughout this period, both in technical and organizational terms. In particular, the most important facts by sector can be summarized as follows.

Following **Development Programs, A** (1950–55) and **B** (1956–61) mentioned above, similar Programs were issued for the following 5 years with extensions of up to 10 years throughout this period. They referred mainly to large Production projects and partly to Transmission and Distribution, reviewed annually and determined the progress of implementation in order to adequately meet electricity demand. Since the early 1970's Special Transmission System development studies also started to be executed, taking into account Generation Station development plans and Distribution needs assessment for new Substations.

Regarding **Production** for the period 1950–2000, the two main domestic sources of energy, lignite and waterfalls, were developed in parallel. After an inter-country agreement, the entry of Natural Gas in PPC's program in 1987 was a significant event. Also, in the early 1960's, PPC was initially engaged in research into the feasibility of using alternative sources of energy, i.e. nuclear power. Over the years, the prospect of building a Nuclear Power Plant had been canceled and by mid-1970 the prospects for development of Renewable Energy Sources (RES) and especially of wind power emerged.



Fig. 10.3 Aliveri Power Station, 1955

In 1981–82 the construction of two pioneering RES projects, the **Kythnos** project (An oil station with parallel operation of wind turbines, photovoltaics and temporary energy storage) and the **Agia Roumeli** autonomous photovoltaic station in Crete, were undertaken. From 1985, RES generated electricity was also possible by Municipalities and other non-PPC public organizations, with the obligation to sell it to PPC or for self-consumption. RES electricity production by private individuals was allowed by law in 1994, which set sale price and obligation to PPC to purchase this production through feed in tariffs.

During this period the development of the **Transmission System** was completed with various interconnections. In 1975 the first 400 kV lines and 400 / 150 kV Substations were put into operation. Significant modernization steps were also made in the construction of transmission lines and substations. The Union for the Coordination of Production and Transmission of Electricity (UCPTE), which was founded in Paris in 1951, was extended in 1987 to include four countries, among them Greece. The Greek Transmission System operates synchronously with the interconnected European System under the coordination of ENTSO-E, which has undertaken the responsibilities of UCPTE and UCTE since July 2009. This synchronous operation is mainly achieved through Overhead Lines 400 kV, with the Systems of Albania, Bulgaria, North Macedonia and Turkey. In addition, since 2001, the Greek System is asynchronously connected via a 400 kV submarine HVDC connection to Italy. Furthermore, in 1995 a new modern National Control Center was put into operation.



Fig. 10.4 National Transmission, 1961

With regard to the **Distribution Network,** rural electrification was almost completed by 1970. Specifically, **in 1960 the proportion of electrified population was 57%, in 1970 it was 95% and in 1980 around 100%.** By 1975, the new 150 kV Distribution Network was put into operation in Attica, the Distribution Control Center in Attica was upgraded and new Centers were built to improve customer service. Since 1973 a Ripple Remote Control system has been installed in major cities and a night tariff has been introduced. Progress was also made in introducing structures standardization. Existing stations were strengthened in all islands and in most of them new diesel engines were built. The interconnection of the islands with the Continental System was promoted using submarine cables. Especially, all the Ionian Islands were interconnected by 150 kV cables during the decade of 1970. In total there were **77** submarine interconnections of voltage level 15 kV or 20 kV completed with the following figures for every decade: 1960–69 (12), 1970–79 (17), 1980–89 (27), 1990–2000 (17) and 4 after 2000.

PPC's progress during this period is apparent from the data shown in Table 1. The table shows that electricity sales and lignite production in the 40 year period 1960–2000 were increased 30 times, while installed power and distribution networks were increased 20 times.

Table 10.1 Characteristic figures of Power System in Greece

Year	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**
Electrified population	–	57%	95%	99%	100%	100%
Sales (GWH)	472	1422	8358	20065	28337	42491
	0.32	***1.00***	***5.88***	***14.10***	***19.90***	***29.90***
KWh/habitant	88	265	976	2106	2923	4113
	0.33	***1.00***	***3.68***	***7.95***	***11.03***	***15.52***
Installed Power (MW)	–	605	2578	5407	8812	11111
		1.00	***4.26***	***8.94***	***14.56***	***18.36***
Transmission Network (km)	–	1960	4286	6612	9098	10551
		1.00	***2.19***	***3.37***	***4.64***	***5.38***
Distribution Network (x1000 km)	–	9,3	58,5	109,6	151,5	190,2
		1.00	***6.29***	***11.78***	***16.29***	***20.45***
Lignite Production (million tons)	–	2,16	7,64	22,70	49,91	63,31
		1.00	***3.54***	***10.50***	***23.10***	***29.31***

(Italics/bold figures indicate respective percentages as of year 1960)

Open Electricity Market Period 2000 – 2020

The European Union Directive 1996/92, incorporated into a national law (1999), resulted in the market deregulation. **PPC SA** entered the stock market, with 49% private participation. PPC carried out its activities with separate divisions, until new stations were built by Independent Producers and new Suppliers became active in the competitive Wholesale and Retail Market respectively. **The National Regulatory Authority for Energy** was established, setting out the details of the operation of the System and the Market according to competition rules. **The Hellenic Transmission System Operator** (DESMIE SA or HTSO) was also established and its objective was to operate, ensure the maintenance and the development of the Electricity Transmission System and its interconnections with neighboring grids to ensure the country's supply of electricity in a sufficient, safe, cost effective and reliable manner.

The Directive 2009/72/EC, incorporated into a national law (2011), resulted in the re-organization of the electricity market. **The Independent Power Transmission Operator** (ADMIE SA or IPTO) and **Hellenic Electricity Distribution Network Operator** (DEDDIE SA or HEDNO) were established in 2012, both subsidiaries of PPC SA. IPTO, since June 2017, followed the model of Ownership Unbundling and is fully harmonized with the above Directive. HEDNO is independently operational and administratively compliant with all the independence requirements that are incorporated in the above legal framework and an active member of E.DSO. By the same law an **Electricity Market Operator** was created. Finally, in 2018 the **RES & Guarantees of Origin Operator and the Hellenic Energy Exchange** were established.

In the last two decades important and key projects have been implemented or are in progress, such as the Italy Greece Link (2001), Major Projects for the Athens Olympic Games 2004, mainly closed type Distribution Centers, Cyclades Islands Interconnection (2018), Crete small AC Interconnection (2020), National Control Center upgrade and modernization (2020), Target Model for Electricity Market (2020), Crete large DC Interconnection (signed in 2020) and others. Interconnection of major Aegean Islands (South Cyclades, Dodecanese, North Aegean) has been included in IPTO's Ten Year Network Development Plan to be completed before 2030.

During the electrification period but also until now, the contribution from the Electrical Engineering Departments of the Greek Universities and especially from the National Technical University of Athens was significant.

Concluding, some milestones worth mentioning are: electricity principles discovered in ancient Greece, first electrification steps in the contemporary times in parallel with the global community, full electrification for the entire country from early 1970's taking into account the huge number of islands, unique tariffs throughout the country, energy production based mainly in domestic sources, connection to the UCPTE system very early, active contribution to all relevant bodies of the European Union from the beginning, compliance with EU rules and others.

10.2 History of CIGRE in Greece

a) Welcome to CIGRE Greece history

CIGRE Greece is the National Committee and the Greek representative organization of CIGRE, which is the foremost global community for collaborative development and sharing of power system expertise. It is proud to be part of CIGRE's global knowledge program of work and is committed to understanding local conditions in Greece and feeding them into the technical program to find solutions for local challenges, as well as to contribute to the wider community. It is also fostering the local talents and skills, helping its members to be prepared for the future and keeping them informed as regards developments from every place in the CIGRE world. Consequently CIGRE Greece's main task is the link of the Greek power engineering environment with the international floor, the support of the participation of its members in the technical work of CIGRE and the organization of various technical meetings of local interest. **CIGRE Greece** is a scientific organization formally established in 1976 and effective **for at least 44 years.**

To begin with, in 1960, a Liaison Office was created to carry out Greek National CIGRE activities, **until 1976**. This was the first contact between Greek engineers active in the domain of electricity and the international body of CIGRE. This Office was under the auspice of the Greek Electro Technical Union and had Ioannis Flabouriaris as Chairman and Menelaos Levachidis as Secretary. The Greek National Committee for CIGRE **was formally created in 1976,** when the GIGRE requirement for an adequate number of members was fulfilled. Following this period and **until 1989,** the Committee was fostered by the Public Power Corporation, the vertically integrated power utility of the country. It was guided

by a three member Administrative Committee, comprised by Chairman, Vice Chairman and Secretary. The first chairman was prof. Ioannis Tegopoulos. Seven different Administrative Committees were elected during the above period. **In the year 1989,** obtaining a legal form, the CIGRE Greek National Committee was transformed to a **nonprofit scientific organization.** The relevant statute with 22 articles was approved by the Greek Authorities in November 1988 and that scheme is used for its operation until today. It runs an organized office in the center of Athens, with a small library and facilities for members meetings.

b) Present Structure and Governance

The National Committee of CIGRE Greece is guided by a seven member Administrative Council, comprised of Chairman, Vice Chairman, Secretary, Treasurer and three Members. This Council is elected by the Committee members every two years. The Administrative Council is headed by the Chairman, who is elected directly by the members also every two years, and is allowed up to two, two year, terms. From 1989 up to 2020 16 different Administrative Councils were elected.

The CIGRE Greece Administrative Council Members for the years 2019 – 2020 are: Chairman: M. Champakis, Deputy Chairman: K. Mavromatos, Secretary: I. Kabouris, Treasurer: C. Papadopoulos, Members: E. Koroniotakis, I. Margaris, S. Papathanassiou.

c) Our Members

For several years since its creation, the National Committee of CIGRE Greece has more than 80 Individual Members and 20 Collective Members, being at the same time also members of the International CIGRE, according to the relevant article of the statute. Thus the Equivalent Members according to CIGRE rules were around 200. Especially, for the years 2017, 2018 and 2019, CIGRE Greece had 82, 84 and 89 Individual Members **I,** 6, 8 and 10 Individual Members **II** and 24, 24 and 28 Collective Members, respectively. **This results for the years 2017, 2018 and 2019 to Equivalent Members 229, 232 and 262.** According to the CIGRE central office report to the Administrative Council of August 2019, for

the years 2018 and 2019 CIGRE Greece classification according to **Equivalent Members** is in the **11th** and **9th** position in Europe and in the **19th** and **17th** position worldwide. According to the same report CIGRE Greece voting weight for 2019, due to the average equivalent membership for the years 2017 and 2018, which was 231.00, was 2.

d) Young members (NGN)

The **Next Generation Network (NGN) of CIGRE Greece** is a brand-new part of Greek NC, following a decision in March 2019, and seeks students and young professional engineers in order to integrate them into the worldwide scientific community. It tries to inspire and motivate young engineers to take their first steps in a world that constantly changes along with CIGRE as a strong stable guide to be up to date to all the latest developments concerning the power systems, so they become the next power system expertise. Joining NGN CIGRE Greece means access to the world of CIGRE with many resources, participations, opportunities and great benefits. The **1st Next Generation Network Meeting** was organized by CIGRE Greece in November 2019 at the National Technical University of Athens.

e) Awards and Distinctions

CIGRE grants several kinds of distinctions, in recognition of services rendered by members:

- The ***"Distinguished Member"*** award is given to a member for his long-standing services to the organization, upon relevant proposal from the corresponding NC. From the year 1998 up to 2020 this title was given to 19 CIGRE Greece Members, thus the list of Greek Distinguished Members with the appointment year is the following: Ioannis Tegopoulos 1998, Vassilios Papadias 1998, Dimitrios Tsanakas 1998, Michael Papadopoulos 2000, Armandos Rigos 2000, Vassilios Samoilis 2000, Dimosthenis Agoris 2002, Evangelos Dialynas 2002, Georgios Georgantzis 2002, Nikolaos Hatziargyriou 2006, Athanasios Koronides 2006, Costas Papadopoulos 2006, Athanasios Georgopoulos 2014, Dimitrios Michos 2014, Markos Champakis 2016, Konstantinos Mavromatos 2016, Ioannis Kabouris 2018,

Emmanouil Koroniotakis 2018, Stavros Papathanasiou 2020.

- The ***"Technical Council"*** award was given to Nikolaos Hatziargyriou (old SC 38) in 2000, to Stavros Papathanasiou (SC C6) in 2013 and to Thales Papazoglou (SC C2) in 2014.
- The ***"Honorary Member"*** award was given to Nikolaos Hatziargyriou in 2014, chairman of SC C6 for 2009–2014.

Regarding the Greek colleagues, who are or were active in other countries, the following distinctions were given by CIGRE: to Antonios Vlastos from Sweden (old SC 15) the ***"Technical Council"*** award in 1997, to Mania Pavella from Belgium the ***"Distinguished Member"*** award in 2000, to Konstantin Papailiou from Switzerland, chairman of SC B2 for 2010–2016, the ***"Fellow"*** award in 2014, the ***"Honorary Member"*** award in 2016 and the ***"CIGRE Medal"*** in 2020.

The ***"CIGRE Greece Administrative Council Chairman Award"*** is a national award established by the Greek NC of CIGRE in the year 2008, apart from other CIGRE distinctions. It is addressed to a former Chairman of the Committee in recognition of his outstanding work, performance and contribution to the operation and development of the NC during his term and in general his overall activities within CIGRE. This national award is given to **ten former Chairmen,** having this position from 1976 up to 2016 and the names are given in Table 2. Furthermore the key figures of the CIGRE Greece regarding Membership for the year 2019 are given in Table 3.

Table 10.2 Chairmen of CIGRE Greece with respective years of terms and appointment year

Tegopoulos	Ioannis	for years	1976–1979	2008
Papadias	Vassilios	"	1980–1983	2008
Tsanakas	Dimitrios	"	1984–1985 & 1993–1996	2008
Rigos	Armandos	"	1986–1989	2008
Manolopoulos	Emmanouil	"	1990–1992	2008
Agoris	Dimosthenis	"	1997–2000	2008
Dialynas	Evangelos	"	2001–2004	2008
Georgantzis	Georgios	"	2005–2008	2010
Koronides	Athanasios	"	2009–2012	2014
Michos	Dimitrios	"	2013–2016	2018

Table 10.3 Key figures of CIGRE Greece regarding Membership for the year 2019

99	Individual Members
28	Collective Members
1	Member in CIGRE Administrative Council
16	Members in Study Committees (one in each SC)
1	Honorary Member
18	Distinguished Members
262	Equivalent Members leading CIGRE Greece classification to 9th position in Europe



Fig. 10.5 Old banners of CIGRE Greece National Committee for the years 1990 to 2018

10.3 Activities of NC CIGRE Greece

a) Memberships in CIGRE Bodies and Study Committees

CIGRE Greece has one Member in the CIGRE Administrative Council, that is: V. Papadias (1986–2002), D. Agoris (2002–2007), E. Dialynas (2007–2018), M. Champakis (2018–today).

CIGRE Greece has for the years 2018–2020 **16 Members in the Study Committees** of CIGRE (one Member in each SC) and many Members in Advisory Groups, Working Groups, Task Forces, etc., resulting in a strong and uninterrupted participation in the International CIGRE activities (i.e. preparation of Technical Brochures, active participation to Paris Sessions, Colloquia, Symposia and Conferences). From the early years of 2000 more than **10 Members** were involved in the Study Committees of CIGRE.

b) CIGRE Greece Technical Events

In order to achieve its goals, CIGRE Greece has, since 1978, already organized **29 Local Sessions** (18 in Athens, 2 in Thessaloniki, 2 in Patras, 1 in Xanthi, 1 in Crete, 1 in Rhodes, 1 in Volos, 1 in Kozani and 2 in Nicosia Cyprus) in Greek language, most of them with more than 200 participants. CIGRE Greece organizes in November 2020 the **30th National Conference "e-Session 2020",** postponed from its initial date due to COVID19, to be held on-line using a suitable platform. The Sessions are considered as the most prestigious event in the country in the area of Electric Power Engineering. They are 2-day biannual conferences with more than 30 scientific papers from industry, utilities and universities, covering all the contemporary issues, practices, trends and challenges in the field of electrical power systems and giving the opportunity to the authors and the participants to exchange views on a broad area in this field. During the last decades the presence of the **Secretaries General** of CIGRE, who also address the audience at the opening session, honor the venue and declare the strong ties between the international body of CIGRE and the local National Committee and its Members (i.e. **Yves Thomas** in Session Athens 1997, **Marc Herouard** in Session Athens 1999, **Jean Koval** in Sessions Athens 2002, Athens 2005, Athens 2009 and in Colloquium Athens 2008).



Fig. 10.6 Publications of CIGRE Greece



Fig. 10.7 20th CIGRE Greece Session Athens 1999

Furthermore, since 1990, CIGRE Greece has organized **15 Technical Meetings** or **Colloquia** in Greece for transferring and discussing the conclusions taken during the international CIGRE Sessions of the same year with more than 120 participants. Especially, **the Colloquium "Athens 2010"** about conclusions of the 43rd CIGRE Session was carried out with the presence of CIGRE **President Klaus Fröhlich** and General Secretary **Francois Meslier.** Conclusions were presented by the Study Committee Chairmen, who were present for the relevant Technical Council Meeting taken place in November 2010 in Athens. Additionally, **the Colloquium "Athens 2018"** aimed to inform CIGRE members on the important issues that were at the heart of the 47th CIGRE Session in Paris and were of particular interest and importance for Greece. The presentations were given in English by invited speakers, among them CIGRE President **Rob Stephen,** who was Keynote Speaker with the subject "CIGRE strategy and the future grid direction", and current and former SC Chairmen and international experts.

For these 30 Local Conferences, as well as for the 15 Colloquia, CIGRE Greece was publishing proceedings, printed editions in the first years and electronic ones during the last 15 years. Apart from these proceedings, a quarterly Bulletin with all domestic and international CIGRE news from early 1990 to summer 2001 was regularly published.

CIGRE Greece has a strong cooperation with the Technical Chamber of Greece and was **co-organizer** of several local Conferences and other events. Among them the following are worth mentioning: The two days Conference **"The new institutional framework of Electrical Power Systems",** taken place in HELEXPO Thessaloniki Congress Center in April 1998 with more than 35 papers and 400 participants, where the new, at that time, issue of restructuring the sector of electricity and the market opening in Power Systems were thoroughly

discussed. Also with the cooperation of the Technical Chamber of Greece and CIGRE SC A2 and SC D1 the two-day scientific meeting and seminar **"Modern Techniques for the Estimation of the Operational Condition of the Electric Systems Equipment"** took place in Athens in November 2004, focusing on special issues of Power Transformers and Cables.

CIGRE Greece was co-sponsor of the significant and well-established International Conference with the title **"The 8th International Conference on Harmonics and Quality of Power ICHQP"** organized by the National Technical University of Athens in October 1998 in Athens. The conference aimed to provide a forum to share information in the area of harmonics and power quality. CIGRE Greece was also co-sponsor of **"The 12th Intelligent Systems Application to Power Systems Conference ISAP 2003"** organized by DESMIE and NTUA in September 2003 in Lemnos Island, Greece. It was dedicated to discuss innovative solutions in the area of operation, control, planning and maintenance of large interconnected but also isolated or weakly interconnected power systems.

c) CIGRE international activities in Greece

CIGRE Greece has organized the **International Symposium of CIGRE "Athens 2005"** with the very important, for the open electric power market subject "**Power Systems with Dispersed Generation - Technologies, Impacts on Development, Operation and Performances"** during April 2005 in Athens. With **80 contributions** from engineers from more than **25 countries** in the world and **250 participants** in this Symposium, there were extremely interesting and creative discussions, as well as useful and practical conclusions. A welcome address was given by Mr. Jean Kowal, Secretary General of CIGRE.

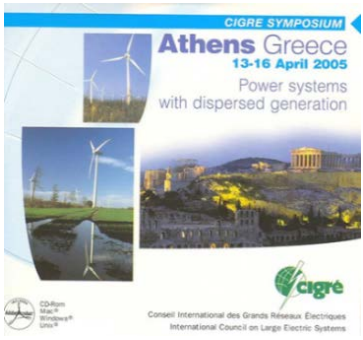




Fig. 10.8 Athens CIGRE Symposium 2005



Fig. 10.9 Venue Athens CIGRE Symposium 2005

Study Committees C1 and C4 annual meetings and corresponding meetings of the associated AGs, WGs and TFs were hosted the days just before the Symposium **"Athens 2005"** in Athens with great success. A few months later, **Study Committee D1 annual meeting** and corresponding meetings of the associated AGs, WGs and TFs were successfully organized during **June 2005 in Crete Island.**

The **CIGRE Technical Council Meeting,** which took place in Athens in November 2010, was a significant event in the history of CIGRE Greece. Taking advantage of this Meeting, TC Chairman Klaus Fröhlich, General Secretary Francois Meslier and the Chairmen of the Study Committees had the opportunity of discussing critical technical issues during the **Colloquium Athens 2010**, which was organized one day before the Technical Council Meeting. The **CIGRE Technical Council spring Meeting** for 2021 is scheduled to be organized in Athens. In the past decades CIGRE Greece has supported several other international CIGRE activities, as **SC Colloquia, WG and Task Force Meetings** in Greece.

d) CIGRE Greece contribution to CIGRE international activities

During the past decades CIGRE Greece had a significant number of allotments for the CIGRE Sessions in Paris, resulting in many contributions by Greek engineers from utilities, universities and industry, with a considerable number of participants. CIGRE Greece has for the 46th (2016), 47th (2018) and 48th (2020) CIGRE Sessions in Paris **5, 5** and **7 allotments,** leading to submission of **5, 7 and 8 papers** respectively (taking into account the joint international papers).

Before CIGRE SEERC establishment, Romanian, Greek and Juko NCs organized the CIGRE Regional Meeting in Romania on **Large regional networks within the Black Sea basin area and the European Interconnection in the third millennium** in 2001.
CIGRE Greece joined SEERC in 2014 and since then has strong connections and permanent bonds. It has a significant involvement in all three Conferences i.e. Portoroz, Slovenia 2016, Kyiv, Ukraine 2018 and Vienna, Austria 2020 (scheduled for November 2020). It has also organized the **2nd SEERC TAC** Meeting in January 2016 and the **6th SEERC TAC** Meeting in January 2020, both in Athens with broad participation and great success. The later was accompanied by the **Workshop Athens 2020** with the subject "TSO & DSO Interaction in operation and planning".



Fig. 10.10 CIGRE Greece Session Athens 2015



Fig. 10.11 CIGRE Colloquium Athens 2018



Fig. 10.12 SEERC 2th TAC Meeting in Athens, 2016



Fig. 10.13 SEERC 6th TAC Meeting in Athens 2020

Table 10.4 CIGRE Greece attendance and number of papers in CIGRE Paris Sessions

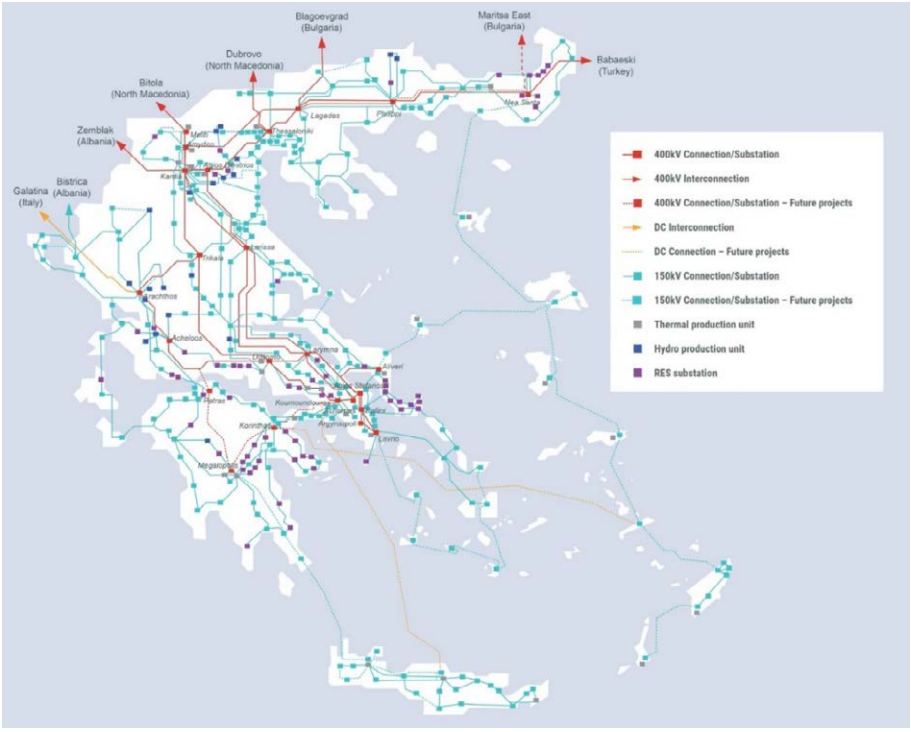
	Year	Number of Partici-pants	Number of Papers	Papers via National Allotment	Joint International Papers
36th Session	1996	17	1	1	
37th Session	1998	18	1	1	
38th Session	2000	20	5	3	2
39th Session	2002	27	7	3	4
40th Session	2004	25	6	5	1
41st Session	2006	10	7	5	2
42nd Session	2008	12	5	3	2
43rd Session	2010	11	5	5	
44th Session	2012	10	5	5	
45th Session	2014	11	4	3	1
46th Session	2016	10	5	5	
47th Session	2018	16	7	5	2

e) CIGRE Greece website

CIGRE Greece operates the internet website www.cigre.gr according to the format and specifications of international CIGRE. On the home page and under the field CIGRE Greece one can find the categories Introduction, Structure and Governance, People and Contacts, Our Members, Young Members (NGN),

Awards and Distinctions and finally News, including a lot of information and details regarding our NC evolution through the years. In the field Events all the past and upcoming events are explicitly presented.

Map of the interconnected high voltage grid of Greece for 2020



(Courtesy of IPTO)

10.4 Country electric power profile for 2019

Consumption: 57,700 (GWh)

(52,174 GWh in the Continental part + ~5,500 GWh in non - interconnected islands)

Amount of household consumption in %: **~30%**

Seasonal Peak load: **9,634** (MW) for Summer (July); **9,411** (MW) for Winter (January)

Population: **10,815,197** according to the latest (2011) census estimates

Generation: Installed capacity 19,029 (MW) Annual production 42,470 (GWh)

Thermal

- Nuclear **0** MW/ **0** GWh
- Gas **4,567** MW/ **15,946** GWh
- Coal **3,904** MW/ **10,418** GWh
- Other **334** MW/ **1,158** GWh (Large CHP plant)

Hydro

- Hydro / run of river 240 MW/ 690 GWh
- Hydro / (pump) storage, generation 3,171 MW/ 3,363 GWh (includes generation from pump units)
- Hydro / pump storage, pumping **699** MW/ **73** GWh (pumping load)

Renewables

- Wind 3,283 MW/ 6,566 GWh
- Solar (PV) 2,639 MW/ 3,707 GWh
- Other RES 192 MW/ 549 GWh

Transmission overhead lines and cables: 150 kV (AC), 400 kV (AC) and 400 kV (DC)

Circuit length for all transmission AC and DC voltage levels: **17,172 km**

Overhead lines length for all AC transmission voltage levels:

10,935 km (in operation)

11,108 km (installed)

Underground/sea cables length for all AC transmission voltage levels:

879 km (in operation)

900 km (installed)

Overhead lines length for all DC transmission voltage levels: **107 km**

Underground/sea cables length for all DC transmission voltage levels: **0 km**

HV Back to Back stations: 0 number of units, 0 MW, total installed capacity

Power Transmission Transformers:

60 Autotransformers (400/150kV)

602 Transformers (150/20kV)

Distribution Network: 0.4 kV (AC), 15 kV (AC), 20 kV (AC)
Circuit length for all distribution voltage levels: **240,186 km**
Distribution transformers (0.4 – 100 kV): **164,552** number of units
Approximated employees' average number in Electricity Supply Industry: **~30,000**

10.5 References

1. Establishment & development of PPC, M. Papadopoulos, Kathimerini, 15 April 2018, p. 26.
2. PPC, the route for period 1975–2000, M. Papadopoulos, Kathimerini r, 22 April 2018, p. 26.
3. History of Electric Energy Sector in Greece, invited speaker M. Papadopoulos, 28th CIGRE Greece Session Athens 2015, 9 & 10 December 2015.
4. The miracle of electrification in Greece, Liagou, Kathimerini, special edition Feb. 2011.
5. N. Pantelakis, the electrification of Greece, from the individual initiative in the state monopoly (1889–1956), Educational Institution of the National Bank of Greece, 1991.
6. UCPTE/UCTE - The 50 Year Success Story - Evolution of a European Interconnected Grid, Secretariat of UCTE, Boulevard Saint-Michel 15, B-1040 Brussels.
7. Official sites of Greek companies: PPC SA, RAE, DESMIE SA, LAGIE SA, IPTO or ADMIE SA, HEDNO or DEDDIE SA, HEnEx SA.
8. Technical Chamber of Greece, weekly Newsletter, announcements and conclusions of CIGRE Greece various events, sessions and colloquia, No 1482, 1587, 1590, 1631, 1692, 1735, 1743, 1795, 1805, 1809, 1831, 1880, 1881, 1907, 1923, 1925, 1926, 1927, 1929, 1930, 1959, 1967, 1968, 1972, 1975, 1978, 1979, 1980, 1990, 1996, 1997, 2001, 2002, 2025, 2038, 2048, 2049, 2077, 2101, 2127, 2192, 2193, 2242, 2316, 2337, from year 1987 up to year 2005.
9. CIGRE Greece, presentation during 41st CIGRE Session, G. Georgantzis, Paris, 2006.
10. CIGRE SEERC 9th MB Meeting in Tbilisi 'Announcement of the 6th TAC meeting and workshop in Athens in January 2020', presentation M. Champakis, G. Georgantzis.
11. Activity report of 2017 of CIGRE National Committee of Greece on CIGRE KMS.
12. The 18th Conference of the Greek National Committee for CIGRE concluded successfully its works, ELECTRA No 177, April 1998, pages 48–51.
13. The 20th Conference Athens 99 concluded with success with the presence of the Secretary General Mr. Marc Herouard, ELECTRA No 191, August 2000, pages 9–11.
14. Official site of CIGRE Greece.

For further information contact:
NC CIGRE Greece
45, Pireos Str., 105 53 Athens
Greece
www.cigre.gr

11. NC CIGRE ITALY

11.1 History of the Electric Power sector in Italy

A short vision of the history of the electrical sector in Italy can be divided into three phases: the first pioneering before 1880 and characterized by personalities of scientific creativity among which :

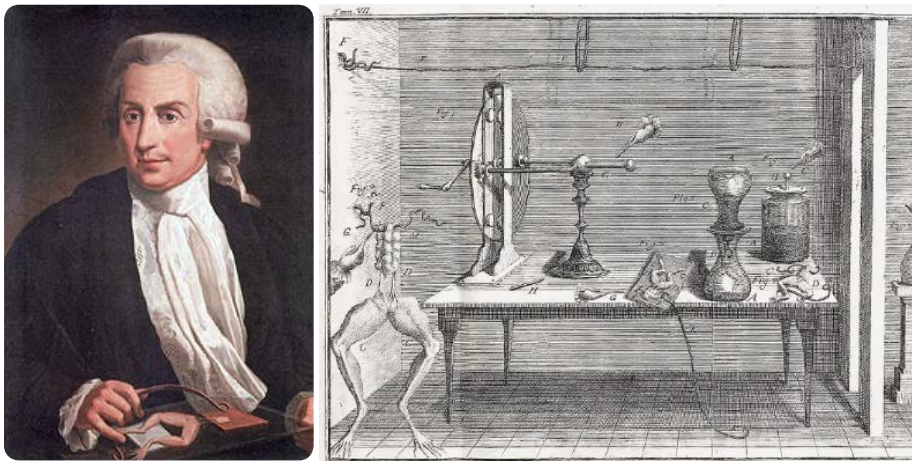


Fig. 11.1 Luigi Galvani

Luigi Galvani (1737–1798), physiologist and physicist remembered for the discovery of biological electricity and some of its applications such as the chemical battery and the galvanometer. Famous is the dispute between Volta and Galvani on the origin of animal electricity that guided many scholars of the physical sciences on electrical and magnetic phenomena.



Fig. 11.2 Alessandro Volta

Alessandro Volta (1745–1827) Inventor in 1780 of the electric capacitor and in 1799 of the first electric generator: the battery. In 1801 Volta presented his invention to Napoleon Bonaparte by reading his "Memory on the identity of the electric fluid with the so-called Galvanic fluid". His name is given to the unit of measurement of voltage: Volt. Volta used for the first time the concept of electric voltage to account for the properties of electricity.



Fig. 11.3 Antonio Pacinotti

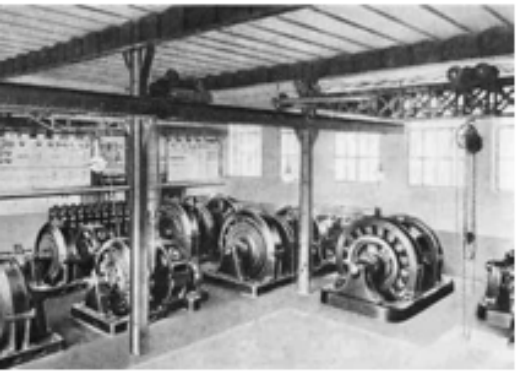
Another important figure was **Antonio Pacinotti** (1841–1912) inventor of the ring that bears his name and that gave origin to the dynamo and the direct current motor.

In 1869 Gramme patented a generating machine in which the pacinotti ring was a fundamental component and at the beginning of the 70s he began to produce his own dynamo industrially, quickly becoming one of the main manufacturers of electric machines in the world.

The activity of the Tecnomasio Milanese of Bartolomeo Cabella, who in 1876 realized the first experiences of electric lighting in Piazza del Duomo in Milan, is very important.

The second phase is characterized by the International Electricity Exhibitions, with the turning point of the 1881 Paris Exhibition, where Edison's lighting system was launched, which was an important event for the development of Italian and European Electrotechnics. The number of Italian exhibitors was the fifth largest with 81 participants behind France, Belgium, Germany and the United Kingdom.

It was after the exhibition that G.Colombo and a group of his Lombard companions decided to build the first Italian coal-fired power plant which was inaugurated in Via Santa Radegonda in Milan in mid 1883, allowing the electrification of the city centre to begin. The plant was equipped with 6 electric dynamo machines with steam generators with boilers of 160 hp each with 8 atmospheres.



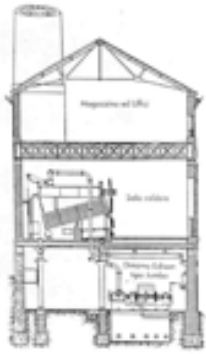


Fig. 11.4 June 1883, Santa Radegonda Coal Power Station



Fig. 11.5 Giuseppe Calombo

The Teatro alla Scala (2640 lamps) was also connected to the power station. A few months later in 1884 Colombo founded the Edison Company.



Fig. 11.6 Galileo Ferraris

The real birth of the Italian electrical industry was due to the work of **Galileo Ferraris** (1847–1897). In the International Electricity Exhibition of 1884 in Turin, Gaulard and Gibbs presented the transformer. Ferraris studied it in depth and in a paper ,presented at the end of 1884 at the Academy of Sciences in Turin, he defined the fundamental principles of operation of the transformer, highlighting losses due to hysteresis and eddy currents and calculating the efficiency that allowed the acquisition of the modern expression of alternate current electric power with reference to the phase shift between current and voltage.

Its most important discovery took place in 1885 with the rotating field motor, when the first prototype of the motor was made in 1885 and other models in 1886.

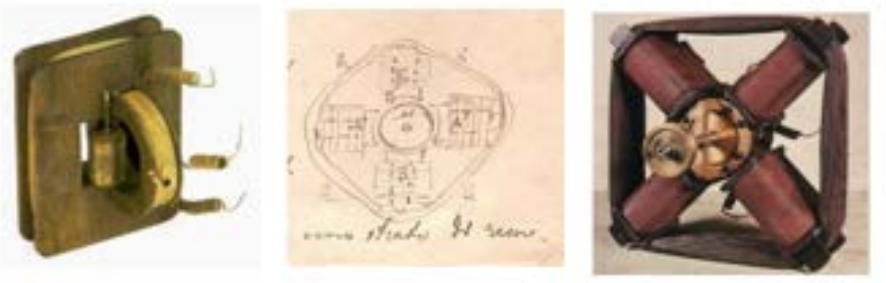


Fig. 11.7 First Prototype, Drawing and Model Rotating Motor



Fig. 11.8 The International Electrical Congres in Chicago in 1893

He participated as vice-president at the Congress of Electricians in Chicago in 1893 invited by Alva Edison and contributed to the definitions of the units of electrical measures: joule,watt and henry adopted on the proposal of G. Ferraris.
He was appointed Senator of the Kingdom in 1896.
On February 7, 1897, at less than 50 years of age, he died in Turin.

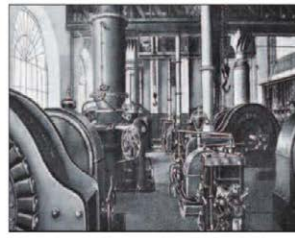
The third phase between the 1890s and 1920 saw the development of all the technologies of Power Electrical Systems: transmission lines reaching 80 kV in 1919, hydroelectric and coal-fired power plants.
The production of electricity in Italy increased from 1.8 million kWh in 1884 to 2 billion kWh in 1912 with an installed capacity of 960 MW. The existing electricity companies in 1913 reached 251.
Two other designers who subsequently gave a contribution to CIGRE were R. Norsa and G. Semenza.
R. Norsa was part of a large group of designers who intervened not only in the scientific field but also in the public debate e.g. in the "Rivista La Riforma Sociale" to promote electricity in various industrial fields.
Norsa was in charge of the electrical machinery of the Hydroelectric Power Plant of Acquoria that had allowed the city of Tivoli to have its streets lit and that would have allowed G. Mengarini director of the Anglo-Roman Company to transport in 1892 in the capital the electrical energy produced through the 5.1 kV Tivoli-Rome Line, the first commercial OHL in Europe



SS Rome Porta Pia



Tivoli - Rome OHL



Acquoria HPP

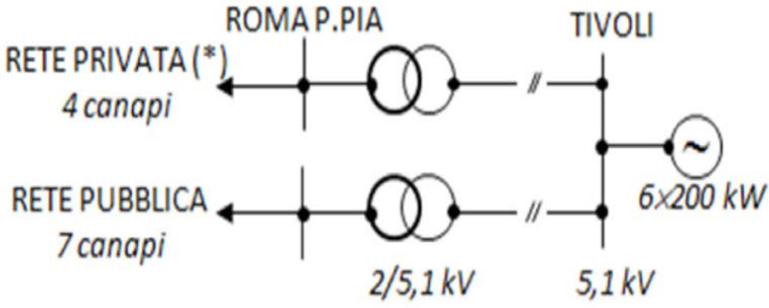




Fig. 11.9 G. Semenza

G. Semenza from 1895 worked at Edison where he reached the position of Technical Director and became consultant to many other industries; with G. Ferraris and C. Brown, Swiss manufacturer of generators, he followed the project of the 13.5 kV Paderno-Milan line (length 32785 m). From the beginning he dealt with the problem of insulation and protection of power lines, designing various types of insulators then built by Richard Ginori, Semenza also cared about railway electrification as he wrote in 1918.

The line connected the "Bertini" hydroelectric power plant of the Edison Group and one of the oldest in Italy in Milan. When it was inaugurated in September 1898, the Bertini was the largest electric plant in Europe and the second in the world.

The plant then set a series of technological records: it was the most powerful hydroelectric power plant in Europe and second in the world only to that of Niagara Falls.

The main purpose of the construction of the plant was to have sufficient power and energy to electrify Milan's tramway network, a public service that Edison had taken over from the Municipality.

On December 19, 1898, the last line still served by horses, that of Porta Ticinese, was run by electric trams: Milan was one of the first European cities entirely converted to electric traction.

11.2 History of Italian contribution in development of CIGRE

The years 1921–1929 Born of Large Electrical Networks

A dry winter following a hot summer in 1921–22 led to a drought which seriously hindered hydroelectricity production in Italy. In the Po Valley this forced local administrators to take immediate action: The provinces of Piedmont Lombardy and Venice (in which most italian industries were located) appointed special commissioners to ration the few available energy between the different industries.

To compund the scarce available resources, electric power was also imported from Switzerland this was possible as some transmission lines already crossed Italian-Swiss border at this time. Power Producers suppliers in France were also involved: french coal-fired power plants in Nancy and Vincey supplied

electricity to Zurich in Switzerland and eventually to the north of Lombardy. The special commissioner for Lombardy, the milanese engineer Angelo Omedeo, reported that the transmission of electric power avoided consequent a widespread shutdown of factories due to the energy scarsity (Vincent Lagendijk *"Electrifyng Europe: the power of Europe in the construction of electricity networks"* ed.TU/E January 2008).

The CIGRE was born in 1921, as many European electrical engineers recognised the benefits of interconnections between existing electricity networks of different countries.
Italy has participated in the CIGRE since its origins in 1921 when its 1th Conference was held in Paris in November. For Italy, U. Del Buono, R. Norsa, and G. Semenza participated.
Del Buono and Norsa dealt with the mechanical stability, power losses and voltage drops of power lines including AEM's Grosotto-Milan line in Valtellina, which in addition to its length, involved high mountain sections that posed completely new problems due to snow and ice loads. Del Buono wrote in 1915 in the magazine Elettrotecnica an article on "Italian personnel in the Italian industry".
Between 1921 and 1929 as shown in Appendix of this chapter, the CIGRE had a continuous development and Italy always participated with its delegates in the general sessions that at that time took place in odd-numbered years. These were years of strengthening of the Italian industry and consequently of the electricity Grid.

The 2th CIGRE Conference in 1923 was attended by 150 delegates representing 20 nations Italy was represented by the General President of the AEI Ing. Del Buono, who was also elected Vice-president of the assembly, by the engineer Semenza president of the CEI (Italian Electrotechnical Committee) and by 11 other delegates. in particular, the conference was divided into three sections with various topics to deal with

- Energy Production and Transformation (electrical substations , oil switches);
- Line construction (mechanical resistance and testing of line components, ageing insulators, underground cables);
- Operation and safety of large networks (regulation, standardization of voltages, service statistics, neutral grounding).

The first topic dealt with the introduction of switched and opportunity of installing outdoor substations.
The second one included , the contribution of engineer Cangia on "Standard piling for large energy transports". Italy with a group of new lines with a rated voltage exceeding 100 kV had, at that time, reached the largest countries in the world.



Fig. 11.10 A. Barbagelata

In the third section Vannotti intervened by recalling the voltage scale that according to the CEI should be referred primarily to equipment rather than systems.
In this conference, needs for a new international committee was already raised.
At the end of the activities, delegates chosen among the representatives of the various nations were officially received at the Elysée by the President of the French Republic. The Italian delegates, in addition to the Chairman Del Buono and Soleri of the AEI included also the delegates of the Italian Elettrotechnical Committee (CEI): G. Semenza and A. Barbagelata.

The **3th CIGRE Conference in 192**5 was characterized by a large participation with 98 contributions. Italy presented 15. The Italian group with 30 participants was the most numerous after the French one. Also in this occasion Italy and its head of delegation AEI General President Prof. Sartori was assigned the Vice-Presidency.
In the first part of the conference Barbagelata and Soldini presented a report on *"The Selectivity in overcurrent protection systems"*.
The criterion of the three sections, already seen at 1923 conference, was maintained and the following interventions were made on the Italian side:
In the first Section (Production and transformation of energy) Sartori and Calzoni presented *"A new synchronization selector"* while Pellizzari presented Soldini's report on *"Interconnection of large networks at different frequencies"*. In the second Section (Construction of the lines) Carcano and Romagnoli presented a memory on *"Large crossings of the Po"* while Emanueli reported on *"The experimental 135 kV cable"* that had entered production for an installation in North America. Finally, in the third section, Faccioli's intervention dealt with on the

behaviour of the waves on the circuits with the experiments he carried out in the laboratories of Ge.El.Co. with 2 million volt discharges aimed at reproducing the phenomena due to atmospheric discharges.

In the **4th CIGRE Conference of 1927,** with 527 participants and 77 papers, Italy participated with only 1 paper presented by Montagni, while the Italian delegation included 8 representatives with Del Buono as head of the Italian delegation who was appointed Honorary Vice President of the Conference .
In the second section of the works, the report on the problems related to the main transmission line poles and the quality of steel required for the profiles with regard to brittleness and therefore the tests of resilience deserves a mention. During the discussion, Del Buono intervened while Montagni presented his contribution *"On the reinforced concrete centrifuged poles for the 220 kV line from Cardano (Trentino) to Milan".*
During the 4th session , the use of fossil fuel was firstly discusses, as a complementary source for hydro generation. In this 4th conference the participating nations were also asked to create National Committees through which to convey the reports of the authors.

In the **5th CIGRE Conference of 1929** Italian participation marked a remarkable recovery with 40 members and 7 between reports and papers. The head of the Italian delegation was A. Taccani of the National Research Council (CNR).
In the work of the three sections, it is worth mentioning the intervention G. Silva on the parallel operation of large power grids and on the recovery of service following an interruption and another paper on the mechanical calculation of overhead lines based on the catenary law.
Another topic of interest is the one reported by the Japanese committee on the problems deriving from the snow load that is deposited on the lines and the system adopted to eliminate them consisting in heating the lines by short circuiting them with a convenient current. This was already practiced in Italy, since many years in many alpine OHLs.
During the presentations the importance of the cinematograph was affirmed as a valuable research and laboratory tool thanks to the acquisition of 600 images per second that by slowing down 40 times allows to dilate the phenomena that occur in 1 second in a time of 40 seconds, typical phenomena of the electrical sector.

The years 1931–1939 The Great Depression and the Second World War

The Sixth CIGRE Conference in 1931 was affected by the Great Economic Depression that hit the world economy. Nevertheless, the total number of participants exceeded the previous ones, while the Italian delegation was 17 members against 40 of the previous edition. The direction of the Italian delegation was taken by Barbagelata, who also assumed the role of Vice-President of the Session, while Del Buono, in addition to being honorary Vice-President, also assumed the Presidency of the study committee *"Neutral grounding"*, while Ing. Roncaldier will be the President of the committee *"Parallel operation"*.

It was during this Conference, 10 years after the first one, that it was decided to transform the Conference into the legal form of a non-profit association, with individual and collective members. The conference was also modified with special speakers on related topics, creating study committees.

Among these, the possibility of bulk energy transmission over long distances using DC system was firstly addressed in this session. Schjolberg and Heriksen dealt with the possibility bulk energy transmission from Sweden to Belgium and France.

The Italian Committee presented two contributions: *"The 125 kV Cismon-Porto Marghera 125 kV line" and "The 220 kV Cardano-Cislago 220 kV line (S.I.P. Group), both with centrifuged reinforced concrete poles"* (Montagni and Silva respectively).

Del Buono, the chairman of the committee, has pointed out that the good functioning of the extra high voltage networks with solidly grounded neutral has become an established fact whose advantages cannot be denied.

A. Barbagelata was a special speaker in the Measurements committee, while in the Parallel operation committee G. Silva described the various economic systems for voltage measurement and synchronisations.The conclusions highlighted an increasingly extensive parallel running of the networks.



Fig. 11.11 L. Emanueli

The **7th CIGRE Session of 1933** despite the world crisis and the pessimistic forecasts, however, marked a high number of participants and nations represented with an equally important number of papers.

The Italian delegation was led by the AEI General President Ing. L. Emanueli.

It was characterized by the large delegation from Germany that had attended the CIGRE sessions for the first time.

Only two papers were presented, but the delegation was reserved for the Presidency of Cables and Lines.
In the insulated cables study committee, L. Emanueli described the characteristics of the experimental installation of a 220 kV self contained oil filled (SCOF) installed on the 220 kV line at Cislago. The Pirelli Cables also described insulated cable connection (50 km long, 66 kV) between the South Dock Power Station and the city of La Plata.
In the Measuring Instruments Committee, A. Barbagelata described the tests on the high voltage gearboxes, the method due to Prof. Bottani derived from the theory that studies the transducers using a single-phase transformer to take into account the capacitance currents, while Crivellari described *"The short-circuit and load tests on 4-wound transformers"*.
The DC transmission committee focused on bulk power transmission over long distances; a possible link between Norway and France was discussed, with a rated voltage between 750 and 1000 kV, using overhead lines and underground cables.

The **8th CIGRE Session of 1935** exceeded the number of partecipants and papers of the previous conferences.
Italy presented two papers signed by A. M. Angelini on *"Voltage variations on alternating current networks"* and *"A device for their rapid determination"* while the second one by M. Artini described the Results of a survey carried out in Italy that classified the ice formations providing a useful tool to increase the resilience of the lines subjected to this phenomenon.
G. Silva partecipated to the second section of the session, in particular dealing with the "calculation of overhead lines" committee.

The **9th CIGRE Session took place from 24 June to 4 July 1937** and maintained a high number of participants with a slight decrease in the total number of papers presented but with 10 from Italy.
The Italian delegation led by A. Barbagelata (representing CNR, AEI, CEI), G. Silva (Unfiel) and Virgili per le FF.SS. (Italian Railways System) was composed by 38 members among which we remember among others Del Buono, A. M. Angelini, L. Emanueli, C. Pramaggiore.
In an increasingly difficult political context, the conference was a useful event to strengthen the bonds of friendship between the participating technicians demonstrating how the High Voltage grid could not ignore the interconnections between the various nations.

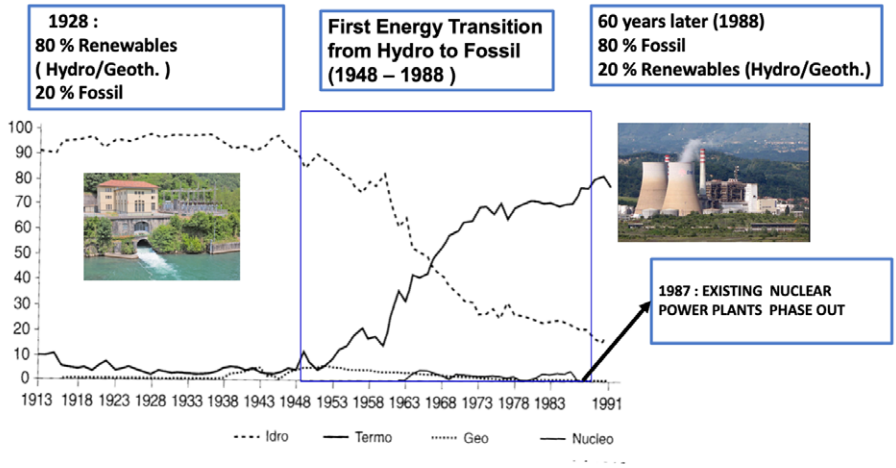
Also on this occasion about twenty delegates from the main nations (including Italy) were received by the President of the French Republic, Mr. Lebrun.
In the technical field Italy stood out in particular :

- in the Measurements committee with 4 papers on improvements and applications of cathodic oscillographs, measurement methods and new devices;
- in the Switches committee with 2 papers on the tests for switches and the CEI standard.
- in the Transformers committee with 1 paper on the test of mercury vapour transformer-rectifier groups

In the OHL committee (2 Italian memoirs) the Italian paper of Pessano dealt with the theme *"On the inconveniences that occur in the power lines near the sea"* a theme still today of the uttermost importance.
In 1939 the Second World War began, the papers of the 10th CIGRE Session were published only in 1940 and the CIGRE ceased its activities, but thanks to E. Mercier, it still had a minimal central structure in Paris to be ready to restart after the end of conflict.
All European nations were suffering from countless damages to the electricity grids and main infrastructures: transformers, control centres, power stations which were the target of war actions and whose reconstruction took a long time and large amounts of money (see Chapter 5 in reference 12.5).

SESSIONI GENERALI CIGRE NEL PERIODO 1921-1939 and Italian Delegates and papers presented				
ANNO	Nazioni	Partecipanti	Papers	Italy Delegates/Papers
1921	12	54	64	3/3
1923	20	394	49	12/7
1925	27	357	99	30/15
1927	28	527	77	8/1
1929	27	703	75	40/5
1931	36	738	100	17/6
1933	30	751	131	15/4
1935	43	900	176	9/2
1937	48	871	119	34/8
1939	38	814	116	6/5

The years 1946 - 1988: From Nationalisation to the First Energy Transition: from Hydroelectric to Fossil



In Italy from 1946 to 1988 two important events characterised the Electricity Grid: the first was nationalisation with the creation of ENEL in 1964 (as happened in the United Kingdom with CEGB and in France with EdF) and the second was the First Energy Transition which, as shown in figure above brought the percentage of renewable generation (hydroelectric and geothermal) from 80% in 1928 to 20% in 1988 and the percentage of fossil fuels (20% in 1928) to 80% in 1988.
The first transition started in 1948 after the Second World War and ended in 1988 after about 40 years.
The first driver was Marshall Plan with the related ERP funds that allowed the construction of 14 thermoelectric units for a total of 836.5 MW and then continued with the construction of units using domestic coal and lignite.The second driver was the technical progress in thermoelectric power plants,which allowed the construction of large size units (namely the standard 320 and 660 MW coal and oil fired ENEL units).

The 11th CIGRE Session was in 1946 after 7 years of interruption; it was decided to anticipate it in an even year, instead of 1947, and all the subsequent general session were held in even years till the 2020 coronavirus pandemic. The Session was a success with 26 Nations represented and 900 delegates of which 20 Italians with heads of delegation A. Barbagelata and G. Silva; more than 100 papers were presented, 9 of which were Italian. Among the topics we must highlight

the one related to machinery with a tendency to units and groups of increasing power (of the order of 100 MW) and with related excitation systems (treated also by the Eng. Santuari). As always in the field of cables, homage was paid to L. Emanueli who was unable to participate.

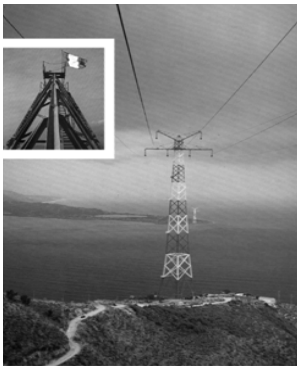


Fig. 11.12 OHL Crossing Messina Strait

In **1948 the 12th CIGRE Session** was held with 1300 participants and 30 nations represented; the papers sent were more than 120; Italy participated with more than 50 members with head of delegation Prof. Visentini of the Superior Council of the LLPP (Public Works) and 9 papers among them as well as those on transformers, synchronous machines and auxiliary services of power plants treated by A. M. Angelini and Brambilla, Silva's paper dealt with the Messina Strait Crossing project and Bianchi's paper by SAE, who presented a report on a new type of lighter and cheaper 220 kV Tower.
Another topic was the one presented by A. M. Dalla Verde on the modifications to existing lines to increase the operating voltage in relation to the progressive reduction of safety margins as a result of knowledge acquired on electrical, meteorological and resistance of materials.

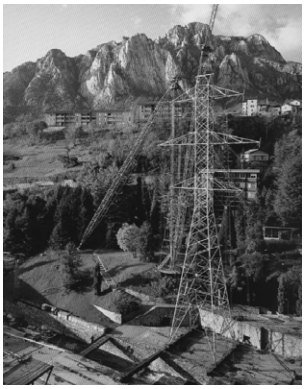


Fig. 11.13 OHL Test facililty Lecco

In **1950 13th CIGRE Session** (which at that time over 1400 permanent members) had 1200 participants with 39 nations represented; the papers presented were 144. Italy was represented by 67 subscribers and 10 papers; the Italian technicians distinguished themselves, as will often happen later on the projects of overhead lines combining research and tests (in figure the SAE test facility at Garabuso in Lecco first in Europe outside the United Kingdom);
in the same session was presented SAE project of the Strait of Messina with span crossing 3.646 meters; mechanical calculation of the towers (weight 500 t and 224 meter high), in relation to the stresses of seismic and wind power.
The project was presented by Caminiti. Construction began in 1952 and led to commissioning in December 1955.

In the following years the Italian presence in CIGRE was consolidated more and more. From 1952 to 1988 first with a strong presence of private electrical companies (Edison, SAE, Ansaldo) and research and testing centers: CESI was born in 1956 and became a laboratory at the service of the electromechanical industry, Universities and Polytechnics, then from 1962 ENEL, established after the nationalization of the electricity sector, took an active part in the CIGRE works. Italian companies such as Pirelli, Ansaldo, Edison, made important contributions on all electrical systems and components during CIGRE General Sessions. Since 1951, CIGRE has been of impressive importance with over 1600 permanent members from 40 countries, 32 National Committees and 15 Study Committees and with participation in the sessions involving thousands of engineers from 5 continents.
In the following we will focus on the salient aspects of the history of the Italian NC and the contribution given to the CIGRE.



Fig. 11.14 G. Silva

From 1957 to 1966 the contribution reached the very top of the Association with nomination **Chairman CIGRE of G. Silva** that we have seen in previous years assiduously participating in the various general sessions.
After the war in 1945 he became adviser and general manager of CONIEL (Compagnia Nazionale Imprese Elettriche) continuing the project of Messina Streat crossing.

In 1954 he presented the *"Abacus for the mechanical calculation of overhead line conductors"* during the **15th CIGRE General Session** in Paris.
At the same time the research and costruction of the 380 kV network started. This contributed on the Italian side, at CIGRE level, in sending studies and papers not only in general sessions, but also from 1966 to the Colloquia that the various SCs organized.
One of the major technical figures of this period was Prof. Luigi Paris who joined Edison in 1950 and worked at ENEL between 1963 and 1982.He was also the CEO of CESI and then Professor until 1998. Paris was one of the main protagonists of the development of the Italian 380 kV network.
He was responsible for the construction of the first 380 kV Edisonvolta Mese-Bovisio line of 90 km which permitted strong interconnection with Switzerland.

For the mountain section that reached 1800 m altitude, used a single Al/A conductor with a 50 mm diameter cable (ANACONDA conductor) patented by Edison-Falck; On the experimental line prior to construction, measurements were also made on the corona effect for both leakage and radio disturbances that were the subject of a CIGRE paper during **16th CIGRE Session in 1956.**

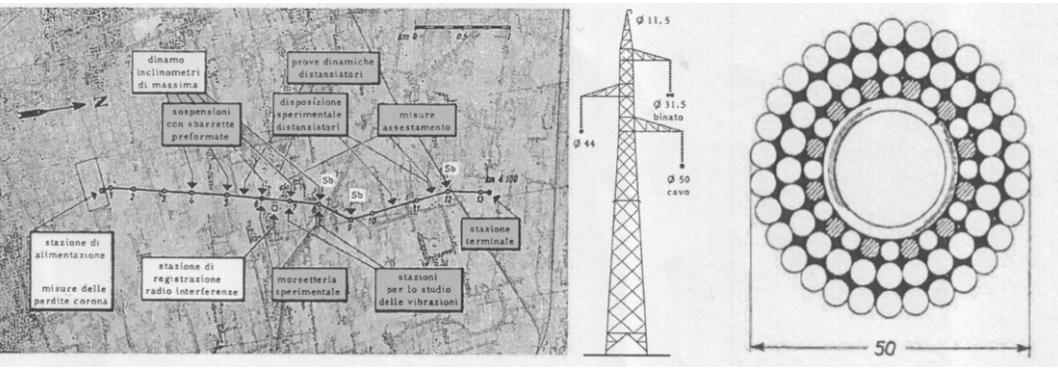


Fig. 11.15 OHL Field Test and Conductor Anaconda ø 50 mm

In the same session he presented also paper on *"Investigations of the Stringinging and Tensioning of Conductors on E.H.V. Lines"* adopted for the construction of the OHL completing studies also in the erection field.
Always as main author presented in the **17th CIGRE Session of 1958,** *"The study of reduced models in the field of HV overhead lines for the evaluation of dynamic phenomena caused by ice due to both conductor breakage and overload detachment".*

In **the 21th CIGRE Session in 1966** he presented a report *"Contribution to the Study of Insulation Coordination from a Probabilistic Point of View".*
In the '60s another important goal was reached in Italy. The company Carbosarda decided to use the coal extracted from the Sulcis mines in a coal-fired power plant to be built in the south of Sardinia (2 groups of 250 MW each), so it became necessary to build a submarine interconnection between Sardinia and Italy. The construction and commissioning of the Sardinia-Corsica-Italy (SaCoI) was completed in 1967. The link (total lengh 413 km: 121 km sea cables and 292 km dc OHL) had a rated power of 200 MW and a rated voltage of 200 kV. It used line commutated converter with mercury arc valves.

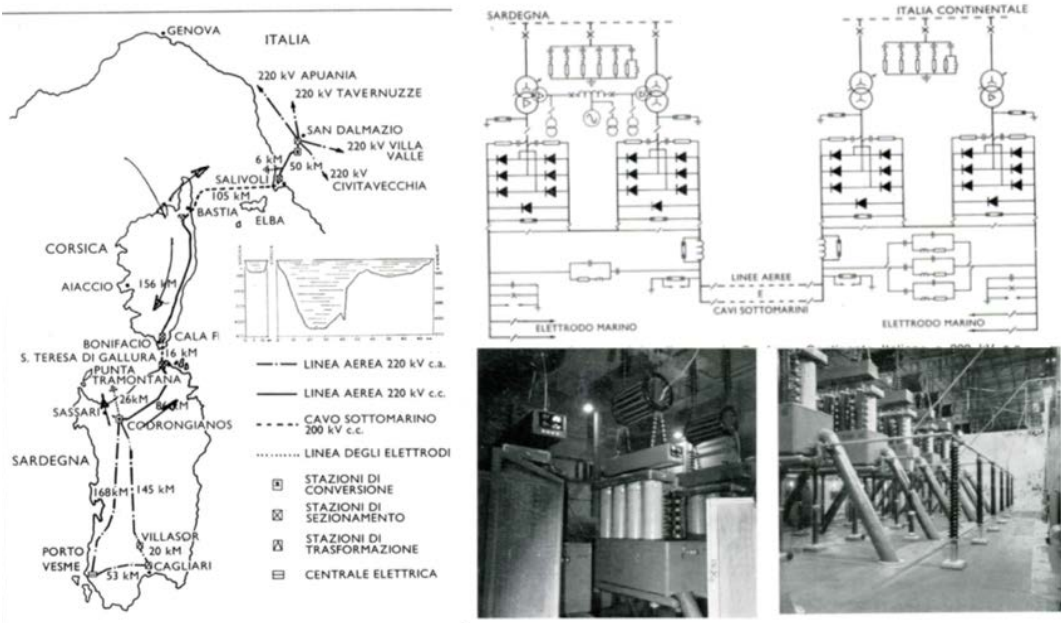


Fig. 11.16 SACOI HVDC Plant

In **22th CIGRE Session 1968** an Italian paper (main author Priaroggia) titled *"200 kV DC Submarine cable interconnection between Sardinia and Corsica and between Corsica and Italy"* decribed the characteristic of one of the two cables used for the link, manufactured by Pirelli. The paper insulated cable impregnated with viscous compound was selected over different cable designs for two reasons: it was the only type of dc cable with some operating experience (Gotland and Cross Channel) and appeared the simplest one from the mechanical point of view for laying in the sea (maximum depth 450 m). Notably, in 2020 both the original cables are still in commercial operation, after more than 53 years of operation. Several papers was presented in the CIGRE Sessions and Symposia and, in addition, SACOI was inserted in the CIGRE reliability report of HVDC links since origin until now.

1966 CIGRE revised statutes and proceeded to a new SC numbers and field introducing time limits for the SC Chairman; New quaterly bulletin Electra was published for its member and including information not only on the life of association but also annual reports of SC and WG.

The italian studies and papers covered all the various new SCs such as Rotating machines and transformers, switching equipment, OH lines and HV insulated cables,Substation, HVDC links and AC power electronics, Materials for elettrotecnology, System Planning and Power System Stability, System insulation coordination, Power system protection and Control, Power System Electromagnetic compatibility.
From 1960 to 1988 the development of fossil fuel Power Plants continued in Italy with a continuous progression of rated power.

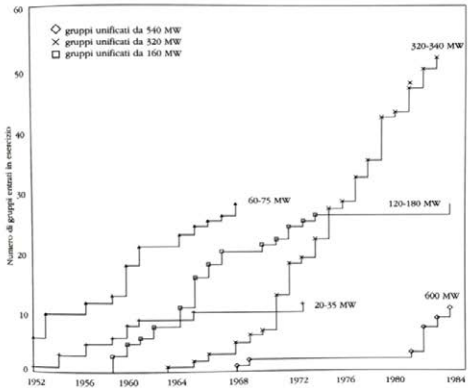


Fig. 11.17 Development Size Fossil TPPs in Italy 1952-1984

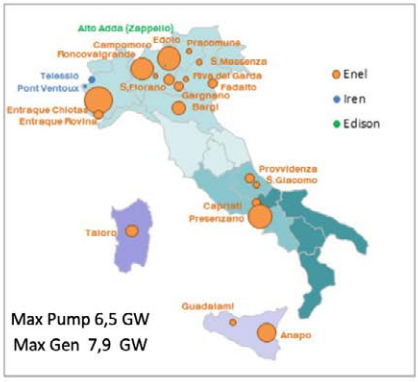


Fig. 11.18 Development HPSPs in Italy 1952-1984

This continuous progression is shown in left figure. At the beginning of '70 the maximun rate of air cooled turbogenerators was about 100 MW while at the end of '80 increased capacity to 600 MW while in the 80s, due to the use of Hydrogen as a cooling medium,the rated power of turbogenerators increased up to 600 MVA and above. The increase of rated thermal unit size allowed for higher efficiency and lower capital and operating costs.
From the grid planning point of view, the development of thermal power plants and nuclear power plants made it appropriate to build Pumped Storage Hydroelectric power stations to store energy produced by the former and supply it during peak periods.
In the 1970s, practically every Italian region (see above figure on the right) had a Hydro Pumping Storage Plant, the largest being installed in the alpine regions (eg. Entracque HPSP 1065 MW,Roncovalgrande HPSP 1040 MW).
This will be of interest in the grid with the future development of renewable sources.

There were therefore numerous Italian reports in the CIGRE Sessions that dealt with issues arising from these developments.

During **the 22th CIGRE Session of 1968** CIGRE decided a complete procedure for the call of papers giving Preferential Subjects and sending to the National Committees for circulation to members and potential authors. The Italian NC was attributed a paper allotment of 10 papers according to the rank of Italy. Another allotment was International for those papers from authors of different countries. In this Session L. Paris and M. Valtorta (Professor at Rome University) presented a paper on SC 32 *"Planning the installation of Large Units in interconnected systems, relevant parameters and their relative influence"* considering two systems: the first isolated and the second interconnected and show relative influence in order to planning the development and operation of the two systems and of interconnection lines for a twenty year period by means detailed computer program.
In the same Session a Working Group of SC13 Circuit Breakers presented a paper on *"Transient recovery Voltage In H V networks - Terminal faults"* taking in consideration the two 225 kV networks (Italy and France) and treating the transients by statistical methods and calculating from these informations some parameters of TRV; G. Catenacci (CESI) was author for Italian part.

The 23th CIGRE Session of 1970 received 122 papers; from Italy 10 papers .
In particular in SC33 Overvoltages and Insulation Coordination presented two important papers.
The first authors L. Paris, E. Comellini and A. Taschini from ENEL described *"Insulation Coordination of an EHV Substation"* that deals with selection of insulation levels for the apparatus of an EHV substation on the basis of statistical criteria according to new rules under study by IEC.
The second one partecipates as author A. Colombo on *"International Studies of Insulator pollution problems"* given contribute to adopt values for H. V. Testing techniques on components.

In **the 24th CIGRE Session** 1972 the mainly contribution of Italian NC continuing in the field of planning Thermal and Hydraulic power plants with a contribution of ENEL in SC 32 authors G. Manzoni, P. L. Noferi and M. Valtorta *"Planning thermal and hydraulic power systems relevant parameters and their relative influence"* that deals with the problem of integration of HPP with reservoirs into thermal

generating systems take in account security criteria and probabilistic features of water availability, thermal capacity and load to have optimum percentage of hydraulic installations and their optimum utilization by computer simulation. This articles following precedent report related to planning gas turbine and HPSP for peak loads.
Other paper was submitted in the SC32 from Turkey in which main author was F. Iliceto (University of Rome) consultant to the Turkish Electricity Authority related to the *"Planning Criteria of the EHV System of Turkey"*. The life of CIGRE permits a knowledge exchange between its members.
In SC21 HV Insulated Cables N. Palmieri and G. M. Lanfraconi treated the *"Extra HV oil Filled Cables (from 300 to 400 kV) laid in vertical shafts"*; this kind of solution is very important for HPSP, was first use in 1955 Montorio HPSP and the authors describe evolution for 1971 Lake Delio HPSP in north of Italy with 12x400 kV oil filled cables in 120 m. Vertical shaft for transmitting 1000 MVA and finally presented design, manufacture and laying critera to realize the 330 kV Kafue cable (Zambia) in vertical shaft having a depth of about 500 m.
In SC 23 Substation two reports come from Italy: the first on *"Automatic Designing of Transmission Lines and Substation"* authors from ENEL (L. Paris was the coordinator) that describes a new tool implemented in ENEL that will be tied into automatic information system for automating design of OHL and Substation; the second one the first to consider *"Adaptation of Substations to their environment both in urban and rural area, including noise problems and oil pollution of subsoil"* authors from a WG in which for Italy partecipate N. Tomatis.

In **the 25th CIGRE Session in 1974** after the oil crisis in 1973 during which in Italy there was other impulse on generation with Nuclear Generation Program and changing Thermal plants with boilers capable of burning fuel oil, heavy oils and gas in order to diversify the sources and their origin. Italy highlight 5 papers: in the SC21 HV Insulated Cables G. Maschio e E. Occhini (Industrie Pirelli) presented *"HV Direct Current Cables: The state of art"* described charactheristics of paper insulated HVDC cables with particular reference to the problems of dc dielectrics like conduction mechanism, space charge effects, stress distribution in steady state and during transients.

- in SC31 L. Paris, F. Reggiani and M. Valtorta *"Possibilities to increase trasmission line loading in well-developed electrical networks"* in which the authors considered the reasons for increasing the loading of OHL's during network development preceding the introduction of a new voltage level. Curves of

the durations of conductor temperatures and the capability to stand such temperatures in relation to the risk of mechanical degrading or clearance reduction was considered.

- In SC32 two paper was submitted by a pool of members of main large System in Europe, the first *"The Planning of Interconnections between electrical systems"*. P. L. Noferi was author of Italy. The report presented a specific methodology for a most rational approach to interconnection planning studies, the second prepared by a pool of ENEL authors *"Simulation of Power System behaviour under severe disturbances causing sequential trips of trasmission lines or heavy power swing"* described a computational programs for simulation of electromechanical transients by means a digital computer.
- in SC33M. Sforzini (ENEL) was coauthor of *"Problems related to the performance of UHV Insulators in contamined conditions"*.
- in the period from 1969 and 1976 a well known contribution to CIGRE was given by G. Quazza director of the ENEL Automatic Control Research Center. He was one of the world leading figures in the field of on-line control of power systems and became Italian national representative on the new SC 32 and was Special Reporter in the 1972 and 1974 general sessions related to SC32. He was also involved in teaching activities at Polytechnic of Milan. Unfortunately he died on August 1978 as a result of a climbing accident in the Italian Alps.

During **26th CIGRE in 1976** three papers of italian NC merits a description.
At SC11 ENEL authors presented a *"Static System for quick de-excitation"* to study the possibility of modifyng the exciter scheme with replacing conventional circuit breaker by a static system base on the use of thyristors; the prototype was tested on hydroelectric unit with favourable results to open the way to the general application of the scheme to the excitation systems of synchronuos machines. In SC21 G. Portinari (Pirelli) and A. Bossi e F. Farneti (ENEL) presented *"Criteria for the qualification of extruded cables"*. The qualification procedure for cables in CIGRE was important step to verify on real cable samples the design of HV and MV extruded cables respect of aging (with thermal cycles test) and voltage transients (lighting impulse test).
Finaly in SC31 L. Paris, L. Salvaderi e M. Valtorta presented a paper related to *"Energy Storage Peak-Load Plants in the Future Energy Production System"*. The papers considers the optimization of the peak-duty mix in a thermonuclear generating system which can be composed by units having at disposal unlim-

ited (Turbogas) or limited energy storage (Pumped storage, battery systems, etc). The foreseen massive utilization of the nuclear source was a program in those years in Italy and this aroused interest in storage-generating means. The paper defined optimization of the basic characteristics of the storage peak duty and suggested how to perform quantitative evaluation by means of simulation method of the Montecarlo type.



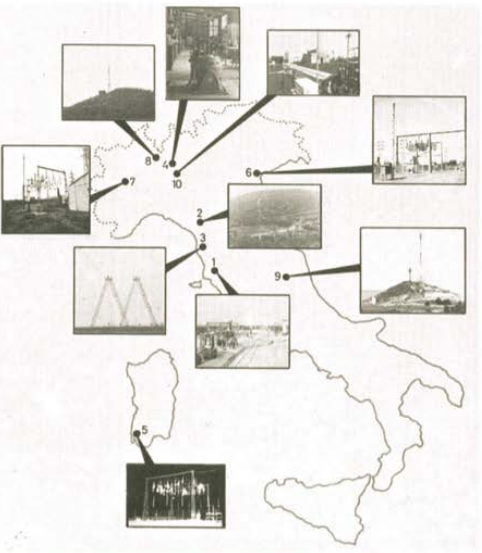
The load in Italy has become roughly four times greater every 20 years while the economic capacity of line also became four times greater when voltage increased from 132 kV to 220 kV and then from 220 kV to 380 kV. Hence a network at the new voltage has been developed in Italy every 20 years : in 1920–30 the 132 kV system, in 1940–50 the 220 kV system, in 1960–70 the 380 kV system.
ENEL assumed that historical trend would continue taking account the programs on Nuclear Power Plants whose unit may even exceed 1500 MW each and grouped togheter.The need to transmit these large volumes of power was one of the decisive factors in the setting up a new voltage level.
As regards the value of the new voltage level after a detailed technical and economic study has shown that, for Italy, a level of 1050 kV was the best. The adoption of a new voltage level was common problem not only in several European Countries but also in URSS and in North and South America. Also CIGRE considered UHV Level as matter of research. The italian UHV project started in 1971 and first stage was completed in 1976. At the Project partecipated also Elettrobras and several Italian Manufacturers as: Industrie Elettriche Legnano, Italtrafo, Tecnomasio Brown Boveri for construction of Trasformer prototype at 1000 kV, Magrini Galileo for construction of GIS Module Substation, Pirelli for Oil Filled Cables, Ceramiche Industriali and R.I.E. for insulators.



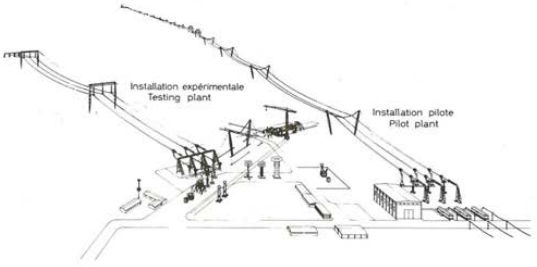
Fig. 11.18 L. Paris

The project was presented in **27th 1978 CIGRE Session** in ENEL report *"Italian 1000 kV Project and related Test facilities"* main author L. Paris in this period Chairman of the Directive Committee in charge of the Project. L. Paris became member of Administrative Council of CIGRE in 1980.
The Project organization was broken down in 8 different Research Groups with a specific task: Corona and Electric Field, Conductors, Physics of discharge and Lightinig and Insulation test, UHV Cables, UHV Lines, UHV Transformer, UHV Substation, Networks Studies and Transient Analysis. The paper described: Main features of the Project, Experimental facilities mainly UHV Electrical test

Equipment, test line, UHV line Model for Corona Test, Pradarena Pass Testing located in the mountainous area subject to heavy ice overloading and high wind, Coltano Testing located in area with winds of medium turbolence, Brugherio laboratories for mechanical and vibration tests, Several Natural Pollution Testing Station: in Sardinia for marine contamination, Sangone and Marghera for industrial contamination Two experimental Stations (Monte Orsa and Sasso di pale) for research on lightining, laboratories of CESI available for some tests on components as circuit breaker, etc. The figures showed facilities location, the sketch of the installations at Suvereto (Tuscany) with the testing plant completed, 800 kV Test transformers and Capacitors Bank and 6MV, 500 kJ impulse generator and voltage divider.



1 – Suvereto testing plant
2 – Pradarena Pass testing installations
3 – Coltano testing station
4 – Brugherio laboratory and natural pollution testing station
5 – S. Caterina natural pollution testing station.
6 – Marghera natural pollution testing station
7 – Sangone natural pollution testing station
8 – Monte Orsa recording station for research on lightning
9 – Sasso di Pale recording station for research on lightning
10 – Cesi laboratories.









The Project created a fall out of several results in CIGRE list of papers from Italian NC.
In the same session was presented:

- SC12 A. Bossi, L. Giannuzzi, G. Manzoni (ENEL), F. Coppadoro (Italtrafo) and G. Sigaudi (IEL): *"Choice of the characteristics of power trasformer for UHV Systems"*
- SC21 E. Occhini, G. M. Lanfraconi, G. Maschio (Pirelli) and M. Tellarini (CESI): *"Self contained Oil Filled cable Systems for 750 and 1100 kV. Design and Testing"*
- SC22 B. Cauzillo, P. Nicolini, P. Paoli (ENEL) and A. Carpena (SAE): *"Mechanical Design Criteria and Construction of New UHV Lines"*
- SC33 G. Santagostino, G. Borgonovo (CESI) and G. Gambelli, L. Lagostena and A. Porrino (ENEL): *"Evaluation of the risk of failure due to switching surges in UHV Networks"*

Italian NC organize also on the matter UHV a Conference of SC31 CIGRE in Tuscany (Tirrenia) in 1977 and Colloquium CIGRE at Siena in 1979.

In **the 28th CIGRE Session in 1980** Italy presented other reports on 1000 kV research, in particular the following:

- SC31 L. Paris, M. Valtorta (ENEL), G. Carrara (CESI), De Franco (Elettrobras) and J. Lepecky (CEPEL, Brasile): *"The 1000 kV -Progress of research at the end of 1979"*
- SC33 G. Santagostino, N. Fiorella (CESI), L. Lagostena, A. Porrino (ENEL): *"Phase to phase to Earth risk failure due to switching surges in UHV Systems"*
- SC36 R. Cortina (Enel) and K. Yamaguti (CEPEL): *"Results of measurement of Corona effects (Losss, Radio-Interference, Audible Noise on large conductor bundles and large diameter tubes"*

In the same time Italy works on Emergency Plan for restoring ENEL electric power after serious fault and consequent partial or total blackout as so far involved only hydroelectric and gas turbine units to supply chosen transport lines (Restoration Lines).

In **the 29th CIGRE Session in 1982** merits a citation two papers:

- SC32 G. Fusco, D. Venturini (ENEL-Dispatching National Center), F. Mazzoldi, A. Possenti (ENEL): *"Thermal unit Contribution to the Electric Power Restoration after a Blackout"*

- SC35 A. Schiavi (ENEL) and Varriale (Italdis): *"Enel power generation and Transmission Control (PGTC) System.technical and managerial aspects of the development of the software for a large scale system"*

In **the 30th CIGRE Session in 1984** continued from Italian NC the report on results on 1000 kV with the papers on:

- SC21 F. Farneti (ENEL), F. Donazzi, G. Luoini (Pirelli) and W. Mosca (CESI): *"Power transmission of Self-Contained Oil-Filled 1100 kV cable system full-scale Tests and Design criteria"*
- SC22 M. Barbarito, A. Clerici (Sadelmi), L. Paris, R. Giglioli (University of Pisa), B. Marzi (Sade Brazil): *"Compact versus conventional EHV Lines: technical and economical comparisons"*
- SC37 L. Paris with authors from ENEL (M. Valtorta, G. Manzoni, A. Invernizzi), Elettrobras (N. De Franco) and Themag Brasil (A. Vian) presented *"Limits of very long distance transmission sytems"*

Others papers are related to SC21 in which was presented not only a development of Cross-linked Polyethylene insulation for HV cables by Pirelli but also a paper on the new sea link between Italy Mainland and Sicily 400 kVca 1000 MVA (three cables plus one spare) instead a new OHL (the first OHL Crossing the Streat was put out of service in 1984) *"Installation of submarine Power cables in difficult environmental conditions. The experience with 400 kV Messina Cables".* The report highlighted evidence difficulties for laying cables due to the simultaneous presence of bottom irregularities and strong tidal currents at 300 m sea depth.

- In SC37 was presented a paper authors: F. Iliceto, E. Cinieri (both from University of Rome) and L. Casely-Hayford (CEO of Volta River Authority) on *"Long Lightly HV Transmission Lines to expand electrification of developing countries applications in Ghana",* presenting technical solutions to replace local supplies from diesel generators by remote supply from hydroelectric sources. Finaly
- in SC38 a pool of member of Ansaldo and CESI (G.Santagostino) presented an *"Evaluation of transient performance of a Static Var Compensator (SVC) for voltage support in a transmission sysyem with Low Short Circuit Power".*

In 1986 after Chernobyl accident Italy decided, after a referendum, to stop the activities on new NPP Construction and in the following year to proceed at phase out of all NPPs in operation. Impact on the Italian electromechanical

industry was severe and also the Italian NC suffered from a point of view of industrial membership.

Any case contribution of Italian NC during **the 31th CIGRE Session in 1986** was maintained at high level with important reports mainly in SC37 Planning and SC35 Comunication and Telecontrol.
C. Martocchia (ENEL) as reference author presented a paper on *"Influence of Uncertainty factors on Transmission System planning. Problems of the Italian System in the coming Years"* taking in account difficulties in forecasting energy demand as result of highly disturbed pattern of economy induced by oil crisis and in other hand because of the major difficulties in obtaining authorizations, problem arise in siting new plants resulting delays in thei commissioning. The paper analyzed these uncertainty factors and described your evaluation not only for italian network but also for new interconnections with foreign countries in particular with a new 380 kV double-circuit lines realized or planned: one between Rondissone (Italy) and Albertiville (France) which holds the record for the highest line in Europe at 2555 meters altitude and the other between San Fiorano (Italy) and Robbia (Switzerland). First was put in operation in 1985 while the second enter in operation at 2003, this explain the validity of the matter of paper very clearly.
M. Valtorta and G. Manzoni presented a paper on *"Reliability Co-ordination in Electric Power Systems"* that complete the first with reliability consideration.

- In SC36 Interference two paper presented a state of art on Electric and magnetic Fields that in the following years became a theme more relevant issue in public opinion acceptance of new lines. The first was presented by WG in the name of SC *"Electric and magnetic Fields from Power Transmission Systems results of an international Survey"* R. Cortina was member of Italian side. The second was related to the *"Research on biological effects of Power Frequency Fields"* and presented by authors coming from CEGB (United Kingdom), EdF (France) and ENEL from Italy (R. Conti as main Italian author).
- In SC14 L. Paris (University of Pisa), P. Tiez (Ansaldo Sistemi industriali) and G. Testi (CESI) and L. Piglione (Polytechnic-Turin) *"Small power tapping from HVDC Transmission System"* described a solution of tapping small powers fron HVDC lines could result benefits for the economic development of crossed regions.

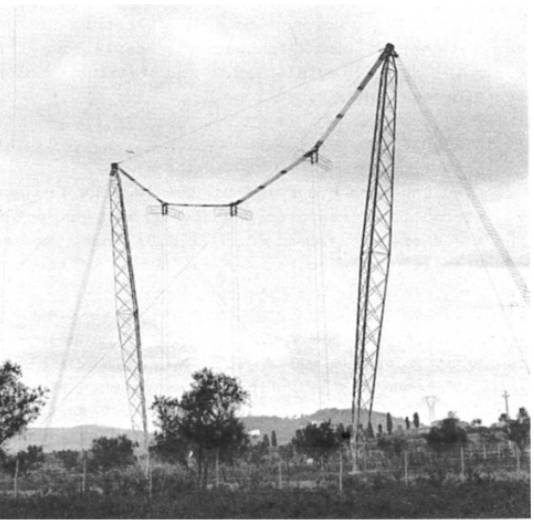


Fig. 11.19 Circus Tower Prototype for UHV OHL

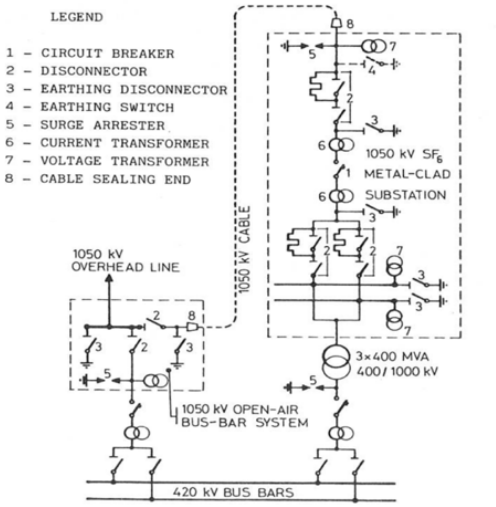


Fig. 11.20 Single-wire Diagram Suvereto SS

The 32th CIGRE Session in 1988 was the first in Palais des Congrés with more than 2000 partecipants coming from 70 Countries. Italian NC partecipated with 10 papers. From these deserved to be reported the following:

- SC38 R. Conti (as main author), Mazza, P. Nicolini and B. A. Cauzillo, L. Giannuzzi (ENEL) presented *"Suvereto 1000 kV Pilot plant: results of the research and plant design characteristics"* describing the final stage development of the Project with construction of pilot plant that consisted in the 1050 kV OHL 20 km long supplied through 420/1050 kV substation from Suvereto node of Italian 420 kV network. Initially was operated under no-load conditions.
- WG38–03 in which there are important expert of Reliability (among others D. McGillis and R. Billinton). Are presents Italian members L. Salvaderi and S. Scalcino (ENEL) that presented at the Round Table on Reliability of Electric Systems a paper on *"Power System Reliability Analysis"* that summarizes the Application Guide concerning application of analytical methods to evaluate reliability aspects in the field of power generation and transmission.

Italy with France registered an other milestone on history of electrical power transmission with commissioning, in January 1987, the first Multiterminal

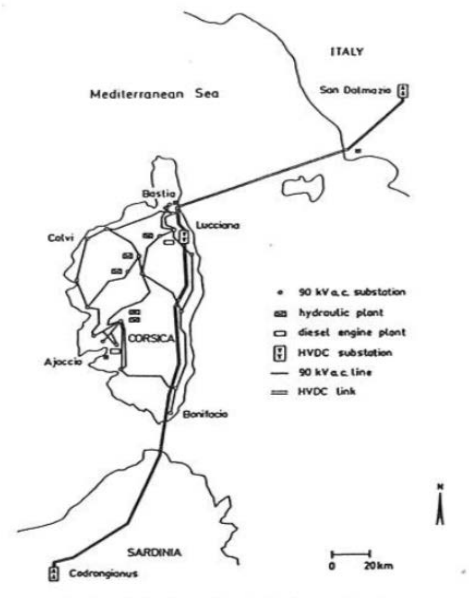


Fig. 11.21 Map of the Link with Lucciana Station

interconnection between three elecytricaly indipendent networks introducing in Corsican grid Lucciana Station in SACOI Plant.
The plant was presented in SC14. Corsica Station installed south of Bastia at Lucciana is tap parallel type, rated for 50 MW at 200 kV.It consists of two six-pulse thyristor bridges of 100 kV each.
The Corsican Station was designed to operate on a static characteristic of currente regulation in rectifier mode as well in inverter mode.
In the figure the map of the Link with Lucciana Station.

The years 1990–1999: From Monopoly to Privatisation

In most developed countries the 1990s were characterized by a revolution of the principles or regulation in electricity system from centralized planning to a new regulation of the market.
Also Italian NC faced with these profound changes in Power System. In 1992 ENEL was privatised.Generation was opened to competition, ENEL was forced to sell 15000 MW of plants to other companies that were forming in the period; in 1995 was Established Regulatory Authorities.
All this had profound changes in the period also within the membership of the Italian National Committee.
Due to large contributions of Italian NC in the CIGRE works we consider only the main important technical issues in the partecipations of Italian CIGRE members.

In **33th CIGRE Session in 1990** there was a record of partecipants more than 2600. Italian NC partecipate with more than 120 member and with 12 papers and in Special Session.

In SC21 Special Report by E. Occhini (Pirelli Cables) partecipated with two topics: New cables with extruded insulation and that cables are not only components of the HV system but also a real system itself.
Other Report of the Session was related to *"Impact of superconductor technology on future power grids"* which was treated by G. Manzoni who described the state of the art in its application on network components (from cables to machinery).
In the SC 11 Italian member presented two paper: the first main Author F. Russo (ENEL) on *"Torsional electromechanical oscillation monitoring for estimating Turbine-Generator Shaft fatigue life expenditure"* taking account the relevant importance in last decade on this matter; the second paper was presented as main author by M. Rebolini on *"Utilization of Static Frequency Converter for start up of Turbogas Unit"*, this solution was applied to gas turbine coupled with multifuel thermal power plant in the conversion of NPP after the Chernobyl accident. In the Emergency Plan (in order to meet increase of power demand in the short and medium term and limit the risks of black-outs due to power deficit) provided the repowering of 13 existing thermal units with a gas turbine having a capacity of 100 MW each and the construction of 5 combined-cycle adopting the solution describe in the paper well proved in HPPP and in large generators separated from the turbine and used as synchronous compensators.

In CIGRE Sessions 34th in 1992 and 35th in 1994 Italian NC presented several important papers:
In both sessions in SC37 L. Salvaderi (ENEL) described the situation in Italy very clearly.
"The Italian Generation System evolution up to 2000 and beyond – Problems,Actions,-Expected Results" and *"The changing Italian Electricity supply industry: impact on the future Generation System"* related to the Italian energy sector dependent strongly from fossils fuels import, in the 1990 figures of more 83 % were recorded in the electricity production. The paper presents the goal of ENEL starting from the second half of nineties with mix of multifuel plants and with higher partecipation of NUGs (Non utility Generators) to reduce abroad imports from 34,6 TWh to 13 TWh at the end of century. Already in this report there were reflections on acceptance by public opinion of electrical infrastructure and accomplishment of the environment protection, particularly the SO_2, NOX control and CO_2 emissions. Were illustrated also today's current topics such as Demand Side management, Energy savings, CO_2 emissions.

In 1992 E. Occhini (Pirelli Cavi), as main author, presented *"Long Island Sound Submarine cable Crossing 345 kV,750 MVA"*; the connection used four Self Contained Fluid Filled (SCFF) cable under Long island Sound each approssimately 13 km long and paper described design, construction and laying power and optical cables.

In 1994 :

- Magnani (Pirelli Cavi) and other coauthors ENEL described the first 1000 kV Underground transmission Line realized as part of 1000 kV project;
- S. Corsi (ENEL) as reference author presented *"System commissioning tests for the SACOI-2 HVDC Three Terminal"*. Tests concluded the upgrading of the two 200 MW Italian Converter stations (based on mercury arc technology) with new 300 MW in air cooled thyristors converters.

In SC12 two papers covered two important aspects of Large Power Transformer: A.Babare (ABB Trasformatori) as main author with others from ENEL, S. Crepaz (Politechnic of Milan) and M. Borsani (Savigliano) *"Transportation Problems of large Power Transformers in conjunction with design characteristics and activities related to on site installation and setting in service"* and *"Repair of large Power Trasformers: Experiences developed in Italy"*.

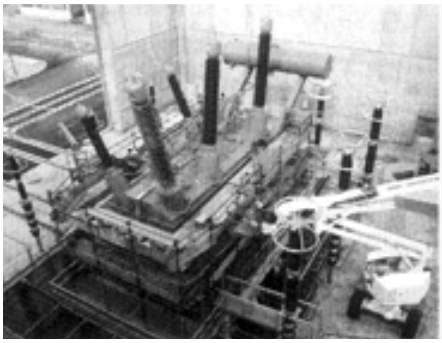
Finaly Prof. F. Iliceto (University of Rome La Sapienza) and E. Cinieri (University of L'Aquila) presented an innovative solution to supply villages and farms in West Africa *"Rural Electrification of developing Countries using the insulated shield wire of HV Lines-New design and operation experience"*.

During **the 36th CIGRE Session 1996** Italian NC presented 11 papers.

In SC11, SC12 and SC21 three memoirs presented by ENEL with Italian industy reported experience on machinery and HV cable :

- G. Tontini, R. Lena (ENEL) G. Galasso (ABB SAE SADELMI), E. Tortello (Ansaldo Energia): *"ENEL Experience on improving Turbine-generators availability and exstending their life"*
- G. Campaniello (ABB Trafo Italia), G. Caprio, G. Zafferani (ENEL), O. Monzani (ABB Trasformatori): *"New development of traditional transformer accessories and components installed on large Units(Step-up and Auto Transformers) operated by ENEL"*;
- F. Donazzi (Pirelli Cavi), B. A. Cauzillo (ENEL), O. Bosotti (CESI): *"Research on the performance of 400 kV Exstruded Cable System under Short Circuit Conditions"*;

The figures show the test facilities: on the left Rondissone for Short Circuit on Transfomer realized in 1990 and on the right CESI labs for cables system.

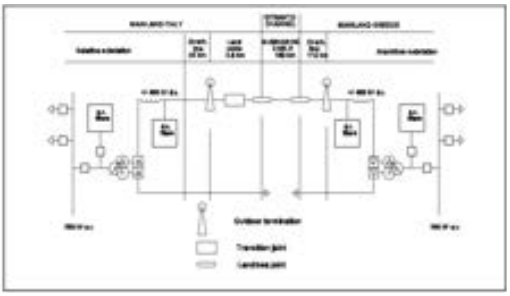




In SC21 Italy marked another record with new Italy - Greece Interconnection (GRITA) Project described in the paper presented by C. Carcano and others (ENEL) and A. Orini and others (Pirelli Cavi) titled *"Qualification test program for the 400 kV HVDC deep water Interconnection between Italy and Greece".*

The link was envisaged to transmit 500 MW at 400 kV in monopolar system with sea current return. Lengh of submarine portion of 160 km across Otranto Channel and maximum water depth of 1000m. All Mechanical and electrical tests followed CIGRE recommendations and paper also dealt the complete sea trial carried out on prototype. For laying cable the vessel was renewed with embedding machine and other relevant equipment.





In SC22 and SC 36 was presented two papers on solutions developed to fulfill the Environmental Impact of Electrical Infrastruttures (the Italian law on Environmental Impact Assessment was introduced in 1992).
P. Nicolini and others (ENEL), L. Paris (University Pisa) and authors from Ministery of Environment presented *"Quantitative Evaluation of the visual impact of OHL"*; R. Conti and others (ENEL) *"ENEL's Experience in assessing occupational and Residential Exposure to power Frequency Electric and magnetic Fields".*
In SC 37-38-39 ENEL presented 3 paper that deserve to be reported:

- L. Salvaderi as main author (ENEL) and P. Maranino (University of Pavia) *"New issues in Bulk Power System planning"* described tools of the Optimal Power Flow Technique: SICRETGRARE based on Montecarlo Methods and OPFGRARE need of performing thousands of hourly studies on the System.
- P. Scarpellini and others (ENEL) and R. Marconato (and others from CESI) *"A Powerful Simulator for Investigating Severe Dynamic Phenomena During System major Disturbances"* described simulator in order to meet great variety of domains and behaviourof the system during disturbances (voltage and frequency first all);
- S. Corsi and others (ENEL) described *"The Regional Voltage Regulator for ENEL'S Dispatchers".*

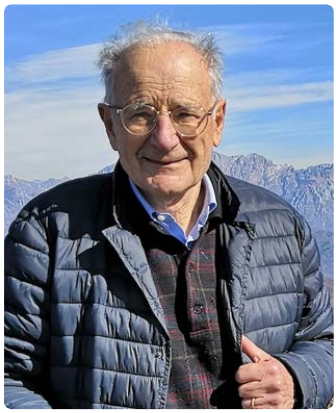


Fig. 11.22 G. Manzoni

In last CIGRE Session of the Century 37th 1998
Italian NC partecipated with 19 papers and more than 140 partecipants.
G.Manzoni replaced Prof. L. Paris as new Chairman of Italian NC.
The papers more relevant in SC12 and SC23 was related to seismic resilience:
Authors from ENEL and ISMES presented *"Seismic risk evaluation for HV power Stations: a case study"*. The memory described results in a substation located in Friuli which suffered a significant earthquake in 1976 completely retrofitting on the critical equipment.
In other report ENEL, ISMES and ABB Trasformatori described *"Mechanical Seismic behaviour of Power Transformers"* in particular was developed "in situ tests" and was defined a complete finite element model of autotransformer installed in ENEL Station which suffered in 1995 an earthquake in North of Italy.

In SC12 was examined by ENEL (main author A. Sala) and CESI *"The problem of internal arc in SF6 insulated Current Transformer"* while F. Iliceto and F. M. Gatta (University of Rome) and A. Babare and G. Bertagnolli (ABB Trasformatori) presented a memory on *"Design and application of variable MVAR output Shunt Reactors with On Load Tap-Changer. Operation experience in Africa"* prosecuting in the task appreciated in CIGRE world to develop electrical systems in central Africa.
In SC21 M. Rahman (Pirelli Cable USA) M. Nassi (Pirelli Cavi) and D. Dollen (EPRI) presented *"Design, development and testing of the First Factory-made High Temperature Superconducting Cable for 115 kV-400 MVA"*. The cable 50 m. long included joints,terminations and cryogenic cooling system.
Always in SC21 F. Donazzi and R. Gaspari (Pirelli cavi) presented a *"Method and system for the management of Power Cable Links"* while A. Orini (Pirelli cavi) described *"A 275 kV, 1000 MVA, Fluid Filled Submarine Cable Link between Penang Island and Malaysia Mainland"* adopting special solutions to bypass mangrove-trees area and a burial of the cables at 2.5 to 3.5 m on the sea bottom to minimize risk of external damages.

The years 2000–2010: Market and Interconnections

In 1999 Italy, after reception of European Directive 96/92 concerning the liberalization of electrical market, adopted first the ISO model in the electricity transmission sector, separating the ownership and development and maintenance of grid infrastructure belonging to 13 networks owners (the main was TERNA controlled by ENEL) from the dispatching and management service, entrusting it to another governement agency called GRTN (Gestore Rete Trasmissione Nazionale) as TSO.
In 2006 Ownerships of the all Transmission Grid was reunified with the Management Service making it dependent on TERNA S.p.A.
At the same time other subjects were established:

- GME, which was responsible for organizing and managing the electric power market fully operational from 2004.

GSE which works for the promotion of sustainable development through the provision of economic incentives for energy production from renewable sources
In 2000, CESI included all research activities of ENEL group in a single structure.
In 2010 the Research Facilities passed under the full control of GSE, assuming the current name of Research on the Energy System - RSE and CESI became an international company including all Test laboratories/facilities and including Consulting Engineering Services.

In **1999 CIGRE published new Master Plan 1999–2009** with new approach for new economy of Power Systems and extend CIGRE's field of action to economic and environment aspects, impact of organizational and regulatory aspects and dispersed generation. The term of "Electric Power System" covered according the MP wide range of topics and in the next part of history we give only a summary of main important communications given by Italian NC.



During the **38th CIGRE Session 2000** the membership Assembly approved statute that was amended by modifying first letter of acronym CIGRE from Conference in Council better reflected the scope of association.
The inaugural session was opened with a speech by Prof Paris who dealt with the theme *"A century of electricity with the CIGRE"*, recalling that while the 19th century was characterized by the steam engine, the 20th century is the century of electricity that started the second technological revolution. G. Manzoni chairman of Italian NC maintained the place in the Steering Committee and in Administrative Council of Association together with A. Clerici. The Italian NC chaired the SC21 Cables with A. Bolza (Pirelli Cavi) and the SC33 Committee with L. Thione (CESI).

Italian NC partecipates with 14 papers which included among others:

- in SC11 G. Bertagnolli as main author (ABB Trasformatori), G. Cannavale, G. Caprio (ENEL) and authors from TEAS (Turkey TSO) and F. Iliceto (University of Rome) *"Power Transmission reliability, technical and economic issues relating to the short-circuit performance of Power Transformers"*. The paper highlights basic factors which play a role in Short Circuit performance of Transformes and influence of specification data and the way they are designed and built. The paper included also failures rate data due to short circuit events and importance for improving reliability execution on prototype first of kind autotransformer a short circuit test (In Italy performed in Rondissone facility).
- In the same SC other paper with coauthors Bertagnolli and Hydro Quebec was related to *"Recent Achievements in performing short-circuit withstand Tests on Large Power Transformers in Canada"* stressing the topicality of the subject matter.

In SC35 and SC39 ENEL presented Components of the new Control System Project with features in the new electricity market environment and an Operator Training Simulator

In **the 39th CIGRE Session 2002** was maintained 10 of previuos SC but at the same time created 6 new SC so we had three SC in Equipment Technologies (A), five SC in Sub-systems (B), six SC System and Energy Market (C) and two SC in Emerging Technologies and Information and Telecommunication System.



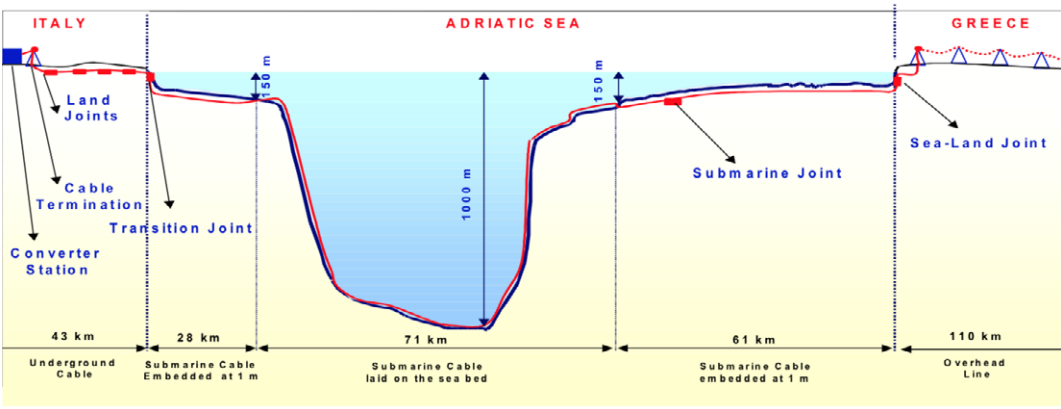
The new Chairman of the Technical Committee Aldo Bolza (2002–2006) completed the implementation of the reorganization of CIGRE Study Committees.
The new Chairman of Italian NC was G.Santagostino replaced G. Manzoni in AC of CIGRE.

Fig. 11.23 G.Santagostino

Italy have 170 Membership equivalents (individual and collective) and in the 39th Session CIGRE 2002 partecipated with 17 papers. The SC are in this General session are not yet with the new SC composition. In the following the most important comunications with main authors.

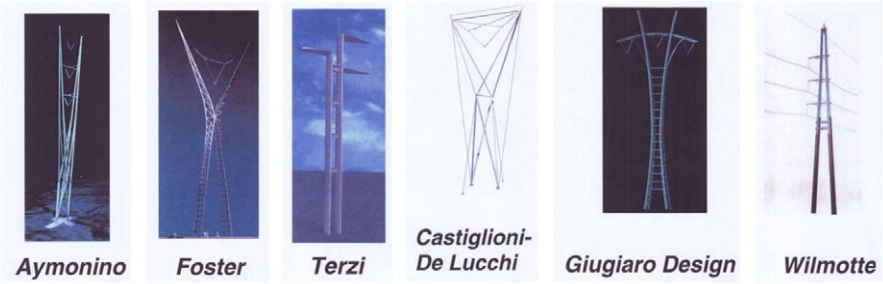
- SC13, F. Iliceto (University of Rome) and Ministry of Energy and natural Resources Turkey presented *"TRVs across circuit breakers of series compensated Lines. Analysis,design,and Operation Experience in the 420 Turkish Grid"*. The physical explanation of the phenomenon was presented analyzing the equivalent circuit of the series compensated system under construction in the North-Eastern part of Turkey.
- SC21, B. Parmigiani (Pirelli cavi e Sistemi Energia) gave *" Prequalification test Experience on EHV XLPE cable Systems"*; test developed according to CIGRE recommedations.
- SC39, including three papers from Italy related to Market and Regulations and tools for support to voltage and frequency control and to solve congestion management and methods for the management of Transmission Operational Risks.
- SC22, G. Pirovano (CESI) and L. Paris, B. Cauzillo (Consultant) described *"Ampacity assessment of overhead line conductors as a compromise between safety and deregulated market requirements"*.

- in SC14, S. Corsi (CESI) and others coauthors of Pirelli, Enel terna, PPC (Greece) and ABB (Sweden) described the Italy-Greece HVDC Link (called GRITA) completed in 2001. The project was sustained by UE founds taking account that in 90's the Greece network was isolated from Europe countries due to conflicts in the Balcan Area. The Link in the final solution was realized as commuted twelve pulse thyristor bridge and coiceived for a possible 1000 MW bipolar extension.



The HVDC link includes:

- two conversion systems - from 400kVac, 50 Hz to 400 kVdc - located in the Galatina and Arachthos stations which include power transformers, smoothing reactors and filters.
- In the final solution the DC OHL lines in Italy between Galatina and Otranto was trasformed during authorization phase in Undergrounding line running about 43 km;
- another short section of land dc cable (less 1 km) at Aetos in Greece;
- a submarine dc cable of 163 km , between Otranto and Aetos crossing the north side of Corfù Island;
- an OHL DC line (110 km) between Aetos and Arachtos in Epiro;
- two submarine electrodes and related ground connections at the italian side and greek costs;

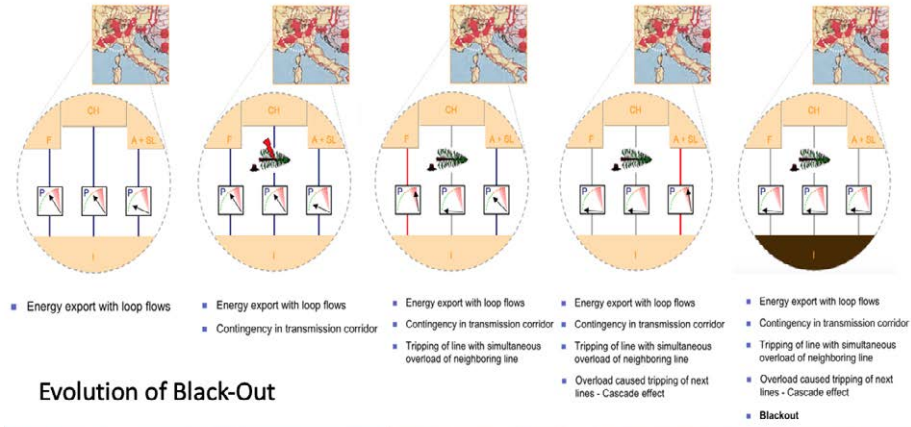


- During SC22 R. Rendina (ENEL, TERNA) made a presentation of the first international competition called *"Sostegni per l'Ambiente"* (Towers for Environment) lanched by TERNA - ENEL's group aiming at encouraging industrial designers to produce towers more environmental friendly than conventional ones perceived by the public as industrial structures.

The challenge was accepted by Architects and Designers of great international worth: Aymonino, Foster, Terzi, castiglione De Lucchi, Giugiaro design and Wilmotte. After examinition from a point of view of technical feasibility an indipendent Jury decided the solutions studied by Foster & partners and Castiglione-De lucchi equally awarded. The Models of all towers were exposed in Modern Art galleries of Rome, Florence and Milan.
Full scale tests on prototype was made at the end of 2002 while the first installation was made in the following years fo "Tavarnuzze 400 kV connections" in the Tuscany area close to Florence to solve a tough opposition due to environmental and cultural peculiarities of the concerned area.

During the night of **September 28th, 2003** the European interconnected electrical system faced a series of disruptions, which started with line flashovers to trees and line trips on the Swiss extra high voltage (EHV) electricity transmission grids. The load of disturbed line is automatically divede among other lines. These transmission lines were already utilized close to their full capacity and overload caused tripping of lines- cascade effect with the separation of the entire Italian peninsula from the UCTE network. Following the separation, the Italian electrical system (and part of the Swiss system, in the Ticino area), suffered an almost complete black-out. The largest blackout in Italian history was a fact. All over the country trains came to halt and traffics light went off.In Rome where the annual all-night festival "Notte Bianca" was taking place, plunged

into darkness. The Roman subway system came to halt, trapping thousands of passengers. The Vatican put backup generators into action,enabling the pope to proclaim new cardinals on early Sunday morning.
Total losses (including Primary, Secondary, Tertiary Sector, WTP Households) was 1182 Million € 0.083% of GDP.
In April 2004 UCTE released its final report.According to the report the black-out had both national and European roots. UCTE also placed the blackout within the context of the development of a European electricity market resulting in an increase of cross- border flows. Yet this was not matched by an increase in cross-border inteconnections capacity. In addition Italian and Frech procedures for handling international flows were not harmonized. Switzlerland, a key country for electricity transit in Europe,did not even have to comply with EU-regulation as a EU non-member.





	Primary sector	Secondary sector	Tertiary sector	Total losses per sector	WTP Households	Total losses per sector incl. WTP Households
Region North	5,25	136,71	60,75	202,71	43,05	245,76
Region Center	20,61	217,61	154,6	392,83	98,18	491,01
Region South	20,89	82,77	97,55	201,2	94,32	295,52
Region Sicily	12,4	33,68	54,61	100,69	49,45	150,14
Total	59,15	470,77	367,51	897,43	285	1182,43
% of GDP	0,004%	0,033%	0,026%	0,063%	0,020%	0,083%

Table 2: Total losses across all regions, sectors and households relevant outage durations (in million €)

In t**he 40th CIGRE Session 2004** Italian NC was presented with 59 delegates and 16 papers .
Italy gave a strong contribution in the workshop on Larges Disturbances.
In fact, in 2003 there were globaly a several black outs, not only in ITALY: North-Eastern United States and South-Western Canada was struck by the largest supply disruption on 14 August 2003, affecting 50 million people; The Nordic transmission system experienced its worst disruption on 23 September 2003 with around 4 million people was disconnected. While large black outs happened in the past these events created considerable concern among policy-makers and general public about transmission network performance.
In the workshop C. Sabelli (GRTN) presented the black-out in Italy: facts and figures on the System during the black-out and the problems occurred for restoring after 14 hrs. the 98% of the system: failures in starting black start units, lack of enough units on house load operation,overvoltages and phase angles,switching from Telecontrol Centers, failure of telecom data and/or voice service.
Sabelli concluded with the contermeasures that Italian TSO must be implemented: from Operational Planning to Real time Control (SCADA and External Network Visibility), Protections and Defence Plans with frequency coordination between load shedding and generator trip settings, Restoration Plans with load rejection and black start capability.

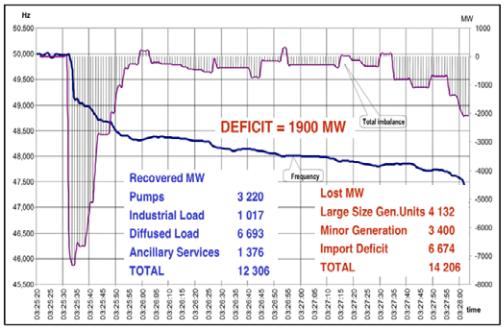


Fig. 11.24 Frequency during the first phase of event

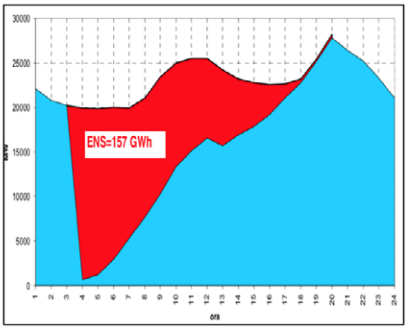


Fig. 11.25 Duration of Restore Energy

Some of the these aspects was developed in papers during the Session.
E. Di Bartolomeo (ENEL TERNA) with CESI on *"improvement in Substation Assets by an innovative system relating events from SCADA"*; M. Gallanti as main author (CESI) presented *"MBI: a maintenance Management System for HV Transmission*

Grids", D:Bisci (ENEL Terna) with ABB presented *"The new aspects of Italian Control System to improve security of operation"*.
Italian NC presented also other three papers related to:

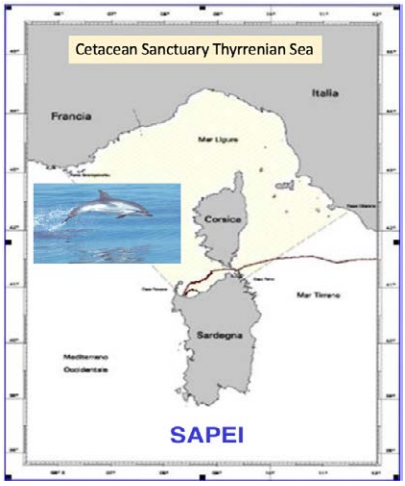
- M. Rebolini (GRTN) with other authors from ENEL-TERNA and CESI *"Feasibility of a new long distance submarine HVDC Link between Sardinia Island and Italian Peninsula (SAPEI)"*, and Prof. Iliceto (University of Rome) prosecuted the works on *"Rural electrification in developing Countries with the shield wire scheme application in Laos"*.



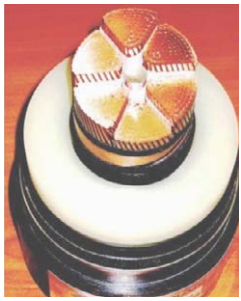
Fig. 11.26 F. Iliceto

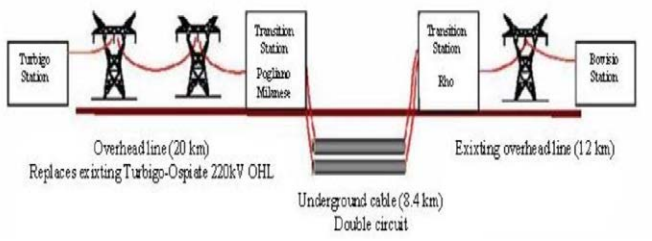
In **the 41th CIGRE Session 2006** Italian NC was presented with 23 papers. During event Prof. F.Iliceto was awarded as Distinguished Member CIGRE for works related on electrification in developing countries (central Africa and sud-est Asia) and for his contribution to interconnection between Europe Grid and Turkey network starting in 2010. Iliceto developed a special protection system to counteract propagation of major disturbances with ENTSO-E System.
The Italian papers covered many new aspects deriving from resources adeguacy to meet electric demand respecting security and quality level in italian libelarized and regulated electricity market.
In the new SC C5 A. Gelmini (CESI) with other authors presented a *"Capacity payment Schemes"*; in SC C6 two papers written by C. D'Adamo and F. Cazzato (ENEL Distribuzione) with CESI and CESI Ricerca and by A. Bertani (CESI) with University of Genoa, Milan and Bologna was related to Operation and Distribution networks with Distributed Generation; A. Capozza (CESI) and other coauthors from University of Cagliari and University of Palermo presented *"A Methodology based on demand Side management for optimal planning of MV-LV Grid in highly urban areas"*; F. Pilo (University of Cagliari) and A. Tsikalakis (National Technical University of Athens, Greece) presented *"Economic scheduling functions to operate Microgrids in Liberalized Energy markets"*.

Other two papers are related with 2 new works in Italy: the first SC B4 presented by corresponding author M.Rebolini (TERNA) with others from CESI and Marine Electronic Sea-Survey *"Environmental issue on the development of New SAPEI HVDC Link"* authorized in 2005 and planned to enter in operation within 2010.



This link will coexist with SACOI2 link in sardinia side.
SAPEI was rated 1000 MW, 500 kVdc, Bipolar System. Submarine lengh of 420 km, 1600 meter depth was record in sea water cables laying and paper describes the marine survey, environmental aspects due to fact the link crossing Cetacean Santuary in Thyrrenian sea, realization of new cathode and uprating existing SACOI2 anode to assure the full coexistence between the two links.
In SCB1 presented by R. Rendina, M. Rebolini, A. Posati, G. Bruno (TERNA), F. Bocchi, M. Marelli, A. Orini (Prysmian) *"The New Turbigo-Rho 380 kV transmission Line: an example of the use of Underground XLPE cables in a meshed Transmission Grid"*. The line cross a sub urban area and OHL became a problem during Impact Environmental Assessment decision was to develop an undergrond XLPE cable system Milliken type copper conductor, with a cross section of 2000 mm^2.





In SC B1 a complementary paper related to UG Cables was presented by C. Di Mario as corresponding author (TERNA) with other coauthors from University of Padova, Prysmian Cables on *"New procedure to compare the social costs of EHV-HV OHL and UG XLPE cables"*.
In SC C2 Italy prosecuted contributions on new solutions for power system analysis monitoring and control with paper *"WAM and ControlSystem: the italian research and development"* corresponding author D. Cirio (CESI) with co-authors TERNA;

In SC A2, E. M. Carlini (TERNA) and D. Bonmann (ABB Germany) described *"Power Flow Control on Italian network by means of Phase-Shifting Transformer"* a solution installed in 380 kV Substation in Italy and that in next years became increasingly used in the European and Noth America Networks for phase angle control.



In SCA1 V. Tartaglione (Ansaldo Energia) described *"Tests on a 500 MVA Hydrogen Cooled Turbogenerator in single shaft configuration"* installed in Voghera Power Plant which was the largest of this type already in operation in Italy. Factory tests were carried out in the testing room facility of the Manufacturer's, at the end of 2003. The tests covered a wide range of aspects: fluidic, thermal and electrical. Besides accurate tests have been carried out for mechanical matter and to determine the conventional losses.

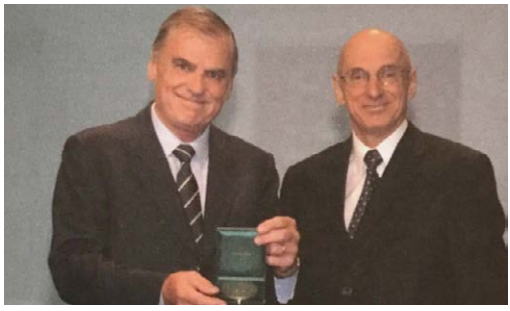
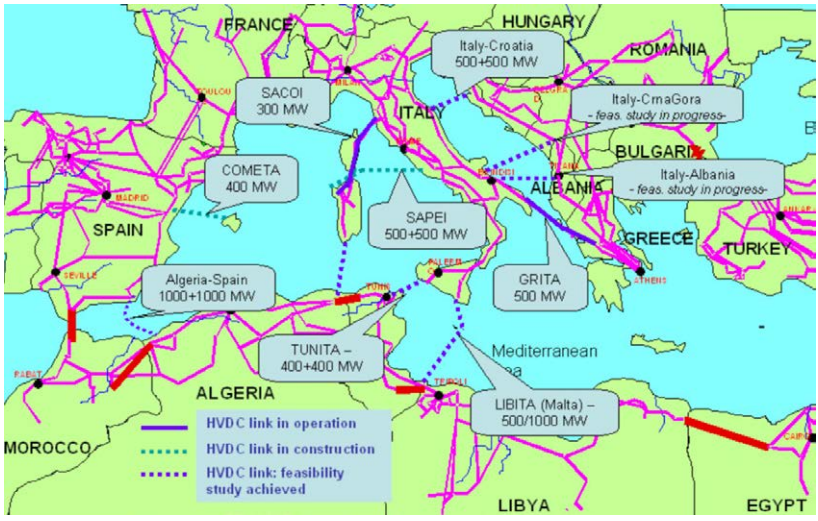


Fig. 11.27 A. Bolza and Y.Filion

The **42th CIGRE Session 2008** accepted more than 400 papers testimony to the success that the CIGRE had worldwide. Italian NC contributed with 29 papers. Now is difficult to examine all (the list complete is in the e-cigre site for consultation) so we highlighted only papers relevant taking account development in electrical sector in Italy. We must also consider that in 2007 in Milan was helded international group to define the new CIGRE Strategic Plan. A. Invernizzi and A. Negri participated in this group for Italy. Was introduced an additional award: **Medal was granted by Chairman of CIGRE Y. Filion to A. Bolza** at the Opening Cerimony at Palais des Congrès in Paris .

In the Opening Session E. Di Marino (ENEL-Distribuzione) partecipated with a presentation on *"Integrating large Shares of Fluctuating power Sources into Power Electric Systems"*. In the presentation was made a focus on the developments in the next years on generation renewables sources towards an active Distribution Grid and necessity of integration planning between TSO and DSO for a strong interoperability to overcame barriers derived from regulatory aspects, market, standardization and investments.
In SC B1 was presented two papers related to *"Technical Challenges in Design and testing the 1000 MW-500 kV HVDC Submarine cables for SAPEI project" (TERNA and Prysmian)"* and *"Compatibility between Electrical Energy transmission Lines and new Railway Infrastrucutres"* (University Padova, TERNA)
M. Rebolini (as corresponding author), G. V. Armani, C. Di Mario (TERNA) with R. Benato (University of Padova) and EOS Switzterland presented an *"Application of Multi-Criteria Methodology for Planning an electric transmission Line"* considering all type of technologies for infrastructures (OHL,Cables).
About the HDVC interconnections B. Cova (CESI) M. Rebolini (TERNA) with authors of GECOL (Libya), STEG (Tunisia) and SONELGAZ (Algeria) presented *"Methodology applied to the Feasibility Study and Technical Challenges to be overcome for linking Europe to Africa through long distance HVDC Submarine Cables"*. In the figure are indicated the links in the feasibility studies (Italian Side) developed by TERNA and CESI .All the links with NordAfrica was blocked or suspended due to internal conflicts in noth africa area after 2011.



The years 2010 - 2018: The Second Energy Transition: from Fossil to Renewable Energy

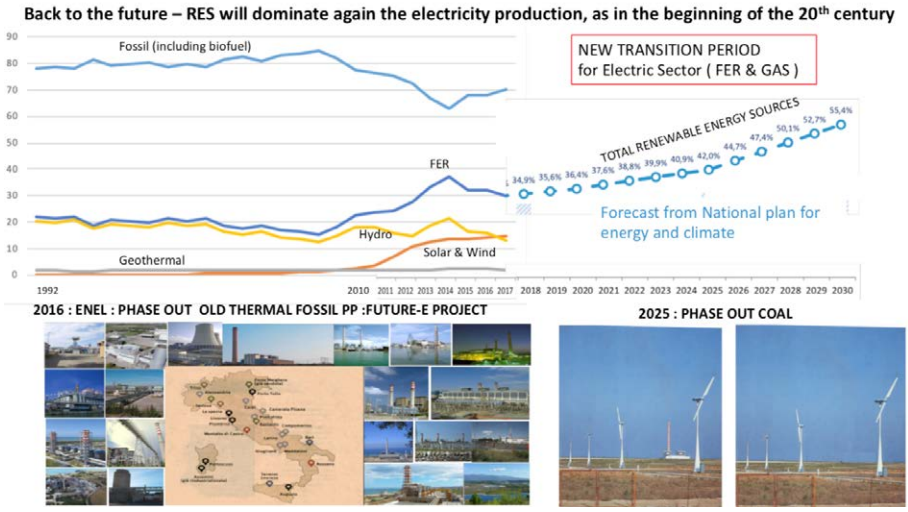




Fig. 11.28 C. A. Nucci and R. Rendina

In Italy the second energy transition can start in 2010 thanks to the first period of incentives for Renewable Energy Sources (RES) that in the period between 2005 and 2010 gave impetus to the construction of solar and wind power plants; ENEL in 2016 decided to close 23 old Thermoelectric Power Plants and plans to close Coal-Fired plants in 2025. The target of the Italian New Plan (PNIEC) is to reach in only 20 years (in 2030) a percentage of electricity generation from renewable sources equal to 55%. In practically a return to the past as we have seen in figure of paragraph 12.3.

CIGRE published in 2010 New Strategic Plan 2010–2020 that considering evolution of Electricity Supply industry and facts shaped the future: growing demand for electricity, climate change and carbon free generation, scarcity and cost of energy, acceptability and upgrading new and existing of power infrastructures gave main technical directions in the decade: prepare strong and smart power system, make the best use of the existing eqipment and systems, answer the environmental concerns, develop knowledge and information.

The new Chairman Of Italian NC was R. Rendina replaced G. Santagostino in AC of CIGRE.

In 2011 **C. A. Nucci and R. Rendina organized a CIGRE Symposium at Bologna** on *"The electric Power System of the future- Integrating Supergrids and Microgrids".* Symposium was a base for Technical Developments on CIGRE Strategic Plan. requirements.

In **General Sessione 44th 2012 M. Rebolini was appointed as New Chairman of Italian National Committee and member of Administrative Council of CIGRE Paris replaced R. Rendina**

Considering the huge quantities of Papers presented by Italian NC in the last 5 General Sessions we will follow the main Italian technical contributions in SC gave in **43th 2010, 44th 2012, 45th 2014, 46th 2016, 48th 2018 Sessions in Paris** and other events organized in Italy. Italy realized and put in operation new links and interconnections inside the Italian Grid and with foreign countries each of them due to innovative solutions created a fall out of System Studies, Technical improvements on equipment and automation and control management.

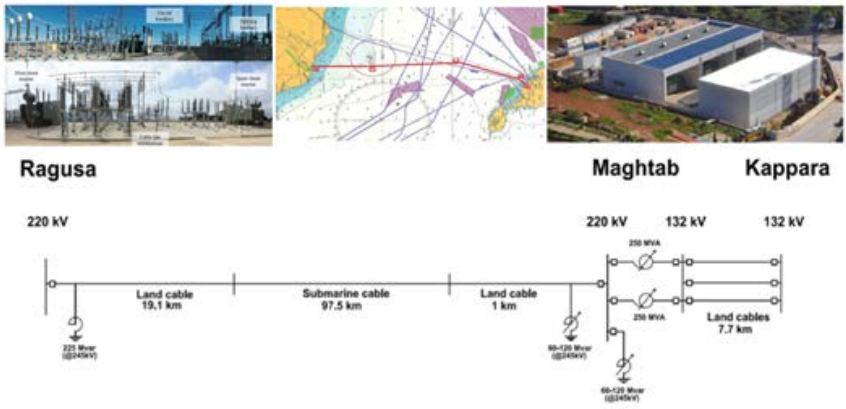
- *SAPEI HVDC +/- 500 kV 1000 MW* link between Sardinia island and Italian peninsula (SAPEI) completed in 2010 Session reaching sea bottom depth of 1620 m. unprecedented records for submarine cables (presented "The realizazion and commissioning phase" by R. Rendina (TERNA) and other authors from CESI, ABB and Prymian in 2012 Session.

The link rendered also Sardinia, Corsica and Italian peninsula a *"An Integrated Multi Terminal Grid in the Mediterranean Basin"* as presented by M. Rebolini as reference author (TERNA). In Session 2014 M. Rebolini (TERNA) presented *"Increased grid performnce using synchronous condensers in Multi in-feed multi-terminal HVDC System"* describing different solution and reasons of installation of 2x250 MVA Air cooled Synchronous Condenser in Codrongianos Substation for improving the performance of the grid regarding Short Circuit Level, Inertia and reactive power control.

In **Session 2018 SC B4** D. Cirio (RSE) togheter with TERNA and Toshiba Italy presented *"Support of VSC-HVDC to the restoration of weakly connected system:the Sardinia case".* The paper examined benefits of a VSC technology acting either as a black start unit or as reactive power support device. The work was developed in the context of Best Paths EU research project.

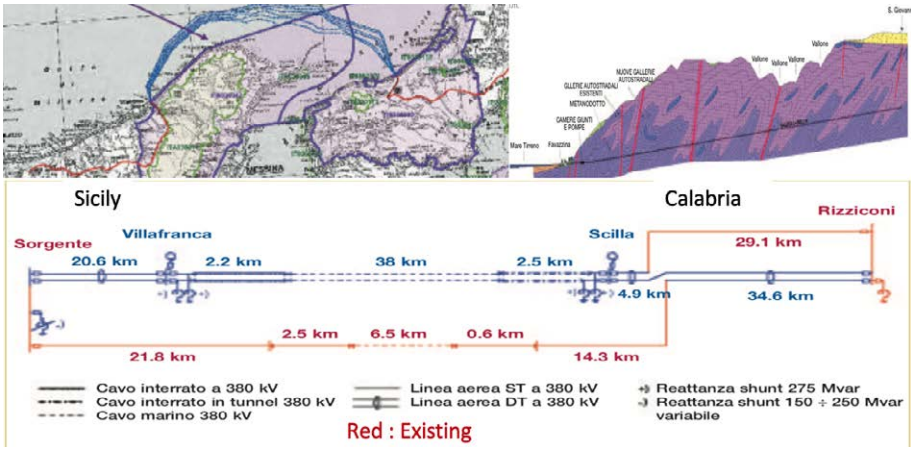
- *Sicily -Malta Interconnector* entered in service in 2014 as single-circuit line 245 kVca using XLPE submarine cable 225 MW rating (the full project

consisted of double-circui line not yet installed). The cable line includes 19,1 km underground in Sicily connecting Ragusa terminal station (AIS type) to the landfall and 99,5 km submarine cable to Maghtab terminal station (GIS Type) in Malta. The project was presented in all phases: **in 2010 Session** was described the *"Feasibility of the project and system electrical studies"* in which are considered different technical options: AC Synchronous interconnection, DC LCC or VSC link. Final decision was to realised AC interconnection. **In 2014** Session F. Palone (TERNA), S. Lauria (University of Rome) and J. Vassallo (Enemalta) presented "Frequency domain studies " and in Session 2016 *"Switching transients on very long HV AC cable lines: simulations and measurements on Malta-Sicily interconnector".*



- *Sicily – Calabria* New 420 kV submarine link between Italian Peninsula and Sicily. Sicily has been connected to the Mainland Italy since 1955 using a 220 kV overhead line with a single span of about 3800 m, which was decommissioned in 1994.

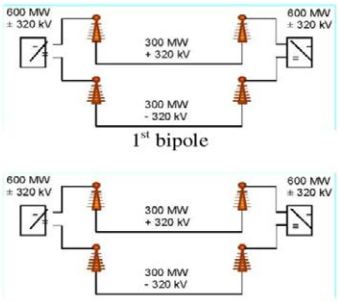
A first 420 kV submarine cable link was installed in 1984, allowing for a higher net transfer capacity between the Sicilian and the Italian networks. Although still in operation, this link is no more sufficient for the secure management of the network, prompting the need for a new and stronger interconnection.The new interconnection entered in operation at the end of 2018.



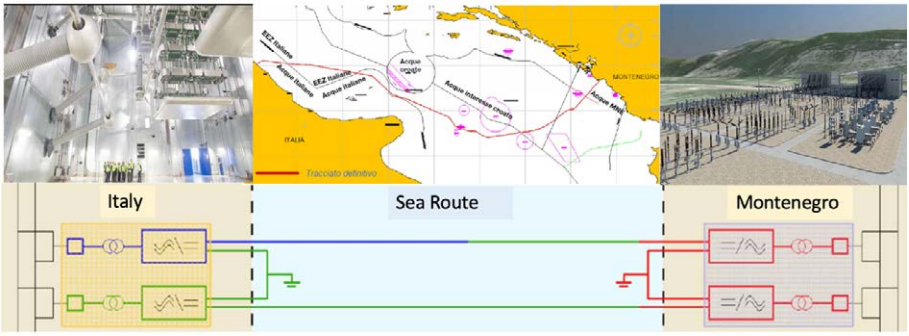
The single line diagram of the system (reporting the connection lengths and final route of cables 380 kV inside a tunnel to arrive at Scilla SS) is shown in figure: the red lines indicate the existing link, whereas the part drawn in blue represents the new connection. The new connection is longer than the existing one because it follows an alternative path, for guaranteeing the reliability and the resilience of the system. The shunt reactor arrangement is thus symmetrical, differentlyfrom the Malta-Sicily Link, in order to allow proper reactive power control. In Session 2018 main authors M. Rebolini, F. Palone (TERNA) and A. Mazza (Politecnico di Torino) presented *"Commissioning and Field Tests Result"* describing network Studies and attendant cables model and validation of parameters.

- **Italy-France HVDC Interconnection called "Piedmont-Savoy": in Session 2018** R. Dezan (TERNA) presented this interconnection as *"Example of sinergy between Electric transmission and highway Infrastructures"*. The system is composed of Double-Bipole in VSC Technology 2 x 600 MW long 190 km across the Alps between Italy and France and will be the longest ever HVDC undergrounding cable project in the world.





- **Italy – Montenegro HVDC link was well described in SEERC Meetings and Conferences.** The interconnection made in part by land cable and marine cable crosses the Adriatic Sea for 423 km and 1200 m deep. HVDC Technology is Bipolar LCC bidirectional with marine electrodes at 500 kVdc at nominal Power 600x2 MW. Link is operating from end of 2019 at 600 MW.



In SC C4 C6 Experience of TERNA in installation of Energy intensive batteries (Sodium-sulphur technology) was presented during Session 2016 with several papers. Are to be reported 3 papers: R. Vanadia (Terna) and Terna Storage s.r.l. *"Authorization procedure for Energy Storage Systems projects installed on the Italian transmission Grid"* N. Di Pietro *"Large scale Italian energy Intensive Storage installation. safety issues and environmental compatibility"*, G. Bruno (TERNA) *"Electromechanical Energy Storage Systems and ancillary services"* while E-Distribuzione experience was treated from a series of report among which F. Cazzato *"Prosumer's Battery ESS in MV Distribution Network , A cost-benefit Analysis in the Italian Regulatort Framework".*

In B1 SC Cables M. Marzinotto (TERNA) presented with G. Mazzanti (University of Bologna) *"A procedure for space charge measurements in HVDC extruded cables"* A. Bareggi (Prysmian) presented *"Development and qualification of 150 kV cable produced with innovative P-Laser technology".*

L. Guizzo (Terna) with CESI presented *"Lyfe Cycle assessment (LCA) of a Double Circuit HVAC cable Transmission Line".*

In **SC D1 and A2** highlighted five papers from Italy: **In Session 2012**

- M. Rebolini (TERNA) presented "Autotransformers evolution, reliability, safely and modelling in the Italian transmission Grid".

In Session 2014
As main author F. Scatiggio (TERNA) *"Preliminary study for use of vegetables esters in big power transformer"*; The paper descrbed the laboratory scale experiments for testing and comparing different vegetable esters existing in the market .
After two years of studies and tests on prototype of a kind new generation Green Transformers 250 MVA 400 kV, TERNA and TAMINI installed the first unit in 2018 in Udine Ovest Substation.


TAMINI GREEN AUTOTRANSFORMER

- F. Scatiggio with M. Pompili (University of Rome) *"Health Index: TERNA approach's fro transformer Fleet management"*.
- M. Rebolini (TERNA) with Tamini Group, Getra group and university of Milan presented *"New Phase Shifting Transformers . Design, manufacturing, testing and Electromagnetics transients Modelling"*.

In Session 2018 - F. Scatiggio with Camlin Power presented *"TERNA Transformer Fleet Knowledge Management through the use of on line-monitoring"*;
Italian SC3 organized in 2015 a International Workshop in Stresa and a visit to Expo in Milan. CIGRE President Klaus Fraulich opened the meeting with the participation of the CEO of ENEL -Distribution and more than 100 delegates from many Italian and European companies. For the first time the CIGRE has involved the world of architecture and energy, in any case present in history of electrical infrastructures, to promote a better acceptance of works. Partecipated Architects: H. Dutton, Frigerio, Bystrup and more than 50 delegates from TSO, DSO and European Italian Manufactures.
H.Dutton with Giorgio Rosenthal was the winner of the second TERNA Beaty Contest in 2009 related to New Towers with "380 kV Germoglio Tower" installed

in Trino -Lacchiarella 380 kV OHL and visited during the workshop. *"Design, testing and Installation of Dutton_Rosenthal Tower"* was also presented by P. Berardi (TERNA) during 2016 General Session in Paris.
During the workshop was also presented a new innovatice lattice steel Tower conceived by TERNA an italian manufacturer Colombo S.p.A. called Vitruvio.



In SC D2 in 2012 Session Cybersecurity was treated by M. Petrini (TERNA) and COL S.p.A. *"System services for the safeguard of digital substation automation systems"* taking account evolution in past decade with introduction of Intelligent Electronics Devices (IED) and digital communication. The latter aspects was treated by G.Dondossola (RSE) *"Security of communications in voltage Control for Grids connecting Distributed Energy resources"* in Session 2014.
Italian SC C4 organized in **Bologna International Colloquium CIGRE in June 2016 on "Lighting and Power Systems".** Chairs of Event was C. A. Nucci and A. Borghetti.
At Colloquium participated, from worldwide, several experts exchanging knowledge, experience and information towards further understanding phenomena associated with lightning and implementation of protective measures against its effect on electric power systems. In 9 Sessions was presented 43 papers.
In SC B3 and SC B5 new solutions on equipment and control was developed due to challenges of upgrading short circuit power on 380 kV network and increasing number of Renewables Power Plants (wind and solar) and the necessity to connect them in fast times as disaster recovery and limit network outages in case of expansions of plant in operation.
In session 2012 V. Iuliani as main author (TERNA) with ABB Italy presented *"Compact Substations for Quick Installation called SCRI"* developed as mobile substation 145–170 kV equipped with cable plug-in termination and assembled on a 40 ft long standar trailer.

In Session 2016 M. Spiranelli (ABB Italy) presented *"ABB PASS (Plug And Switch System) called MOS 420 kV for Transmission Substation"* described compact pre-fabricated HV modules provided functions of Circuit breaker using single chamber 420 kV/63 kA as interrupting unit, combined disconnector-earthing switch and Current and Voltage Transformers.



Fig. 11.29 SCRI



Fig. 11.30 MOS 420 kV

In SC 2 Italian NC presented solutions on Restoration Strategy coming from difficulties registered after 2003 Black Out .
In Session 2014 and 2018 was described in two papers one of G. Giannuzzi with Swissgrid and CESI and the second presented by R. Zaottini (TERNA) *"Test experiences on 380 kV grid top-down restoration from Neighbouring Countries (Switzerland and France) to South of Italy"*. The papers included preliminary Simulation Studies and results and the execution of re-energization test. The Strategy is based on a configuration of the network in operation that allows long stretches of lines in cascade to be set up in the event of a blackout and on the sequencing of these connections from abroad by closing a limited number of circuit breakers. The procedure, now part of Terna's restart plans, create frequency stability provided by the connection with the rest of Europe.



G. Giannuzzi (TERNA) **in 2010 and 2012 CIGRE Session** treated also *"On-line Analysis in a Dynamic Security System Environment"* and a *"Very Short Term a Optimal Dispatching for an Advance Dispatching"* joyntly developed with CESI and current in operation in the National Control Center.

Resilience was treated in several papers particularly in SCB2 in Session 2012 G. Pirovano (RSE) and TERNA coauthors described *"The Italian approach to reduce risks of wet-snow accretion on conductors of existing OHL"* while in Session 2016 M. Forteleoni (TERNA) and CESI treated the *"Assessment on ignition of electric arc and flashhover distances between OHL and surrounding vegetation".*

SC5 Market was introduced with reform CIGRE in 2002 and Italian NC was always presents.

In Session 2010 Italy presented three papers.

G.Mauri (ERSE) with A2A s.p.A.*"Integration of active customers into SmartGrids: experimental test facility and results".* Dedicated facility was developed to evaluate the benefits from prosumer, plug in vehicles and aggregators for demand side integration.

R. Caldon and others from University of Padova *"Role of Storage systems amd market ancillary services in active distribution networks management"*;

P. Pericolo (TERNA) and University of Pavia *"Impact of wind generation on the voltage control ancillary service and development of the Italian transmission System".*

In Session 2014 CESI and TERNA presented always on Market Integration a *"Optimization of storage resources to mitigate risks of overgeneration from RES non-programmable in Italy".* In Italy at the end of 2013 total power installed wind farms and solar plants reached 15.5 GW.In particular in the southern regions of Italy covered an increasing share of electricity demand consequently the operational conditions did not allow complete integration of Variable Renewable Energy (VRE).In SC2 P.Pelacchi (University of Pisa) and TERNA described *"Dynamic Thermal Rating of Italian Transmission Lines"* that allowed exploiting performances of conductors (currents significantly higher than steady state thermal limits) minimizes curtailement of VRE in south of Italy.

In Session 2018 D. Pugliese (Enel) made *"The estimation of the value of lost Load"* relevant in the regulation of incentives and penalties imposed in distribution and transmission companies for quality service and a key parameter in regulation of capacity remuneration mechanism.

In other paper L. Ortolano (TERNA) and RSE, DSO Edyna, Siemens and Selta *"Smart TSO-DSO interaction schemes and ICT solutions for integration of abncillary services from Distributed Generation"* described Italian pilot plant to demonstrate

a smart managemet of entire electrical grid and solve challenges in transmission and distribution networks.
At the end of this period during plenary Session 2018 **M. Rebolini in Paris was awarded of Fellow Honorary Member CIGRE from R. Steven, Chairman of CIGRE .**
During the same Session **L. Michi replaced M. Rebolini as Chairman of Italian NC CIGRE.**
M. Rebolini still remain in the Steering Committe of CIGRE.



Fig. 11.31 M. Rebolini and R. Stephen



Fig. 11.32 L. Michi

The years 2019–2020: What is Future after Coronavirus Impact
In January 2020 a viral Covid-19 epidemic breaks out in China in Hubei Province and in a few months it turns into a global pandemic.
CIGRE for the second time in its history is forced to postpone the General Session.
CIGRE, formed in 1921, will celebrate its 100th Anniversary in 2021 with this Centennial celebration held at Palais des Congres in Paris, France in August.

From an historical perspective our great family of CIGRE endured a Session in 1939 whereby "heavy storm clouds already threatened the world" (Quotes from 1946 Opening session by Ernest Mercier, President of CIGRE from 1933 to 1948). "They burst with the implacable fury of a world wide cataclysm".

For the 25th Anniversary delegates called for a great Paris Session in 1946. President Mercier continued "You have eloquently answered by easily beating all your previuos records, for today there are 950 delegates, thus showing your impatience to resume those trusting and warm contacts of which you had established

the tradition, like members of a single great family dispersed all over the globe".

Electricity like viruses don't know borders, but electricity is stronger and essential to fight against them helping medicine scientists to develop medicines and vaccines.
But electricity needs men and women to take care of it and distribute it.
We, in the CIGRE, are and we will be those men and women.

11.3 Achievements of the Italian NC CIGRE

ITALIAN CIGRE PEOPLE IN CIGRE GOVERNANCE

Members Administrative Council of CIGRE
1958–1966 G. Silva (also chairman of CIGRE)
1980–1998 L. Paris
1998–2002 G. Manzoni
2002–2010 G. Santagostino
2010–2012 R. Rendina
2012–2018 M. Rebolini
2018–2020 L. Michi

Chairman Technical Council of CIGRE
1958–1966 G. Silva
1978–1984 L. Paris
2002–2006 A. Bolza

Chairman Study Committee of CIGRE
A. Bolza, G. Carrara, G. Catenacci, D'Arbela, P. Gazzana, Priaroggia, A. Iliceto, A. Invernizzi, T. Leardini,
G. Manzoni, M. Marelli, A. Negri, C. Nucci, M. Sforzini, G.Silva, L. Thione, and M. Valtorta.

CIGRE AWARDS

CIGRE Medal
2008 – A. Bolza

CIGRE Honorary Member
1992 Mario Sforzini, 1996 Giancarlo Manzoni, 1999 Luigi Paris, 2002 Lorenzo Thione, 2008 Angelo Invernizzi, 2012 Antonio Negri, 2012 Carlo Alberto Nucci.

CIGRE Fellow
2016 Carlo Alberto Nucci, 2018 Massimo Rebolini

CIGRE Distinguished members
1996 A. Clerici, R. Cortina, F. Reggiani, G. Santagostino,
2000 E. Tortello, A. Invernizzi,
2002 A. Pigini,
2006 B. Parmigiani, F. Iliceto, R. Conti,
2008 A. Giorgi, E. Colombo,
2010 C. Imposimato, C. Sabelli,
2012 M. Marelli, F. Scatiggio,
2014 M. Rebolini, V. Tartaglione, B. Cova
2016 S. Malgarotti, G. Pozzati, F. Cazzato,
2018 R. Benato, P. Mazza, M. Petrini, F. Pilo.

ITALIAN MEMBERSHIP IN CIGRE

CN ITALIA MEMBERSHIP	
ANNO	Equivalent Member
1998	
2004	164
2008	201
2009	200
2010	209
2011	228
2012	239
2013	307
2014	333
2015	336
2016	325
2017	326
2018	329
2019	324



Secretary CN Italy since 2003



Rank	EUROPE 46,36%	6865	AMERICA 18,88%	2796	AFRICA & MIDDLE EAST 6,19%	917	PACIFIC AND ASIA 28,57%	4231
1	RUSSIA	809	BRAZIL	965	GCC NC	273	CHINA	1068
2	GERMANY	732	UNITED STATES	876	SOUTH AFRICA	176	JAPAN	876
3	UNITED KINGDOM	636	CANADA	409	TURKEY	123	INDIA	682
4	FRANCE	529	ARGENTINA	170	EGYPT	97	AUSTRALIA	589
5	SWITZERLAND	405	CHILE	142	JORDAN	73	KOREA	421
6	SPAIN	349	PARAGUAY	60	IRAN	58	THAILAND	194
7	ITALY	325	COLOMBIA	48	No NC AF	53	MALAYSIA	167
8	SWEDEN	316	Andean NC	47	ISRAEL	42	NEW ZEALAND	144
9	NETHERLANDS	252	MEXICO	44	ALGERIA	23	No NC PA	70
10	NORWAY	242	No NC AM	37			INDONESIA	21



Symposia/Colloquia organized by ITALIAN NC Period 1977-2020				
Year	Type	Location	Argument	Papers
1977	Simposium	Tirrenia	SC 31	52
1979	Colloquium	Siena	EHV Systems	35
1983	Symposium	Firenze	Control application for Power System Security	64
2011	Symposium	Bologna	Electric Power System of the future:Supergrids and Microgrids	177
2015	International Workshop	Stresa Milan-Expo	SC C3 Innovative Electrical Networks for a Sustainable Development in Low Carbon Scenarios	26
2016	Colloquium	Bologna	SC-C4 System Technical performance Lighting and Power Systems	43

12.4 References

1. Storia dell'Industria Elettrica in Italia 1. Le origini : 1882–1914 a cura di G. Mori Editori Laterza 1992
2. Atti Rivista Elettrotecnica: Numeri del 15 Dicembre 1923; 15 luglio 1925; 5 Settembre 1929; 15 luglio 1927; 25 Novembre 1931; 15 Ottobre 1933; 10 Dicembre 1935; 25 Settembre 1937; 10 Settembre 1946; 10 Agosto 1948;
3. Vincent Lagendijk "Electrifyng Europe: the power of Europe in the construction of electricity networks" ed. TU/E January 2008.
4. Storia dell'Industria Elettrica in Italia Vol.2. Il potenziamento tecnico e finanziario 1914–1925 a cura di Luigi De Rosa Editori Laterza 1993
5. The History of CIGRE Edizione 2011
6. L'opera di Luigi Paris – Selezione dei Paper; Milano 2005
7. Storia dell'Industria Elettrica in Italia Vol.3 Gli sviluppi dell'Enel 1963–1990
8. ENEL 1996–2002 Dal monopolio al Mercato, C.Testa, Maggioli Editore 2003
9. Session Papers General Session CIGRE Paris from e–cigre.org
10. Electra Revue CIGRE annals

Note: All figures are download from CIGRE documents and papers.

12. NC CIGRE ISRAEL

12.1 History of the Electric Power System in the Land of Israel

Electricity in Israel is a synonym for Israel Electric Company – IEC. The Electric Company was founded on March 29, 1923 by Pinchas Rotenberg, following a strenuous and intensive process vis-a-vis the British regime then ruling the Land of Israel. As early as 1921, and against all odds, Rotenberg has signed two agreements, largely in virtue of his charismatic personality and many connections. Two agreements that will in the future, in March 1926, become franchises granting the Electric Company the exclusive right to produce electricity, conducting it and selling it throughout the British Mandate territory in the Land of Israel for 70 years. The then British colonial minister, Winston Churchill, who saw that as a mean for fulfilling the British Crown's commitment under the Balfour Declaration, was a staunch supporter of this scenario. The vision of Israeli electricity was launched. Three months after the company was founded, the first 300 kW diesel generator power station in the Land of Israel was inaugurated on June 10, 1923 in Tel Aviv, becoming an indicator of the independence of the Jewish community. Equally important, the foundation of the station served as a landmark for the beginning of modern industry in the country. Two years after the inauguration, electricity started to be produced in two other similar diesel-generator power plants, in Tiberias and Haifa.

"Naharayim" - a wonder of electricity and water

Before even immigrate to Holyland Rotenberg conceived the idea of establishing the hydro-electric power plant south of the Sea of Galilee, in the area where the Jordan and Yarmouk rivers meet, thinking that this will only be one of 13 plants he hoped for along the Jordan river. The power plant- dubbed "Naharayim" (bi-river) began operating in 1932 when the Electric Company expanded its operations to the eastern banks of the Jordan river. This Transjordan power plant was the first and only one of its kind, and with an output of 18 megawatt it catapulted the electricity generation capacity in the country, founding a flourishing and prosperous community of employees of IEC - plant's operators and their families, next to the power plant. The power plant operated for nearly 16 years until the outbreak of the War of Independence that interrupted Rotenberg's hydroelectric dream. At that time, the electric company's production system already included two steam power plants, in Haifa (1935) and "Redding" in Tel Aviv (1938).

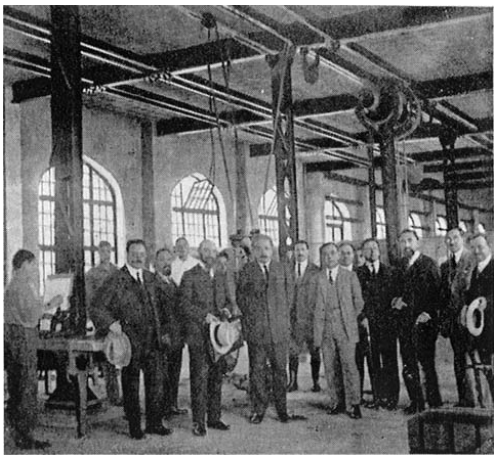
Jerusalem Electrical Company

Since 1928, a separate electric company has been operating in Jerusalem, the "Jerusalem Electricity and Public Service Company". The company operated under a franchise granted during the Turkish rule to the businessman Euripides of Bromatis, for the provision of public services - electricity, water and transport within a 20 km radius of the Dome of the Holy Sepulcher in the Old City of Jerusalem. Throughout its entire years of operation, the Jerusalem company has been to some extent the "little sister" of Eretz Israel Electric Company.

The development pace of Jerusalem as the capital of Israel, after the War of Independence, was rapid. New neighborhoods were built in it and government offices and the Knesset were relocated to Jerusalem. To improve the electricity supply, the Electrical Company connected the Jerusalem company to its facilities and even sold electricity to it. On February 14, 1952, and agreement was signed for the purchase of the Jerusalem Company, but its approval was delayed until October 1954, when the Jerusalem Company started operating as a subsidiary of the Electric Company. In 1964 the two companies merged and Jerusalem became the Company's third district by joining its two existing districts, Northern and Southern.

On January 10, 1954, the Government nationalized the Company by purchasing 95% of its shares. The transfer of ownership to the Israeli government also resulted in the relocation of the offices of its board of directors from London to Israel, and for the first time, in late 1954, a new and entirely Israeli board of directors was formed.

Academy in Israel



The cornerstone for Technion Institute of Technology in Haifa was laid in 1912. In 1923 Albert Einstein visited the building.

The Department of Electrical Engineering in Technion (Haifa) was established in 1937 and was de facto the first Technological School in Palestine.



One of the founders of Electrical Department and in time, the future Decan of Electrical Engineering Faculty was Physicist **Franz Heinrich Ollendorff** (1900–1981). Professor Ollendorff received his PhD. from Humboldt University of Berlin - Germany in 1921. He was a student of Max Plank and assistant to Albert Einstein and worked in Max Plank Institute. His Advisor for doctorate was Hans Lorenz. After he finished his studies he moved to University of Danzig where he performed a Research on radio frequencies. He prepared generations of students and wrote books which were used in Israel.

Professor **Jehuda Naot** (1910–1996), another very known lecturer in Technion was born in Germany in 1910, receive its engineering degree and PhD in Scuola per Ingenieri, Padua, Italy in1933 and later worked in University of Ferrara (1933–1934), Polytechnic Institute of Brooklyn, N.Y. (1963–1964). He worked in Technion since 1937 and as a Professor since 1966. Professor Naot prepared generation of engineers in High Voltage, Overhead and Cable Lines.

Professor **Michael Erlicky** (Erlich, 1924–2011) was born in Lodz, Poland and with the beginning of the Second World War in 1939 stopped his school studies in 1940 and was moved to Ghetto Lodz. In 1944 his family were transferred to Auschwitz. After liberation by Russian Army from concentration camp in 1945 he restarted his studies in Lodz Polytechnic where he received his MSc. in 1949 and in 1954 finished his doctorate. Until 1957 he worked in Lodz Polytechnic. In 1957 he emigrates to Israel and immediately started to work in Technion, Haifa. He prepared 13 students for PhD. degree and 60 students for Magister degree. For many years he was Vice Dean for Technical stuff. He was involved in High Current issues – Planning and Optimization of High-Power Systems, Electromagnetic circuits, Transformers, Electrical Machines and large Electrical Systems. He significantly influenced the development of Israeli industry and especially the development of electrical infrastructure.

Professor **Juliush Preminger** was born in 1924 in Lodz Poland. After Second World War start his studies in Vrotzlav and in 1952 received Doctor Degree. He emigrates to Israel in 1957 and worked in Technion, Haifa on issues of control and operation of Power systems. In 1962 he became a professor and in 1967 full professor.

Professor **Avraham Aleksandrovitch** was born in 1928 at Grodno (Poland) and after his studies in Technical University in Shetzin he received his first degree in 1951. In 1956 he received his Magister degree in the next year was accepted for doctorate studies. In 1957 he Immigrate to Israel and started to work as assistant and lecturer in Technion Institute of Technology. His expertise was in Electrical Generators and Motors.

The 1970's: The coal revolution

In the early 1970s, the IEC's reached close to one million customers. It was decided to build a particularly large power plant to meet the growing electricity demand. The plan was to set up 4 units near Hadera (capacity of 350 MW each), enabling a 60% increase from existing 1,451 MW of installed capacity nationwide. The coal unloading at the station, as imaginary as it may seem, was planned to be made directly from the ships, to a pier to be built at sea, without any breakwater protection, 2 km from the shore – unprecedentedly elsewhere in the world. The dock construction was operational and proved been economically justified. In 1984 all the plant's units operate at full capacity after the completion of this complex project. In the 1980s the National Center for Load Control (the system management unit) was also established to supervise the soundness of the various production units installed throughout the country, and their remote operation, automatically if necessary. A new Power Plant "Rotenberg" in Ashkelon (2 units, of 550 MW each) began operating in 1990, exemplified Hebrew work at its best: entirely "blue-and-white" design, executed the engineering stuff of IEC's design department, promoting local industry by increasing the local investments in site components. In 2000, a second offshore dock was operational for "Rotenberg".

The National Electricity Carrier

During the 1990's, in preparation for the operation of the Rotenberg power plant, IEC began installing a 400 kV UHV power line – the "National Electricity Carrier" alias the "Electricity Highway", for the inter-connection of more and more stations. By the end of that decade, it was already stretched from Zeb-

ulon switching station in the north, through Even Sapir switching station in the Jerusalem area in the east and until "Ramat Hovav" in the south, enabling optimal utilization of the production system, as it was established in a circular structure, having the capability to feed on parallel interconnected lines, providing maximum backup for electricity flow, especially in an "electric island" country like Israel.

Opening to Competition

As of mid-2020, IEC served about 2.9 million households, commercial, agricultural and industrial customers throughout the State of Israel being a unified company (99.85% of IEC's share capital is held by the State), producing, transmit, deliver and supply the greater part of the electricity in Israel. The installed output of its facilities reached 12,752 MW, produced by 16 production sites, operate 5,661 km of a transmission network, 66,670 km of high voltage and low voltage lines, 11 switching stations and 148 substations. Following the end of electricity supply concession for IEC in Israel, in 1996 after long debates, the Electricity Sector Law was passed, shifting the sector from a franchise regime to regulation by forming a licensing regime as basis for a competitive economy: "The purpose of this law is to regulate the activity of the electricity sector for the public benefit, while ensuring reliability, availability, quality, efficiency and energy efficiency, all while creating conditions for competition and minimizing costs". The law promoted the ability to introduce competition within the market, with an emphasis on private production, prescribing also the establishment of the Electric Public Affairs Authority (PUA) as an independent regulatory entity that determines the tariffs in the electricity sector. Only in 2013 did private manufacturers began to essentially enter the electricity sector while IEC, as a vital service provider, have to purchase the entire private produced electricity.

As of end of 2019, IEC produces 67% of the total installed capacity in the market and by the end of 2020 the share reduced to 54.7%.

The 2000's: The natural gas age revolution

In 2004 the gas transition begun, starting with "Eshkol" power plant in Ashdod, and since then IEC incorporated natural gas as a significant fuel in its production system: this fuel is cheaper and cleaner than coal, fuel oil and diesel, assuring an overall significant reduction of the resulting generation process emissions, particularly SOX and NOX. This move

was important to IEC and practically revolutionized the entire economy. In addition, 2 significant actions assisted in salvaging the electricity sector from its distress, setting IEC and the State of Israel at a course to a new era of energetic independence:

1. The discovery of large gas reservoirs ("Tamar" - off the coast of Israel) and their integration within the production system in 2013.
2. The construction of a liquid natural gas float (LNG) serving as offshore connection point for vessels unloading natural gas into the offshore Israeli's gas pipeline.

Since 2015 IEC chose to construct new stations and convert existing production units into bi-fuel units that can consume other different types of fuels when needed. By the end of 2019, natural gas began to flow also from the second discovered "Leviathan" gas reservoir. By the end of 2019 the fuel map of electricity production divides as follows: 53.1% natural gas + LNG, 45.8% coal and 1.1% diesel and fuel oil.

The National Plan: Smart use of electricity and energy efficiency

The high standard of living and continued increase in demand, but with limited ability to generate more electricity, in 2007, the Ministries of Energy, Environment and IEC commonly launched a National initiative for "smart use" of electricity, with focus on reducing the electricity demand, promoting energy efficiency, to avoid shortage management situations. At the time, IEC's production capacity reserves were, for a considerable period of time, only 4%, compared to typical production reserves worldwide of at least 25–20%.

Alongside with different actions and out of IEC's commitment to its customers, the production reserves where completed in 2010 (1st stage), with 5 new production (~ 1,000 MW), and subsequently, the installation of steam additions of "combined cycle" (CCGT) in several gas turbine stations in the following years (2nd stage). Since, IEC continuously transformed a significant number of gas turbine stations into CCGT power plants, and constructed new plants based on this technology. The efficiency of a power plant utilizing CCGT reaches 56%.

Environmental protection and sustainable development

The IEC includes environmental responsibility thru long-term sustainability with minimal footprint of its activities. The environment topic constitutes an integral part in daily IEC operations, and subject to comprehensive regulation and scrutiny by public and municipalities.

IEC uses state-of-the-art manufacturing technologies and high-quality fuels (with reduced sulfur content), strictly monitors its production processes and executes emissions reduction projects - all to ensure a continuous reduction in the environmental impacts.

Renewable energies

Since 2008, the Ministry of Energy promotes the solar sector as per quotas set by the Israeli Government. For 2020 the target was set to 10%, to 13% by 2025 and 30% by 2030.

The Israeli government is committed to the Paris climate agreement and is close to getting 10% of its electricity from renewable sources by 2021 and planning 30% in 2030.

Society in the Cyber Age

IEC, critical service provider, is committed to supplying electricity at any given time and in every situation, especially during emergencies. The cyber warfare is a strategic threat to IEC, defending daily against hundreds of thousands of cyber-attack attempts against IEC's systems the most cyber-attacks attempts in Israel. To ensure the continued existence of the infrastructure and computing systems, in 2014 IEC established an innovative cyber war room. The system includes a world leading monitoring, detection, command and control system, and manned 24/7 by a team of skilled experts, analysts, development professionals and information security professionals. The accumulated experience and skillfulness of IEC in many technological and professional fields, especially in the field of critical infrastructure protection, and in the IT fields, has quickly made it an expert in this area as well. Today, IEC advises and provides training in various fields, and even leads toward collaborations with other countries.

The decentralized electricity revolution

The upcoming decentralized electricity revolution is founded on three main capabilities: Renewable energies, electricity storage and smart grids. In about 20 years, this real technological revolution will end the era of the large power plants, by means of smart communication, C&C systems, as well as advanced IT systems. As a first step toward this future, IEC initiated the installing of Advanced Distribution Management System (ADMS) capable of comprehensive management of decentralized production sources, synchronizing the received network information, operates automatically and have "self-healing" capabilities.

In 2016, smart meters were introduced, transmitting consumption data over low-voltage power lines to the national energy metering management center. For its various operations in field of Sustainability and Corporate Responsibility IEC has been awarded for several years in a row the maximum rating of MAALA indexPlatinum+.

Community Involvement

IEC initiates dialogue with the communities adjacent to its facilities and, through youth education programs in schools and in the community, promotes the formation of a conscious and behavioral change with respect to energy efficiency. Since 2005, IEC has been conducting the "Path of Light" program - an educational-community leading program for the safety and smart use of electricity. Guided by 170 company employees and its retirees, the program is successfully implemented in all sectors (over 200 local authorities and in thousands of schools and kindergartens). To date, over a million students have been trained within this program.

Communication Project – A groundbreaking National project

IEC established an advanced fiber-optic communication infrastructure over ultra-high voltage and high voltage lines, as part of the ongoing C&C system for electricity generation and Transmission processes. Further down the line, for the purpose of selling services on a business basis, it was decided to take advantage of the fact that this infrastructure exists anyway, and that the company has tens of thousands of electricity poles that can serve as the basis for rapid deployment of an optic fiber network.

Starting with 2010, IEC slowly implements a groundbreaking technologically most advanced nationwide communication project, deploying fiber-optic communication infrastructures throughout Israel. This infrastructure will enable to provide home and business customers with ultra-fast communication, positioning Israel at the forefront of the world's developed countries.

Reform

In June 2018, a historic Governmental decision was passed, approving the electricity sector reform. This is a historic milestone for IEC and its purpose is to ensure the stability of the production and the supply, while maintaining competitiveness and profitability for the benefit of all households and the industry in Israel. The reform included several key axes, including:

- Transferring the ownership of the system management unit from the hands of IEC to a separate Government company to ensure full competition between the producers in the market;
- The sale of several IEC plants with a production capacity of 4,500 MW to the private market; - The construction of 2 CCGTs by IEC and the preservation of 4 coal units at "Orot Rabin";
- Opening of the supply section for competition;
- Setting financial stability goals for the company;
- Currently, in the middle of profound structural change, IEC continues its endeavor to streamline and consolidate its financial strength, permanently increasing its efforts for intelligent network development and to enter in new and competitive areas of activity.

Israel, the Energy ("e") Island

Energy security has re-emerged as one of drivers of European energy policy and even of the EU's external policy. For Israel, energy security has always been the main objective of energy policy, and it is probably the most affected country by energy geopolitics in recent history. Israel is an e-Island: its network is not connected to the systems of its neighboring Countries. With the discovery of 800 BCM of natural gas off its shoreline in 2009, Israel is phasing out Diesel and coal-fired Power Stations, replacing with mostly gas-fired Generation and PV. Israel is interested in considering its inclusion in a potential Pan-Euro-Mediterranean Energy Region modeled after EU regulations and policies. Israeli policymakers long favored a proposal to build a pipeline to Europe through Turkey. The most ambitious proposal is to build the world's deepest and longest pipeline, to Italy through Cyprus and Greece.

12.2 CIGRE in Israel

As a Technical Association, CIGRE was less popular among Israel's Academy stuff, inside Industry's professionals and less known even along Local Communities of engineers, this until 1997. In 1983, only two engineers were recorded to have paid their membership fees:

- Eng. Eli Neutra MSc.: then Head of R&D Laboratory in Chief Engineers Division of Israel Electric Corporation (IEC), being the only one receiving the famous CIGRE Journal.

- Eng. Alex Levinzon MSc.: a young engineer in the same laboratory starting his CIGRE membership in the same year and founder of CIGRE NC Israel in the future.

It was only after 14 years that the conditions were appropriate to organize the first CIGRE meeting and to establish the Israel National Committee. This historic meeting was held in Haifa, on June 3rd, 1996 and more than 30 people attend it, among them:

- Chief Engineer of Israel Electric Corporation (IEC)
- Head of R&D Division (IEC)
- Head of Design Division (IEC)
- Chief Engineer of Transformer Manufacturer (then ELCO)
- Chief Engineer of Cable Manufacturer (then CVALIM)
- CEO of Switching Equipment Manufacturer (then FEUICHTWANGER)
- Prof Julius Preminger (Technion Institute of Technology)
- Prof Avraham Aleksandrovitch (Technion Institute of Technology)
- Representative of Siemens Israel Switchgear Manufacturer (then MITUG)
- Head of Transmission and Substation Division (IEC)
- CEO of ENERLEC Company, and others.

In 1997 the CIGRE NC Israel was legally registered following the unanimous vote of its members on the Internal Statute Document - signed by the Founders members and approved by CIGRE AC in Paris. Today CIGRE NC Israel has 55 members, most of them actively involved in different SC and WG. Our Distinguished Members are very well-known specialists and contributors in CIGRE realm: Bruno Fainaru, Anatoly Shkolnik, Alex Levinzon, Marcel Ellenbogen.

In 2011, NC-Israel hosted the SCC3 and it's WG's annual meeting in Dead See Resort and Tel Aviv.

The subsequent International Symposium on

LONG DISTANCE AND CROSS BOARDERS ELECTRIC POWER SYSTEM INTERCONNECTIONS: STRATIGIC NEEDS, SUSTAINABILITY, ENVIROMENTAL AND SOCIAL ISSUES

is one of the most successful one in the history of SC C3, taking into consideration the 2 main subjects discussed there:

- MEDGrid: Development of Interconnections in the Mediterranean basin, as well as between Southern and Eastern European Countries with Europe, in the framework of the Union for Mediterranean

- European Commission - Smart Electricity Systems: Role for HVDC backbone or super grids.



Fig. 12.1 Cigre Colloquium in Israel

Each year NC-Israel organizes 2 Colloquiums.
The most appreciated subjects in the last 5 years were:

- *Civil Applications of Drones.*
- *New Technologies, Tests and Monitoring.*
- *Solar and Storage Technologies, Design, Integration in the Grid.*
- *Electricity Markets and Regulation.*

The CIGRE NC – Israel is currently managed by:
Alex Levinzon – Chairman and Marcel Ellenbogen - Secretary



Fig. 12.2 Alex Levinzon and Marcel Ellenbogen

12.3 Israeli electricity systems characteristics today

Basic facts

- Area: ~ 22,000 km²
- Population: 8.8 Mil
- Number of TSOs: 1 and one TMS
- Number of DSOs: 6, only 1 in the next few years
- Peak load: ~ 13,000 MW
- NO Interconnections "ELECTRICITY ISLAND"

Transmission

Transformation System

- Switching Stations: 11
- Substations: 147
- Private Substations: 49

Power Lines

- 400 kV: 760 km
- 161 kV: 4,525 km
- 115 kV: ~ 100 km

Distribution

Capacity

- Medium & Low voltage lines: ~ 50,000 km
- Distribution Transformers: ~ 48,100
- Customers: ~ 2.8 Million

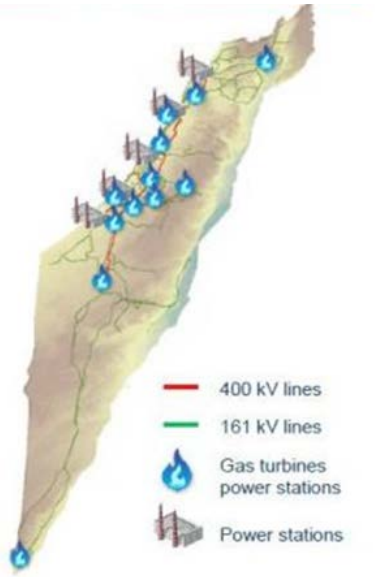


Fig. 12.3 Israel power system

12.4 References

1. Investor presentation, Israel Electric Corporation, Business update as of 12/31/2019, April 2020. https://www.iec.co.il/EN/IR/InvesrorR/IEC%20Investor%20Presentation%202019FY%20Final%20(English).pdf

13. NC KOSOVO

13.1 History of electric power sector

a) Early time of electricity

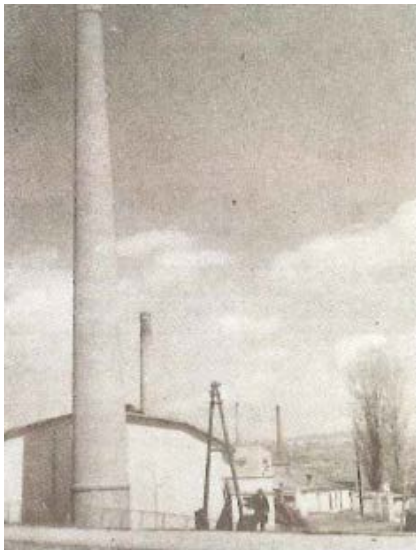


Fig. 13.1 TPP, 60 k VA, Prishtina 1927

For the first time, electric lamps in Kosovo began to illuminate in 1922 in the city of Ferizaj by means of a 25 kVA generator. This plant managed to operate only five years (1922–1927). Later, the diesel power plant "Kosova" was built in 1926 to produce electricity only for industrial needs, with capacity of 50 kVA.
In 1927, the power plant with a capacity of 60 kVA started operating for the first time in Prishtina, whereby Prishtina's electrification was made possible, lighting some of the main streets. In 1927, in the village of Magure, the electric power plant "Goleshi" was built for the needs of the Golesh mine, with capacity of 90 kVA.

During the same year (1927), in Mitrovica, a small hydro power plant ,capacity of 70 kVA on the Iber River started operating, whereby Mitrovica's electrification was made possible for the first time. A year later, in 1928, the English company "Mines Trepça Limited" installed a diesel generator in Stanterg with a capacity of 100 kVA.



Fig. 13.2 HPP, 50 kVA, Mitrovica, 1927



Fig. 13.3 Combined Plant (diesel-hydro) in Peja, 110 kVA,1928

In 1928, a diesel generator with a capacity of 110 kVA was installed in Peja, whereby Peja's electrification was made possible for the first time. During the day, electricity was used for the needs of the mill, while at night it was used for lighting some of the main streets and about 75 households with 1–2 electric light bulbs.

In 1929, a hydro power plant was built on the Lumbardhi River in Prizren with a capacity of 160 kVA, enabling the lighting of Prizren.

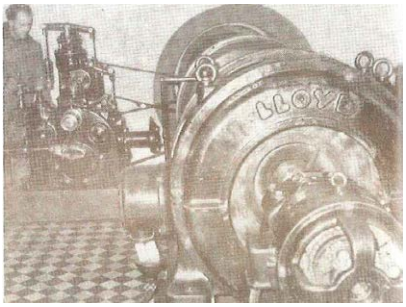


Fig. 13.4 HPP, 320kVA, Prizren, 1929

Table 13.1 Main Power Plants constructed in Kosovo till 1938 (before WWI)

No.	Location/City	Installed Power (kVA)	Type of Power Plant	Construction Year	Dedicated
1.	Ferizaj	25	diesel	1922	public
2.	"Kosova"	50	diesel	1926	industrial
3.	Prishtina	60	thermal	1927	public
4.	Mitrovica	70	hydro	1927	public
5.	Peja	110	diesel-hydro	1928	public
6.	Prizren	160/320	hydro	1928/1936	public
7.	Trepça - Zveçan	1560, 2250 3740, 9300	thermal	1930, 1932 1934, 1938	industrial
8.	Çeçevë	540	hydro	1930	public
9.	Radavc	180	hydro	1934	public
10.	Gjakova	300	diesel	1937	public

In 1938, the hydro power plants of Radavci and Mitrovica were put into operation, which at that time supplied the cities of Peja and Mitrovica. HPP Radavci had a capacity of two turbines of 180 kW each, a total of 360 kW, which were enough for public lighting of Peja and some customers. The same level of lighting continued until after World War II. After the WWII, the further development of the country's electrification began. In 1945, the distribution company "Elektrokosova" was established by the Assembly of Kosovo.

Electrification was increasing rapidly in the 1950s. The construction of the genuine electricity grid began with the commissioning of the Kozhnjer Hydro Power Plant in Deçani, in 1957. This had a capacity of 3.3 MW in each of the two turbines, namely 6.6 MW in total.

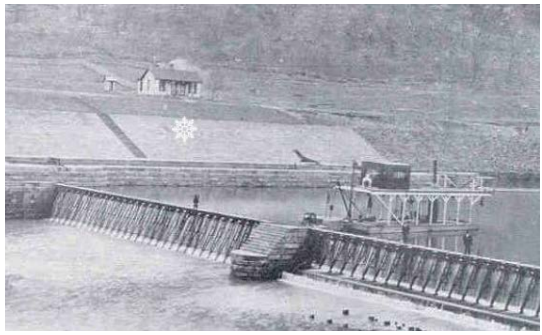


Fig. 13.5 HPP Kozhnjer, 2 x 3.3 MW, Decan, 1957

Following the construction of the first HPP Kozhnjer in Deçan, the first 35 kV line was built to distribute energy from this hydro power plant. At the same time, the first block of the thermal power plant "Kosova A" was put into operation, having a capacity of 65 MW, which mainly generated electricity for consumption outside Kosovo.

b) First connection of AC three phase electricity

The installed capacity of 65 MW, as the first unit of TPP Kosova at that time was the largest Power Plant in Southeast Europe (Balkans). It was commissioned on October 21, 1962. Due to the increased electricity demand following the Kosovo's economic growth and urbanization, during the years (1964–1975) in TPP Kosovo A were added new units:

- Unit A2, 1964, with installed capacity of 125 MW
- Unit A3, 1970, with installed capacity of 200 MW
- Unit A4, 1971, with installed capacity of 200 MW
- Unit A5, 1975, with installed capacity of 210 MW



Fig. 13.6 TPP Kosovo A, 1 x 60MW, Obiliq, 1964

The installed capacity of 65 MW, as the first unit of TPP Kosova at that time was the largest Power Plant in Southeast Europe (Balkans). It was commissioned on October 21, 1962. Due to the increased electricity demand following the Kosovo's economic growth and urbanization, during the years (1964–1975) in TPP Kosovo A were added new units:

- Unit A2, 1964, with installed capacity of 125 MW
- Unit A3, 1970, with installed capacity of 200 MW
- Unit A4, 1971, with installed capacity of 200 MW
- Unit A5, 1975, with installed capacity of 210 MW

At the end of 1975, the total installed capacity of TPP Kosovo A (5 units) was 800 MW of electricity. As energy demand from industry and household customers continued to increase the construction of the TPP Kosova B began in the late 1970s.



Fig. 13.7 TPP Kosova B, 2 x 339 MVA, Obiliq, 1980

The first Unit B1 of TPP Kosovo B with installed capacity 339 MW was commissioned in 1983, while Unit B2 with the same capacity 339 MW was commissioned one year later, in 1984. Both units with 678 MW added to the existing 800 MW, totaling over 1400 MW of installed capacity.

The 1970–1980 decade was the time when Kosovo made the greatest progress in its history. In addition to political advancement and the development of education, the economic development also increased rapidly. It was this decade when most of the country's electricity grid was built. Kosovo's electrification was officially completed in 1983, when the entire territory of Kosovo, including the villages, was energized.

c) Development of Electric Power System

The history of the development of the Kosovo Electricity System is as early as the beginning of the construction of the first large energy-generating capacities. Thus, the first 110 kV transmission line was built in 1955 but it only began to be utilized as a 110 kV line in 1958, which was originally built between SS Vallaçi and SS Buteli (Skopje/Northern Macedonia), dedicated mainly to industrial needs, to then continue with other 110 kV lines to connect other substations such as SS Prishtina 1, SS Prizreni 1, SS Gjakova 1, SS Peja 1, SS Ferizaj 1, and others.

A few years later, by the end of the 1960's, the first 220 kV lines were built in parallel with the construction of new generation units in TPP Kosova A. The first 220 kV overhead power line is the line built in 1960 between SS Kosova A and SS Krushevci (Serbia), to then continue with the construction of other 220 kV lines with Macedonia and Albania during the years 1977 – 1983 – 1988.

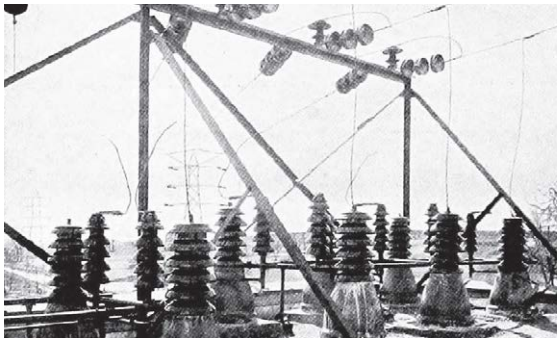


Fig. 13.8 Substation and HV Switchgears, 1960's

In the second half of the 1970s and early 1980s, the first 400 kV lines were built to connect the 400 kV Kosovo Electricity System with Serbia, Macedonia and Montenegro parallel with the construction of new generation units in TPP Kosova B. In 2016, the newest 400 kV interconnection line was built between Kosovo and Albania, having a length of 243 km.

13.2 History of CIGRE in Kosovo

The National Committee CIGRE Kosovo was established in 2016, following earlier initiatives after the war of 1999, for the establishment of the NC CIGRE Kosovo. Subsequent to the establishment of the NC, application for membership to CIGRE Central Paris was submitted. NC CIGRE Kosovo, represented by the Vice chairperson Pranvera Dobruna Kryeziu, was officially recognized as the 59th member of CIGRE International during the Administrative Council meeting in Auckland, New Zealand in 2017. In the same year, NC CIGRE Kosovo became the 16th member of the regional CIGRE – SEERC.

a) Kosovo participation in the former Yugoslav CIGRE Committee activities (1953–1990)

The participation of Kosovo, as a part of the membership of former Yugoslav CIGRE Committee was active through the participation of numerous university professors, experts and electrical engineers.

b) Short History of the National Committee of CIGRE Kosovo

Founded under the Electro technical Society of Kosovo, NC CIGRE Kosovo welcomed the participation of Industrial Companies from energy sector of Kosovo such as: generation, TSO, DSO, supply, private and public universities etc.

Table 13.2 Elected leadership of NC CIGRE Kosovo for 2016–2020

Period	President	Vice President	Secretary
2016–2020	Mehmed Bula	Pranvera Dobruna Kryeziu	Xhevat Lila

13.3 Activities and achievements of NC CIGRE Kosovo

The year 2019 marked NC CIGRE Kosovo's first international event, whereby the Committee organized its First Conference, enriched by sixteen Study Committees which processed a total of forty-five papers on a multitude of preferential topics submitted from Kosovo, Albania, Croatia and Northern Macedonia. The first CIGRE Conference of Kosovo was held on 06–08 November 2019, at Hotel SIRIUS in Pristina city, Kosovo.

Table 13.3 The list of conferences organized by National Committee of CIGRE Kosovo 2017 to 2019

No.	Place/ City	Country	Year	Number of Participants	Number of Papers	Papers form Kosovo	Abroad papers
1.	Pristina	Kosovo	2019	178	45	33	12



Fig. 13.9 First Conference of NC CIGRE Kosovo, November 06–08, 2019, Pristina, Kosovo

13.4 Country electric power profile / RES vision

Consumption: **6070** (GWh)
Amount of household consumption in %: **~42%**
Seasonal Peak load: **759** (MW) for summer (Jul); **1253** (MW) for winter (Dec)
Population: **1,782,115** according to the latest (2019) census estimates

Generation: Installed capacity **1,430** (MW); Annual production **5,718** (GWh)

Thermal: Coal **1,288** MW/ **5,403** GWh
Hydro: Hydro / run of river **49** MW/ **156** GWh
Renewables:

- Wind **34** MW/ **91** GWh
- Solar (PV) **10** MW/ **11** GWh
- Other RES **49** MW/ **57** GWh

Transmission overhead lines and cables (AC): 400 kV, 220 kV and 110 kV
Overhead lines length for all transmission voltage levels:

- **1,411** km (installed)

Power Transmission Transformers:

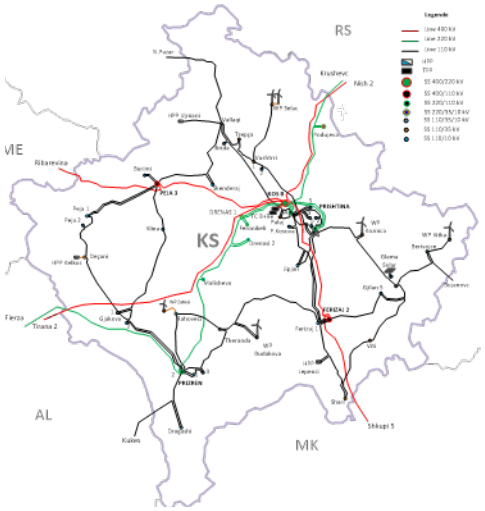
- 3 Autotransformers (400/220 kV)
- 4 Autotransformers (400/110 kV)
- 9 Autotransformers (220/110 kV)
- 71 Transformers (110/x kV)

Distribution Network (AC): 0.4 kV, 10 kV, 10(20) kV and 35 kV

- Circuit length for all distribution voltage levels: **27,309** km
- Distribution transformers (0.4 – 35 kV): **4,762** number of units
- Approximated employees' average number in Electricity Supply Industry*: **~8,000**

Population	1,782	milion
Area	10,905	km²
GDP/capita	3,815	€

Transmission Network – 2019	
Voltage level	**Length (km)**
400 kV	280
220 kV	238
110 kV	877
110 kV under-ground cable	16



Generation of electricity in Kosovo 2019		
Thermal Power Plants	**5,403 GWh**	(94.5 %)
Hydro Power Plants	**156 GWh**	(2.7 %)
RES	**159 GWh**	(2.8 %)
• Small HPP • Wind • Solar • Other		

RES Future vision - Scenario till 2030			
Planned	**2020**	**2025**	**2030**
Wind	34 + (105)	184	336
Solar	7	70	150
Small HPP	49	91	103
Biomass/Gas	0	14	130

13.5 References

1. Kosovo Energy Corporation, History of electricity in Kosovo, Documentary Film, 1978, www. kek-energy.com
2. KEDS & KESCO, "The history of electrification in Kosovo from the first light to the last house", October – December 2018, www.keds-energy.com, www.kesco-energy.com
3. Transmission, System and Market Operator of Kosovo, Transmission Developed Plan 2018–2027, September 2018, www.kostt.com
4. Energy Regulatory Office of Kosovo, Annual Report, 2019, www. https://www.ero-ks.org
5. Ahmet Drini, MONOGRAFI për Ndërmarrjen "ELEKTROKOSOVA" – Distribucioni në Prizren 1929 –2014, Shënime dhe kujtime, Prizren, 2015
6. Kosovo Agency of Statistics, Statistical Yearbook, 2019
7. Archive of National Committee CIGRE of Kosovo, 2016 – 2019

For further information contact:
NC CIGRE Kosovo
Str. Isa Boletini no. 39, 10000 Pristina
Kosovo
WEB: www.cigre-ks.com
E-mail: info@cigre-ks.com

14. NC CIGRE N. MACEDONIA

14.1 History of the electricity sector

The electrification on the territory of the Republic of North Macedonia has begun in Skopje, in 1909, when the first thermal power plant (TPP), shown in Fig. 14.1, started its operation. The installed capacity of the power plant was 45 kW DC power and it operated on voltage level of 220 V. The electricity from this power plant was used for supplying an electrical pump in the city water utility, the lighting of the municipality building, the house of the Turkish vali and a single city street.



Fig. 14.1 The first TPP in Skopje, built in 1909

The other cities on the territory of North Macedonia were supplied by small diesel aggregates. Until the end of the Second World War, two TPPS and two hydro power plants (HPPs) were built. The first one was the HPP Pena (1.76 MW), which started its operation in 1927, followed by the TPP Diesel (1 MW) in Skopje in 1933, the HPP Matka (4.16 MW), in 1938 and the TPP Probishtip (1.28 MW) in 1940. Both HPP Pena and HPP Matka were connected to the city of Skopje by two 35 kV lines with total length of 60 km. These overhead lines are the first elements of the transmission system on the territory of North Macedonia.
HPP Pena was damaged in the floods of the Pena river in 1979, but it was fully reconstructed in the period of 1980–1984 and it operated with installed capacity of 2.5 MW. In 2008 a project for automatization was conducted and the plant was reconstructed once again. The reconstruction led to increase of its capacity,

which at present, is 3.3 MW. It has two Francis turbines and two synchronous generators, of 2 MW and 1.3 MW. The net drop is 72 m and the average annual production is 13 GWh.

HPP Matka was built on the river Treska, just at the end of the Matka canyon (Fig. 14.2), at about 14 km outside of Skopje. The construction of HPP Matka followed the construction of the first artificial lake in the country, which started in the thirties of the last century. The civil works for the HPP Matka started in 1935 and the construction was completed in 1938 when HPP Matka started its operation. In 2008, the water inlet system was reconstructed and a completely new HPP was built at the same location. The installed capacity of the new HPP Matka is 9.6 MW, it has a Caplan turbine with vertical axes and a synchronous generator with a static excitation system. The average annual electricity production of HPP Matka is about 30 GWh. The old HPP Matka was decommissioned and in 2016 it was turned into a museum (Fig. 14.3). Since 1994, the area surrounding HPP Matka is considered as monument of nature. The lake is also famous for its underwater cave Vrelo, which is among the deepest caves in Europe, with more than 200 meters of depth.



Fig. 14.2 Matka Canyon



Fig. 14.3 HPP Matka



Fig. 14.4 HPP Matka Museum, the old machine building and equipment



Fig. 14.5 Construction of the hydro-power system Mavrovo (1947–1960)

The end of the Second World War and the establishment of People's Republic of Macedonia as a constitutional part of the Yugoslav Federation, mark the second phase of the development of the electricity system. At that time, first electric power company was established, which was the basis for development of the power utility company that would exist in different organizational forms in the years ahead. The construction of the few small plants started right after the Second World War, with the TPP Madzari, followed by the HPPs Zrnovci, Pesocani, Sapuncica, and Dosnica. In 1949, the concept for development of a 110 kV network was developed. Its realization started with the construction of the 110 kV transmission line Skopje-Veles, which was 38 km long and was operated as 35 kV line until 1960.

This period also marked the beginning of the development of the hydro-power system Mavrovo, consisting of the artificial lake Mavrovo with total water accumulation of 275 million cubic meters and three HPPs – HPP Vrutok, HPP Vrben and HPP Raven. The first phase of the construction started in 1947 and the artificial lake Mavrovo was completed in 1952. The accumulation collected the water of an area of about 500 km^2 encompassing the mountains Shar Planina and Korab by using a complex system of canals and pipelines with total length of about 130 km. Additionally, a maintenance and access road system of 167 km was built to enable access to the HPPs and the lake. In 1957 and 1958 two units were put in operation in HPP Vrutok with installed capacity of 37.5 MW respectively. A year later HPP Raven (12.8 MW) and HPP Vrben (12.8 MW) also started their operation, which meant a completion of the first construction phase of

the hydro-power system Mavrovo. The development of the hydro-power system Mavrovo required adequate development of the transmission network. Therefore, the 110 kV line HPP Vrutok – substation (SS) Jugohrom – SS Skopje 1 was built, thus marking the development of the 110 kV network. Until 1960 three 110 kV lines were put in operation, allowing connection between HPP Vrutok and SS Bitola 1, SS Skopje 1- SS Stip and a 150 kV line connecting SS Bitola with SS Lerin in Greece.



Fig. 14.6 Development of the power system until 1970

The sixties of the last century were a period of further development of the electricity sector. During this period, activities for utilization of the hydro potential of the Crn Drim basin commenced. Consequently, in 1965 HPP Globocica (42 MW) and in 1969 HPP Spilje (70.2 MW) started their operation. In addition, during that period, two other HPPs were put into operation – HPP Tikves (two units each 46 MW) in 1968 and in 1970 HPP Kalimanci (12.8 MW). In this period the first ring in the 110 kV network was completed and two connections from SS Skopje 1 to TPP Kosovo A were established, as depicted in Fig. 14.6.

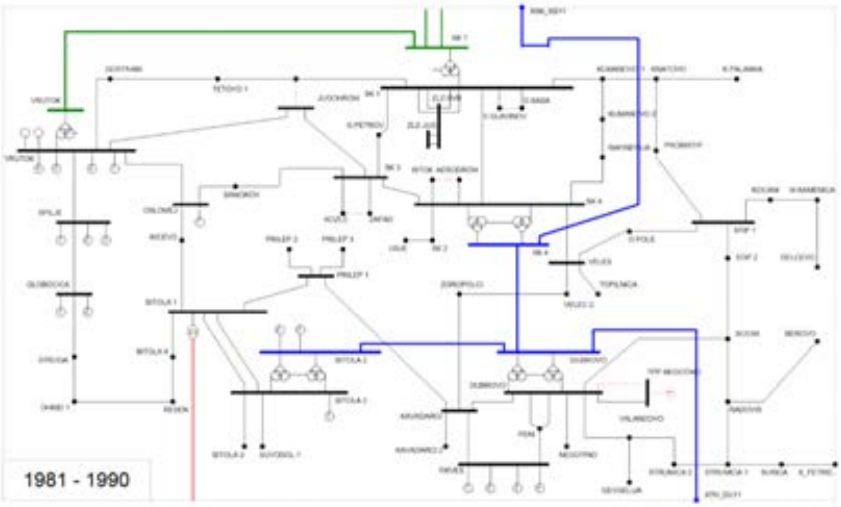


Fig. 14.7 Development of the power system 1981–1990

By the end of the seventies, two large TPPs were build and the project for building TPP Bitola has already started. The development of the 400 kV network was characterized by the construction of the interconnections with Kosovo and Greece, i.e. building the 400 kV lines between SS Skopje 4 – SS Kosovo and SS Dubrovo – SS Thessaloniki. This allowed synchronous operation of the transmission network of Socialistic Republic of Macedonia with the other socialistic Republics in former Yugoslavia and with Greece. During the eighties of the last century, the TPP Bitola was completed, so the three blocks were operational in 1988. One year before, in 1987, the transmission system of Social Federative Republic of Yugoslavia was synchronised with the UCPTE system. This period was marked by expansion of the transmission system, as described on Fig. 14.7.

Since gaining its independence, North Macedonia continued to develop and maintain its transmission network and the interconnections with the neighboring countries. At present, North Macedonia is interconnected with all neighboring countries, except with Albania. The interconnection with Bulgaria was completed and operational since January 2009 and at present, the project for building the interconnection with Albania (SS Bitola – SS Elbasan) is under development. This project will complete the Corridor 8 (East-West) for electricity transmission in the region Bulgaria – North Macedonia – Albania – Italy. The power generation sector also expanded with the completion of HPP Kozjak

(80.5 MW) in 2004, wind park Bogdanci in 2014, complete revitalization of the Mavrovo hydro-power system (increasing the accumulation capacity and the HPPs capacity) which was completed in the same year. The last decade was also characterized by increased installation of small renewable energy sources technologies – mainly small photovoltaic power plants (PPPs) and small and micro HPPs. Private investments also enabled the construction of the fist large combined heat and power plant, TE-TO (230 MW) in Skopje. Currently, the power production company – ESM is in the process of building the first large PPP. In the past few years, MEPSO has implemented a series of projects to upgrade and revitalize the transmission network. Fig. 14.8 shows the activities from a recent project of MEPSO for reconstruction of the high voltage equipment at the SS Skopje 4.



Fig. 14.8 Reconstruction of SS Skopje 4, July 2020

The period from 2004 and onwards is also related to the restructuring of the power sector. In 2005, at a time when power markets, both theoretically and in practice, were at the early stages of development on a global level, the necessary preconditions for opening a power market at a national level were established – the Energy Regulatory Commission was founded, the Energy Law was amended to establish a power market, the vertically integrated enterprise for power production, transmission, distribution, and supply "Elektrostopanstvo na Makedonija" was restructured and a power market operator and transmission and distribution system operators were established. Three separate companies were formed – ELEM – the joint stock company for electricity generation in

state ownership, MEPSO – the transmission system operator with a subsidiary functioning as market operator, and ESM – the distribution system operator and supply company. The process continued with privatization of ESM which became a part of the EVN AG Austria in 2006 and after the re-branding, it started operating as EVN Macedonia AD Skopje. The process of liberalization introduced new companies in the sector – electricity trade and supply companies and provided conditions for competition in these segments. Following the adoption of the adoption of the latest energy legislation, compliant to the Third Energy Package, the electricity market operator (MEMO) was established and the certification processes of MEPSO was completed.

14.2 History of CIGRE in North Macedonia

The history of the National Committee of CIGRE in North Macedonia is related to the history of JUKO-CIGRE, the association of power systems engineers established in 1951 in the former Yugoslavia. Macedonian engineers have been actively participating in the organization and the activities of JUKO-CIGRE. The first Conference of JUKO-CIGRE that was hosted by the Macedonian engineers was held in 1962. Furthermore, prof. Stanimir Jovanovski from the Ss Cyril and Methodius University, Faculty of Electrical Engineering in Skopje, was president of JUKO-CIGRE in the period 1980–1986.



О Д Л У К А

за основање на Македонски комитет на меѓународната конференција за големи електрични системи - СИГРЕ

Член 1

Со основа Македонскиот комитет на меѓународната конференција за големи електрични системи - СИГРЕ (во понатамошниот текст МАКО-СИГРЕ), со седиште во Скопје, на улица "Даме Груев" бр.14-а.

Член 2

Основачи на МАКО-СИГРЕ се:

а) Колективните членови:

1. ЈП "Електростопанство на Македонија" - Скопје
2. Електротехнички факултет - Скопје
3. "Електроинвест - 11 Октомври" - Прилеп
4. АД Фабрика за кабли "Жичара" - Кочани
5. АД "Раде Кончар" - Апаратна техника - Скопје
6. Рудник за бакар "Бучим" - Радовиш
7. АД "ЕМО" - Охрид

б) Индивидуални членови:

1. Ристо Миновски, ЕТФ Скопје
2. Никола Чернобаровски, Министерство за стопанство
3. Павао Андонов, ЕСМ Скопје
4. Димитар Стојанов, ЕСМ Скопје
5. Драган Никаловски, ЕСМ Скопје
6. Љупчо Јаковски, РЕК "Битола" Битола
7. Димитар Чапов, Електропренос Скопје
8. Костадин Стефановски "Електрострумења" - Струмица
9. Јасмина Мамут, ЕТФ Скопје
10. Бубомир Николовски, ЕСМ Скопје
11. Мишајло Толевски, ОЗИС Скопје

и уште 139 останати стручњаци од областа на електротехниката кои доставија пристапници за членство во МАКО-СИГРЕ.

Член 3

МАКО - СИГРЕ има за цел и задача на домашен и меѓународен план да се бави со стручни и научни проблеми од поширокото на производството, преносот, дистрибуцијата и потрошувачката на електричната енергија, како и со производството на електрична опрема, што значи дека ќе се бави со актуелните проблеми на македонското електростопанство и електроиндустријата.

Членовите на МАКО - СИГРЕ ќе имаат широки можности за свои стручни усовршувања и подигање на техничката култура.

After the breakup of Yugoslavia, a number of motivated engineers strived to continue the organized activities of the professionals working in power systems. In 1992, building on the experiences of JUKO CIGRE, prof. Risto Minovski, Dimitar Capov and Dimitar Stojanov, with the support of the transmission company "Elektroprenos - Skopje", have begun the process of establishing a National Committee (NC) in CIGRE. MAKO-CIGRE, the National Committee in the International Committee on Large Electric Systems was



Fig. 14.9 Excerpt from the Decision to establish the NC taken on 24. 06. 1996

established on 24th of June 1994 at the first meeting of the General Assembly. An excerpt of the original Decision for establishing MAKO-CIGRE is presented on Fig. 14.9. The founders of MAKO-CIGRE were seven collective members, including "Elektrostopanstvo na Makedonija", the Faculty of electrical Engineering in Skopje and a number of industrial partners from the country. Apart from the eight individual members who are the founders of the NC, 139 engineers and professionals from the power sector became members of the NC. The General Assembly verified the mandates of the presidents of the Study Committees (SCs), who had the obligation to establish the SCs and organize their work. Upon invitation of the organizers, the Vice-president of the Government, Mr. Jovan Andonov was present at the first meeting of the General Assembly. In 1996, MAKO-CIGRE became a member of CIGRE.

In 2002, by the Decision of the Executive Board of MAKO-CIGRE, the association has undergone certain transformations and 16 SCs were established, in accordance with the SCs in CIGRE Paris. The association continues to function with the following organizational structure: the General Assembly, consisting of all members of the NC, Executive Board consisting of the President, the Vice President and the General Secretary of the NC, the presidents of the SCs, former distinguished members and representatives of the industrial partners and the Supervisory Board. In 2011, aiming enhance the operational activities of the NC, a Secretariat of the NC was established. It includes the elected representatives of the NC – the President, the Vice President and the General Secretary of the NC as well as representatives from the presidents of the SCs and the industry and a former distinguished member. Past presidents of the NC are: prof. Risto Minovski (1994–2004), Mr. Aleksandar Sekerinski (2004–2013), prof. Rubin Taleski (2013–2018). At predent, the President of the NC is Mr. Blagojce Trpovski, who was elected by the General Assembly in December 2018. Former Vice Presidents of the NC were Mr. Stojko Mojancevski, Mr. Aleksandar Sekerinski and prof. Rubin Taleski. At present, Vice President of the NC is Mrs. Eva Shukleva, who was also a former General Secretary of the NC. Present General Secretary of the NC is prof. Aleksandra Krkoleva Mateska.

In 2014 the NC marked 20 years and in 2019, 25 years of its establishment. The

20 year anniversary was marked with a series of 20 events, including technical visits, public discussions and panel sessions, social events and a Ceremonial General Assembly with distinguished guests as the President of CIGRE, Prof. Dr. Klaus Frölich and the General Secretary of CIGRE, Mr. Philippe Adam, as well as representatives from the NCs of Bosnia and Herzegovina, Montenegro, Slovenia, Serbia and Ukraine. These events confirmed the dedication and voluntary work of the members of the NC and the fruitful cooperation with CIGRE and the NCs from South-East Europe.



Ceremonial General Assembly with distinguished guests from CIGRE, representatives of NCs from South East Europe and MAKO-CIGRE Secretariat, 9. October 2014



Prof. Dr. Klaus Frölich, President of CIGRE at the Ceremonial General Assembly in Skopje, 9. October 2014



Technical visit for the members of the NC– Wind park Bogdanci, 3. September 2014



Pannel discussion – Liberalization of the electricity sector, 1. July 2014

Fig. 14.10 Three of the 20 events to mark the 20th Anniversary of the NC

Among the major objectives of the NC throughout the years was to engage in the activities of CIGRE and support individual and collective membership in the international association. During the first years of the establishment of MAKO-CIGRE, the number of individual members was set at 40 individual members, which gradually grew and in 2011 there were 61 individual and 1 collective members. In 2020, the NC of North Macedonia has 55 individual members in category I and one individual member in category II in CIGRE.
Throughout the past 26 years, the members of the NC have been active participants in the events organized by CIGRE and were members of SCs and Joint Working Groups, thus shaping the history of the NC in the international environment. Prof. Leonid Grcev was member of SC 36 in the period 1996–2000 and prof. Vlastimir Glamocanin was observer in SC 37 in the period 2000–2002 and member of the SC C1 starting from 2008. Other observers were Mr. Aleksandar Sekerinski in SC 12 and SC A2, prof. Slobodan Mircevski in SC A1, prof. Risto Ackoski in SC C4, prof. Atanas Iliev in SC C4, prof. Krste Najdenkoski in SC A2, Mr. Toni Paspalovski in SC A1, Mr. Todor Angjusev in SC B5 and other observer members. Prof. Leonid Grcev was also a member of a number of working groups and task forces, as JWG 36.04, TF 33.01, TF C4.4.06, WG C4.04, WG C4.2.01, JWG C4.4.02. Other members of working groups and task forces were Mr. Ivan Kukoski in WG A1.04, prof. Milan Cundev in WG A1.19, prof. Vlatko Stoilkov in TF A1.20, Mr. Laze Dimitrievski in WG A1.13 as well as prof. Krste Najdenkoski, Mr. Milos Bukvic in WGs within SC A1, and Mr. Todor Angjusev in WG within SC B5.
MAKO-CIGRE actively participated in the idea for establishing a regional organization in the framework of CIGRE. These activities started in 2013, when the Memorandum of Understanding was signed for establishing SEERC. Prof. Rubin Taleski, who was President of the NC at that period was a dedicated supporter of the idea.

14.3 Past and present activities

Among the major activities organized by the NC are the biannual conferences. The first Conference of MAKO-CIGRE was organized from 24th to 26th of September 1996 in Struga. It had 210 participants and 79 papers were presented. Since then, MAKO-CIGRE has organized 11 conferences. The last, 11th Conference was organized from 6th to 8th of October 2019 in Ohrid.



Fig. 14.11 Opening ceremony of the first Conference of MAKO-CIGRE

Similarly to the other conferences organized by the NC in the past, the 11th Conference was very successful, with more than 400 participants, including 60 participants from abroad. After the peer-review process, 113 papers were accepted and 92 were presented at the Conference. Traditionally, one of the three utility companies – ESM, MEPSO, EVN is the general supporter of the Conference. ESM, the power generating company was the diamond sponsor of the last Conference. The support of these companies for the activities of the NC is multi-fold, i.e. apart from the financial support, their engineers are actively participating in the NC's conferences as authors of papers and participants of the conferences. The NC of North Macedonia has an excellent cooperation with both the industry and the academic community. The representative offices of global, regional and national companies are regular participants of the conferences, providing participants with overview of the latest technology developments through technical presentations, discussions and technical exhibitions. Furthermore, the support of the academic community is most significant in the preparation of scientific papers and active discussions and cooperation with fellow engineers from the industrial sector. The papers that are a result of mutual projects are very well accepted by the participants and generally, have the most fruitful discussions during the conferences.



Mr. Blagojce Trpovski, President of the NC and members of the Organizing Committee of the 11th Conference



Participants of the 11th Conference

Fig. 14.12 Opening ceremony of the 11. Conference of MAKO-CIGRE

Table 14.1 presents the list of past conferences, the number of accepted papers and participants.

Table 14.1 Organized Conferences by the NC (1996–2019)

Conf. no.	Period & Location	Number of papers	Number of participants
1	26–28 September, 1996, Struga	79	210
2	23–25 September, 1998, Struga	120	240
3	3–6 October, 2001, Ohrid	115	310
4	26–29 September, 2004, Ohrid	119	288
5	7–9 October, 2007, Ohrid	142	226
6	4–6 October, 2009, Ohrid	124	259
7	2–4 October, 2011, Ohrid	123	220
8	22–24 September, 2013, Ohrid	118	200
9	27–29 September, 2015, Ohrid	110	300
10	24–26 September, 2017, Ohrid	107	350
11	6–8 October, 2019, Ohrid	113	410

Apart from the conferences, the NC organizes technical visits, panel discussions, technical presentations and traditional social events for its members. These activities aim to provide the environment for exchanging experiences, knowledge, building and maintaining network of engineers in the field of power engineering.

The NC continuously supports students enrolled at the power engineering studies at the Faculty of Electrical Engineering and Information Technologies (FEEIT), Ss Cyril and Methodius University in Skopje as well as power engineering students from the Technical Faculty in Bitola (TFB), Ss Kliment Ohridski University. The support started in 2012, when the best three graduated students from the power system studies from FEEIT and one from TFB received rewards from the NC. The next year, the support increased, as the NC provided scholarships for the best enrolled students in the first year of studies at FEEIT and TF. Students who are authors of papers participate in the conferences organized by the NC without registration fees. Furthermore, since 2015 the NC organizes special sessions for student papers, thus promoting technical sciences, the value of engineering knowledge and the principles of CIGRE among engineering students. The NC has also been a supporter of the Student Conference on Energy Efficiency and Sustainable Development organized by the students from FEEIT since 2013.

14.4 Country power electric profile/ RES vision



- The majority of the electricity production is from the generators owned by ESM and includes thermal power plants, hydro power plants and a wind power plant. The generation capacity also includes a combined thermal power plant, small hydro plants, photovoltaic plants, biogas and biomass plants.
- Transmission system operator – MEPSO
- Network length (km) ~ 2,200 km
- Served area (km²): 25,713 km²
- Annual transmitted energy (TWh) ~ 8,130
- The 400 kV transmission lines are the backbone of the transmission grid

in North Macedonia. They form a 400 kV ring comprised of three transmission lines connecting the largest consumption located in the northern part of the country with the largest production facilities located in the south-western part. Also, the 400 kV transmission lines are used for interconnecting to the neighbouring power systems.

- The 110 kV transmission grid connects the large hydro power plants, all of the larger cities, as well as the industrial centres.

Installed capacities and annual electricity production, including RES

Technology	Installed capacity (MW)
Biomass power plants	0.6
Combined heat & power plants	287
Hydro power plants	698
Thermal power plants (lignite)	1,034
Photovoltaic power plants	24
Wind power plants	37
Biogas power plants	7

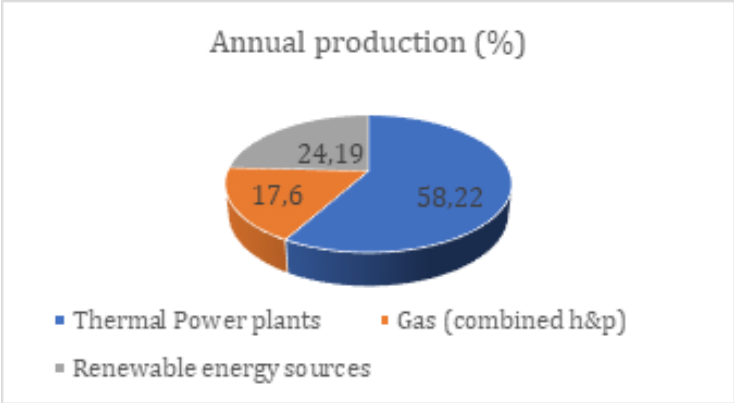


Fig. 14.13 Installed capacity and annual production in North Macedonia

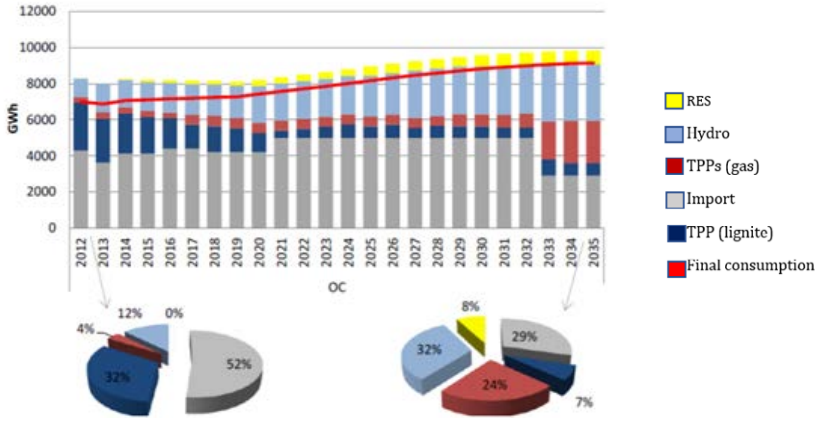


Fig. 14.14 Electricity production, Basic scenario for the developments until 2035

14.5 References

1. K. Naumoski, A. Paunoski, E. Achkoska, E. S. Atanasova (coordinator), A Study on the Development of the Transmission Network in the Republic of Macedonia in the period 2010–2020, MEPSO, Strategic Planning Department, in consultancy with Energy Institute Hrvoje Požar, Technical Faculty Bitola, July 2011.
2. EVN Macedonia Elektrani Skopje, elektrani.mk.
3. Matka Exhibition Center, Skopje, Matka.com.mk.
4. History – Energy Flows Throughout the Years, ESM-Power Plants of North Macedonia, esm.com.mk.
5. MAKO-CIGRE, 20 years of MAKO CIGRE, 2014.
6. Reconstruction of SS Skopje 4, News, MEPSO, mepso.com.mk
7. 2019 Annual Report of the Energy and Water Services Regulatory Commission of the Republic of North Macedonia.
8. D. Bajs, M. Atanasovski, A Study for the estimation of the total costs for RES integration into the power system of the Republic of Macedonia, Energy Institute Hrvoje Požar, MEPSO, April 2017.

Further information:
Faculty of Electrical Engineering and Information Technologies
attn: MAKO CIGRE
ul. Ruđer Bošković br. 18
PO Box 574
1000 Skopje, Republic of North Macedonia
mako-cigre.mk
info@mako-cigre.mk

15. NC CIGRE MONTENEGRO

15.1 History of electric power sector

At the beginning of the 20th century, the Principality of Montenegro had an area of 9,475 km², and in the first years of the 20th century, the principality had a population of just over 200,000. The majority of Montenegrin citizens lived in the countryside (more than 85%), while in urban settlements there were about 25,000 inhabitants. Today, Montenegro has about 630,000 inhabitants and an area of 13,812 km².

a) Beginnings

The first use of electricity in Montenegro began at the end of July 1904, but not for public purposes (street and house lighting), but for special purposes (power supply) for the needs of the radio-telegraph station Montenegro – Italy. Based on incomplete data and comparison with the equipment that the stations of the same type had, electricity was obtained on Volujica from at least one hundred batteries or diesel engines of at least 8 hp.



Fig. 15.1 The building of the first power plant in Cetinje

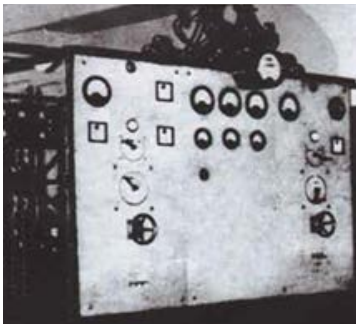


Fig. 15.2 Control panel of the first power plant in Cetinje

In addition to the construction of industrial plants and roads, the modernization efforts, which not only had economic significance, but also symbolized Montenegro's entry into the new era, include the beginning of the first power

plant in Cetinje for public use. It was on August 27, 1910, the day before the beginning of the celebration of the fiftieth anniversary of the rule of the Montenegrin sovereign, Prince Nikola and his proclamation as king, and Montenegro as a kingdom.

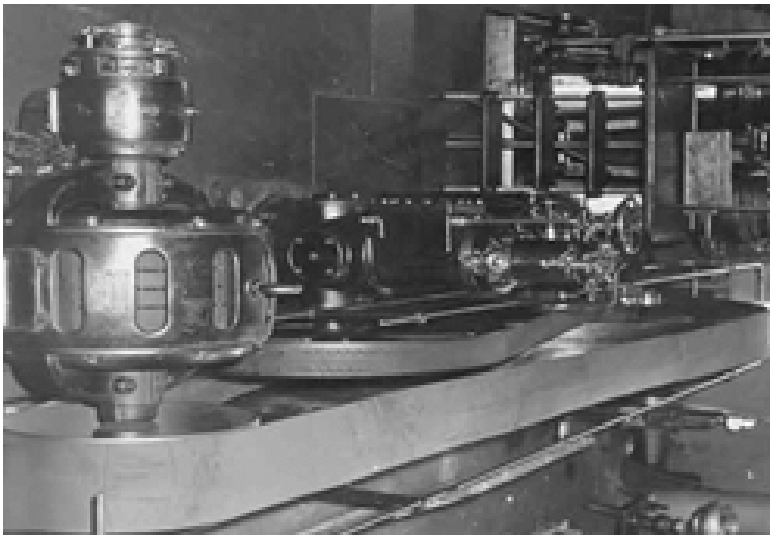


Fig. 15.3 Plant of the first diesel power plant in Cetinje

The construction of this power plant began at the end of March 1910 and was built by the company "Emanuele Kraus from Trieste (Italy)" Emanuele Kraus - Trieste / Ufficio tehnico industriale. Most of the equipment was purchased in Vienna and Graz. Two 60 hp diesel engines and two 55 kVA generators each were purchased in Graz.
This date is also an official day which is celebrated as the Day of Elektroprivreda Crne Gore AD - Nikšić, today's company. The power plant, although not in operation, is still operational and is symbolically put into operation at the celebration of the day of the Electric Power Industry of Montenegro.
The second power plant for public needs was put into operation on August 10, 1913, and was located on the Montenegrin coast in the town of Bar. This power plant had two diesel engines, with a total power of 66 hp, as well as two three-phase alternating generators, with a total power of 60 kVA. The generators produced a three-phase current with a frequency of 50 Hz and a voltage of at most 250 V.

During the war of 1916, a new power plant was installed in Montenegro, which belonged to Austria-Hungary. It was a dedicated power plant for the needs of the repair company "Arsenal"in the city of Tivat, with a power of 53 kW.
From December 1918, the Kingdom of Montenegro ceased to exist as an independent state and became part of the newly created Kingdom of Serbs, Croats and Slovenes, and later the Kingdom of Yugoslavia. The data on the number of power plants from 1938 also testify to the accelerated development of the electric power potentials of the Kingdom of Yugoslavia. In seven years, that number has grown from 618 to 781, of which 245 are hydropower plants and 356 are power plants powered by other energy sources. In the area of the Zeta's Banovina, which included today's Montenegro, there were 18 headquarters in 1931. Two years later, the number of power plants in the area of the Zeta's Banovina increased to 29, of which 15 were private, 10 municipal, and 4 military. Of these 29 power plants, 15 were powered by diesel engines, 10 by gas, and four used hydropower to power them.
Based on data on public power plants in Montenegro until 1931, the following statistical review can be reported: in addition to power plants in Cetinje and Bar, which were installed before 1918, all other power plants were established in the Yugoslav Kingdom. The power plant in Herceg Novi started operating in 1925, in Kotor in 1926, in Nikšić and Podgorica in 1927, in Risan probably in 1928, in Zelenica, Lepetani and Kolašin in 1929, while the power plant in Tivat does not state the date when put into operation. Of these eleven plants, four were municipal-owned (plants from Cetinje, Podgorica, Nikšić and Kolašin), and five were privately owned. Most power plants used diesel engines as power, while two were steam-powered - solid fuel (plants from Risan and Kolašin), and one used gas as fuel.
Of the power plants in Montenegro, the highest power in kW had a power plant in Tivat (390 kW). The gas power plant in Zelenica had the lowest power, only 8.2 kW. Power plants in Kolašin, Zelenica and Herceg Novi produced direct current, and all others three-phase.

The first thermal power plant with a power of 70 kW in Montenegro was built in Pljevlja in 1937.

The first hydroelectric power plant "Podgor" was put into operation in March 1941, and it had a power of 300 kW. It had a stone-concrete dam with a channel for bringing water to the plant, 1,100 meters long. The plant's mechanical plant consisted of two turbines from brand "Ganc", with 250 and 150 hp, as well as two generators.

Until 1941, the length of the low-voltage network was about 180 km, while the lines of the voltage level of 6 kV were about 30 km. The average annual production of electricity in Montenegro was about 1 million kWh. During the war, the existing power plants were significantly damaged and were mostly out of order.

b) Development of Electric Power System

After World War II, Montenegro was formed as a federal unit within today's borders. Enormous efforts were made to enable the existing electric plants for the production of electricity, so that in August 1945, 19 power plants were already operating in Montenegro.
At the end of 1947, there were 22 power plants in Montenegro. There were five hydroelectric power plants and 17 thermal power plants in operation. Several Montenegrin towns received electric lighting for the first time, and at the beginning of June 1947, 11 villages were electrified. The contours of the transmission network were also visible. The first 15 kV transmission line in the post-war period was built in 1946.
Due to unprofitability, diesel power plants (4 diesel power plants up to 1.5 MW) are being abandoned, and the construction of hydro power plants is starting, given the fact that Montenegro has significant hydro potential. Thus, in the period 1950–1965, the following were put into operation: HPP "Rijeka Mušovića" (1950) with a capacity of 1000 kW, HPP "Slap Zete" (1952) with a capacity of 1300 kW, HPP "Glava Zete" (1955) with a capacity of 4,400 kW and HPP "Perućica" (1964) with a capacity of 200 MVA.

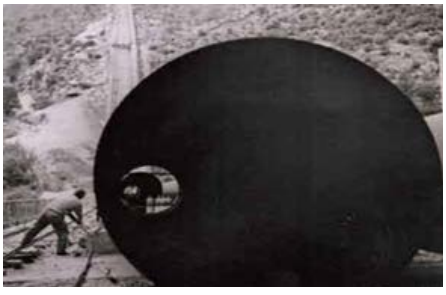


Fig. 15.4 Works on the construction of the pipeline for HPP "Perućica" in 1962



Fig. 15.5 HPP "Perućica"

This power plant itself produced 937 GWh in 1964, which was 30 times more than the total production from 1956. HPP "Perućica" was later expanded with two more generators of 65 MVA each, and today the installation of another generator of 65 MVA is in preparation and it represents the most important hydro power plant in Montenegro.



Fig. 15.6 Overhaul of HPP "Perućica"



Fig. 15.7 Overhaul of HPP "Perućica" generator

In pre-war Montenegro, there were only 11 substations, while immediately after the end of the war, by 1950, another 29 substations with a transmission ratio of 10/0.4 kV and 35/0.4 kV were built, and in the construction phase there were another 20 TS of the same transmission relations.
In the period from 1945–1953, 135 towns and villages were electrified, which was 5 times more than in 1939. In 1953, the first 110 kV transmission line Nikšić - Bileća (Bosnia and Herzegovina) was built for the needs of the Željezara Nikšić and its supply from the direction of HPP "Jablanica" in BiH. In 1966, work began on the construction of HPP "Piva" with an installed capacity of 360 MVA on the river of the same name. The power plant was put into operation in 1976.

After the construction of TPP "Pljevlja" with an installed capacity of 210 MVA in 1982, there was a long period of stagnation in the construction of new sources of electricity in Montenegro, and later civil wars and the breakup of SFR Yugoslavia, years of sanctions and blockade by the international community, caused economic collapse, and even the destruction of many businesses. The consequences of this condition have lasted or are still being felt today.

In the middle of the sixties of the XX century, the transmission network consisted of: two 110 kV transmission lines, one two-system 110 kV transmission line and two 220 kV transmission lines. At that time, the electricity system of Montenegro was connected to the UCPTE interconnection, that is, to the European electricity system. The first delivery abroad from the Montenegrin power system was made in 1972. By the end of 1971, about 500 km of 110 kV transmission lines, about 200 km of 220 kV transmission lines, 6 110/35 kV substations and 1 220/110 kV substation were built. In the first half of 1983, the construction of the 400 kV network through Montenegro was completed, as well as the unfolding of the 400 kV lines at the 400/110 kV substations to Bosnia and Herzegovina and to Kosovo.



Fig. 15.8 HPP "Piva" under construction



Fig. 15.9 Lučina dam of HPP "Piva"

In 1984, the following were also built: SS 400/110 kV Podgorica 2, SS 400/220 kV Pljevlja 2 and RP 400 kV Ribarevina as well as the second phase of the transmission line 400 kV Kosovo - Ribarevina - Podgorica - Trebinje, the southern highway 400 kV Yugoslav 400 kV network called "Nikola Tesla". This was a historic moment for the Montenegrin power system, because it was only then that it gained a strong connection with the Yugoslav power system, both east and west. The electricity system of Montenegro is thus connected to the major European electricity interconnections OES, SEV and UCPTE.

In the mid-1980s, analyzes were performed in the electricity distribution on the choice of medium voltage level and the possibilities of adopting 110/10 kV transformations, ie 110/20 kV instead of 110/35 kV. Due to the fragmentation of consumption, terrain configuration and the already built 35 kV, it was concluded that the adoption of the 110/20 kV transformation would require significant

investments for which there were no funds. Thus, the development of the 35 kV and 10 kV network with the associated 35/10 kV and 10/0.4 kV substations continued. 110/10 kV substations were built in some cities, but 35/10 kV substations were also retained.

From the commissioning of TPP Pljevlja until the beginning of the XXI century, there was no construction of new sources of electricity in Montenegro. However, in January 1992, a computer system for monitoring the operation of the Montenegrin power system was put into operation at the National Dispatch Center, which today has grown into a modern SCADA system.



Fig. 15.10 Village electrification in 1970.

The distribution network in the suburbs was previously built with bare ACSR conductors and wooden impregnated poles, but for more than 20 years it has been built and reconstructed with self-supporting cable bundles and reinforced concrete poles wherever possible. The first modern street lighting in Montenegro (mercury lamps) supplied by the Belgian company "Schreder" was given to the main street in Podgorica, in November 1970. Today, public lighting, to be more energy efficient, is being reconstructed, designed and built with LED lamps.

In the electricity distribution system, in 2011, the replacement of electricity meters with modern meters for remote consumption reading and remote control began. To date, the installation has been installed on over 85% of the meters out of a total of 375,000 distribution consumers. The implementation of the SCADA system in the distribution network is planned. Thanks to the adoption of legislation in the last 6 years, a dozen small hydropower plants have been built and put into operation, which are connected to the electricity distribution system.

c) Organization and future

After the construction of the first power plant in 1910, the "Electricity Company" was formed. From then until today, the area of today's Montenegro has changed both spatially and socially. The electric power industry also changed its names and ways of organization.
Several smaller companies were united for the first time in 1975 (supplemented in 1985) into a single Electric Power Industry of Montenegro. The newly formed company was engaged in the production, transmission and distribution of electricity, as well as the design and construction of power facilities of all voltage levels.
The modernization and reorganization of companies with a significant reduction in the number of employees was stopped by the war in the former Yugoslavia and the international isolation of Montenegro.
Following the EU directives and the opening of the electricity market, in 2002 the Energy Regulatory Agency of Montenegro was formed, and later the Montenegrin electricity market operator, while within Elektroprivreda the functional units were formed: Production, Transmission, Supply and Distribution, as well as organizational whole of Electrical Engineering.



Fig. 15.11 TPP "Pljevlja", 1986.



Fig. 15.12 Administrative building of EPCG AD - Nikšić, 2017.

From the composition of Elektroprivreda Crne Gore AD, in 2009, the Montenegrin electricity transmission system A.D. (CGES) was separated and formed, as a separate legal entity - Transmission System Operator, and at the end of 2015, Montenegrin Electricity Distribution System d.o.o. (CEDIS) as a Distri-

bution System Operator founded by Elektroprivreda Crne Gore AD. Within Elektroprivreda Crne Gore AD - Nikšić, the entities engaged in the electricity industry still include Electricity Production and Supply, as well as development and other joint services.

The first major production facility based on renewable energy sources was the wind farm on Krnovo, put into operation in 2015 with an installed capacity of 72 MW. The 46 MW wind farm on Možura was put into operation in 2019.

There are also plans to build a wind farm on Gvozd with a capacity of around 55 MW and on Brajići with a capacity of 100 MW.
In addition, the construction of the Briška Gora solar power plant on the coast near Ulcinj, with a capacity of 250 MW, as well as a solar power plant near the capital Podgorica with a capacity of about 50 MW, is currently planned.



Fig. 15.13 SS 220/110/35 kV Podgorica 1, 1961.



Fig. 15.14 SS 400/110/35 kV Lastva, 2019.

Regarding the electricity transmission network, in the last ten years a significant number of substations have been revitalized, as well as the construction of overhead high voltage transmission lines, the most important of which is the 400 kV from TS 400/110/35 kV Lastva - TS 400/220/110 kV Pljevlja, as and expanding the network to connect new sources.
It is important to note that with the construction of a 400/500 kV converter plant near TS Lastva and the laying of HVDC submarine cable with a voltage level of 500 kV, transmission power of 600 MW, an underwater cable connection between Montenegro and Italy was achieved. The cable and converter plant

was put into operation in 2019. In this phase, one cable was laid that enables unipolar transmission, and the plan is to lay another cable and enable bipolar transmission of DC +/- 500 kV, with a total transmission power of 1000 MW. With this construction and further realization of the plans, the electricity transmission network, ie the electricity system of Montenegro, is becoming an increasingly important hub of the transmission network of Southeast Europe.

15.2 The Montenegrin NC of CIGRE

At the initiative of EPCG and ETF Podgorica, experts from Montenegro who were active in JUKO CIGRE and others established the Montenegrin Committee of the International Council for Large Electric Networks - MNE NC CIGRE, at the Founding Assembly held on March 29, 2008 in Podgorica. During 2008, study committees were constituted, and all necessary acts were adopted.
The Montenegrin CIGRE Committee was accepted as a full member of the international CIGRE at the 118th session of the Administrative Board held in Paris on August 23, 2008.
Montenegro is not starting its activities within CIGRE now, because since the founding of JUKO CIGRE in Zagreb on December 3, 1951, in accordance with its capabilities, it has constantly participated in the activities of this prestigious association. Distinguished professor at the Faculty of Electrical Engineering in Podgorica, Milorad Velašević, was the president of JUKO CIGRE from 1975 to 1979.



Fig. 15.15 Founding Assembly of Montenegro NC CIGRE, 2008.

During the formation of MNE NC CIGRE, we emphasized that we will strive for cooperation with other national committees of CIGRE, and especially with those from the former Yugoslavia with whom we have been together since 1951. There is a common interest for the exchange of technical information and experiences, for organizing joint thematic professional and scientific discussions, forums and round tables on current problems in the power industry. Montenegro The CIGRE Committee, on the basis of common interest and previous informal cooperation, with the CIGRE National Committees: Austria, Bosnia and Herzegovina, Croatia, Greece, Hungary, Italy, Macedonia, Romania, Slovenia, Ukraine and Serbia, decided to establish a CIGRE Regional Committee for Southeast Europe - called SEERC.



Fig. 15.16 The first president of Montenegro NC CIGRE – prof. Dr. Milutin Ostojić at the Founding Assembly, 2008.



Fig. 15.17 Flayer - The jubilee "10 Years of MNE NC CIGRE" celebration

The Memorandum of Understanding was signed on May 13, 2013. at the Second Conference of Montenegro NC CIGRE.
The Regional Council was formed in accordance with the CIGRE Statute and was officially recognized by the CIGRE Administrative Council at its meeting in September 2013, in Kazan (Russia).
So far, the Montenegrin CIGRE Committee has organized six Conferences, which were attended by almost 1,500 domestic and foreign experts. A total of 524 papers were published.

Table 15.1 The list of the conferences of Montenegrin NC Cigre from 2008–2019.

	I	II	III	IV	V	VI
Year	2009	2011	2013	2015	2017	2019
Location	Pržno	Pržno	Pržno	Igalo	Bečići	Bečići
Number of papers	88	71	66	106	97	96



Fig. 15.18 Opening ceremony of 6th Conference of the Montenegrin NC CIGRE, Bečići, 2019.

In various social circumstances since 1951, this famous organization has nurtured high standards of the engineering profession, regardless of which side of the department its staff acted on: as professors, managers, reviewers or authors. It was the biggest and lasting contribution to the development of the profession and the improvement of knowledge and necessary standards in Montenegro. It is worth noting that the Committee did not only work in the service of engineering, but also educated young people in the spirit of our tradition, which requires us to respect our origins and the diversity of our cultural and historical space.

15.3 Country electric power profile / RES vision

Electricity generated (TWh), 2019

Coal	1,39011
Hydro power	1,6974 (Small 0,08034)
Solar power	0,00098
Wind power	0,29394

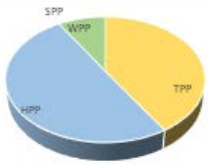




Fig. 15.19 The Power System of Montenegro, 2020.

Area	**13 812 km²**
Population	**631219**
Number of electricity consumers	**382 552**

Cosumption	
Industry (GWh)	**635**
Distribution (GWh)	**2342**

Transmission grid
400 kV (km): 284
220 kV (km): 338
110 kV (km): 642
110 kV (km) cables: 7.3

Distribution grid
35 kV (km): 1017
10 kV (km): 5054
0.4 kV (km): 13351

Power balance in 2019
Generation: 3,267 (TWh)
Consumption: 2,416 (TWh)
Imports: 1,139 (TWh)
Exports: 0,881 (TWh)
Losses: 0,493 (TWh)

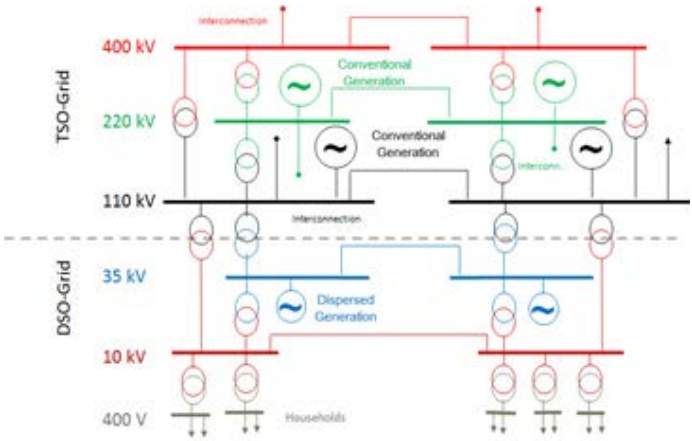


Fig. 15.20 Structure of Electrical Power System

15.4 References

1. Ž. Andrijašević, Z. Folić, D. Papović: 100 years of the Montenegrin electric power industry, EPCG AD, Nikšić, 2010.
2. JUKO CIGRE, 40 years of work, 1951–1991., Zagreb, 1991.

16. NC CIGRE ROMANIA

16.1 History of the Romanian Electric Power System

The condition of the Romanian electro-power industry prior and after the foundation of the Romanian National Committee of CIGRE.

The beginning of electricity use in Romania may be considered as year 1882, when a power plant on steam was commissioned in Bucharest and which supplied the royal palace through an underground cable with a voltage of 2 kV DC. Two years later, in 1884, in western Romania, Timisoara was the first city in Europe having installed the street electric light on about 59 km and using the power generated by a local thermal-power plant with a power of 4 x 30 kW, 2 kV DC.

Between 1886 and 1900, relatively low power hydro-power and thermal-power plants were commissioned in various localities in the country mainly devoted to street lightning. Other notable events, in the same period, were following: the first electric trams (1894, in Bucharest), the first three-phase electricity generation, 50 Hz (1898), the first interconnected operation of two relatively close power plants (1899).

The development of power energy generation determined the setting up of the General Society of Gas and Electricity, in Bucharest, in 1906, the first organizational entity at the regional level.

In the first decades of the 20th century, the increase of electricity demand both in the public sector and in the industry and transport sectors, determined the commissioning of new power plants (the Diesel-power plant Bucharest-Filaret, with units of 675 Power Horses, the largest in Europe of the year 1908), of the first power transmission line of 55 kV (1916) and of the first electrified railway of 58 km in length (1913).

- The end of the First World War finds Romania in the following conditions:
- The main cities had electricity installed,
- The large localities had their own power plants that were separately operating on coal, oil or gas, with a low hydro-power potential utilized,
- There were no applicable regulations on the energy sector development,
- The technical staff consisted-mainly-of relatively few engineers trained in the Western Europe Universities.

The increase of the electricity demand both in the public sector and in industry and transports led at the beginning of the 20th century to the commissioning

of some power plants (Bucharest Diesel Power Plant - Filaret - 1908), of the first 55 kV overhead power line (1916), the first 58 km electrified railway line (1913). At the end of the First World War, the main large cities had their own power plants that operated isolated using coal, oil or natural gas. Unfortunately, there were no regulations regarding the development of the electricity sector and the technical body that was concerned with supplying consumers with electricity consisted mainly of a few engineers, trained in high schools in Western Europe.

Starting with the third decade of the 20th century, the first plans for the electrification of Romania (1921) and for a National Energy System (1938) initiated by the engineer Dumitru Leonida appear. Also, new power plants are put into operation and the first zonal interconnections are made through the 60 kV (1923) and 110 kV (1930) overhead power lines with the related power stations.

The personalities in the field of electricity of the time (Constantin Bușila, prof. Constantin Budeanu, prof. IS Gheorghiu) participated in the definition of Romania's Energy Policy and were involved in the establishment on June 26, 1926 of the Romanian National Institute for the Study of Planning and Use of Sources de Energie - IRE, aiming to promote the interests of its members in relations with public authorities, civil society, similar associations in the country and abroad, with various institutions that have concerns in the field of energy. The IRE defends the individual and opinion rights of its members, according to the IRE Code of Professional Ethics, through the care of the IRE's Ethics and Honor Council.

16.2 History of the Romanian National Committee of CIGRE

In 1926 IRE joined CIGRE, activating in this forum through the Romanian National Committee (CNR) for CIGRE and actively participating in conferences through its members.
The first Chairman of CNR CIGRE was Constantin Bușila, and he held this position between 1926–1939. In 1939 CNR – CIGRE stopped its activity due to the war until 1948 when it starts again under the mandate of Professor Constantin Budeanu.
Professor Budeanu was the Chairman of CNR CIGRE between 1948 and 1958. Between 1958 and 1962, Călin Mihăileanu was the Secretary of CNR CIGRE.

From 1960 to 1972 Adrian Georgescu was the Chairman of CNR CIGRE, as a representative of MEE.
From 1962 until the interruption of the connection with the CIGRE Association, ISPE had the task on behalf of MEE to provide the CIGRE secretariat, the secretary being Mr. Liviu Groza between 1962 and 1974.
From 1976 Dumitru Popescu became the Chairman of CNR CIGRE until 1988 when the committee ceased its activity because the contribution was not paid according to the statutory obligations.
An interruption of the CNR-Cigre activity took place between 1988–1990, imposed by severe economic and political constraints implemented in the last years of the communist regime's existence.
CNR CIGRE was recreated in 1991, with a new structure corresponding to the democratic framework resulting from the 1989 revolution and the Romanian participation in CIGRE was resumed in 1992.

In 1991, CNR CIGRE started its activity again, Dr. Călin Mihăileanu being elected Chairman. Thus, Călin Mihăileanu was the Chairman between 1991 and 2000.
Between 2000 and 2010 the Chairman was Prof. Dr. Dorin Cristescu.
Between 1996 and 2010, the secretary of CNR CIGRE was Dr. Sorin Pispiris.

Today, the activity of CNR is supported by the Romanian National Association of CIGRE founded in 2007.

Table 16.1 Members of CNR Romania after founding Association

Year	Collective members I	Collective members I	Individual members
2006	17	2	65
2007	17	2	65
2008	17	2	64
2009	17	1	64
2010	17	1	109
2011	32	1	167
2012	34	1	181
2013	38	1	191
2014	40	1	205

Year	Collective members I	Collective members I	Individual members
2015	41	1	210
2016	42	1	219
2017	33	1	171
2018	37	1	188
2019	37	1	194

Since 2010, Chairman of CNR CIGRE was elected Dr. Ciprian Diaconu, from CNTEE Transelectrica SA, Vice President Dr. Constantin Moldoveanu of SC Nova Industrial SA, and Secretary Dr. Ioan Hațegan, of CNTEE Transelectrica SA. This leadership was reelected after eight years in 2018 for a four-year term and is still in office.

In the years that followed, CNR CIGRE attracted most of the experts in the field and attracted all the important players in the country in the field of high voltage networks.
The organized scientific activities were carried out with a wide audience and were followed with interest by CIGRE members but also by other specialists. The collaboration with the specialized university education has increased by organizing common round tables and by stimulating the students in order to participate in CIGRE activities, free access to ELECTRA magazine for 40 students from 5 university centers, free access to conferences, possibility to increase the level by contact directly with specialists.
The development of the activity is observed by the large number of conferences and specific activities organized, the increase of the number of members after 2010.
Of note are the two international conferences organized by CNR-CIGRE, namely in the odd years *"International Conference on Condition Monitoring, Diagnosis and Maintenance - CMDM: Modern Management Technology"* (2011, 2013, 2015, 2017, 2019), and in the other years CIGRE Regional South-East European Conference - RSEEC: *"Innovation for efficient and effective management, solutions for power systems of the future"* (2012, 2014, 2016, 2018, 2020 under organization).

47 CIGRE Conferences have taken place since its inception. Romania's participation in these conferences was active, being oriented towards the topics of the Study Committees that debated topics faced by the Romanian energy sector. The Romanian specialists worked as members in the SC and were involved in

the working groups of these SCs and in the elaboration and publication of some technical documents.
The following is a brief overview of the main activities carried out by CIGRE members (collective and individual). It should be emphasized that between 1956 and 1988 there was a special emphasis on the activity of collective members (enterprises and institutions belonging to MEE and Universities).

16.3 Activity and achievements of the Romanian NC CIGRE

CNR-CIGRE had a permanent collaboration with the CIGRE Association and initiated actions in order to organize in Romania meetings of some Study Committees and international conferences initiated by the Study Committees.
The following are the CIGRE events organized in Romania:

- 1965 Meeting of the Study Committee 4 - Protections by relays, from Bucharest, organized by the care of professor Corneliu Penescu.
- 1967 Meeting of the Study Committee 31 - Planning and improvement of the electrical networks, in Bucharest organized by the care of the secretary of CNR CIGRE Liviu Groza.
- 1973 Meeting of the Study Committee 33 – Overvoltages and Insulation coordination, in Neptune organized by the care of Professor Gleb Dragan.
- 1997 CIGRE Symposium in Neptun with title *"Impact of DSM, IRP and Distributed generation on Power Systems"* organized by SC 37&38 and with local support by Călin Mihăileanu.
- 2001 BLACK SEA EL-NET meeting organized in Suceava in collaboration with CN Transelectrica SA and SC Electrica SA and with CN from Greece and Serbia entitled *"Large Regional Networks with the Black Sea Region and the European interconnection in the Third Millennium".*
- 2013 Annual meeting of Study Committee A1 joint colloquium with CMDM in Bucharest.
- 2019 Annual meeting of Study Committee A3 joint colloquium with CMDM in Bucharest.
- 2011 Organization of the ***International Conference Condition Monitoring Diagnosis and Maintenance 1st Edition - CMDM 2011,*** Radisson Blue Hotel Bucharest. The conference was attended by 257 guests from 26 countries, from 4 continents with 66 papers and 6 tutorials. The conference also had an exhibition with 12 stands presenting companies' products on the conference profile.



- 2012 Organization of ***International conference Regional South East European Conference 2012 - RSEEC 2012, 1st Edition,*** Sibiu, Romania. The conference was attended by 154 guests from 12 countries with 54 papers. The conference also had an exhibition with 4 stands presenting companies' products on the conference profile.



- 2013 ***International Conference Condition Monitoring Diagnosis and Maintenance - CMDM 2013.*** The 2nd edition, held in joint session with the CIGRE A1 Study Committee, had 260 registered participants from 32 countries on all continents. 50 articles presented for 4 days, 6 tutorials presented by experts, 4 days of exhibition with 12 suppliers of important products and services from the energy systems market.

- 2014 Organization of the ***International Regional Conference South East European Conference 2014 - RSEEC 2014,*** 2nd Edition, Timișoara, Romania. The conference was attended by 160 guests from 12 countries with 57 papers. The conference also had an exhibition with 5 stands presenting companies' products on the conference profile.

- 2015 ***International Conference Condition Monitoring Diagnosis and Maintenance - CMDM 2015***. The 3rd edition had 230 registered participants from 21 countries. 61 articles presented during 4 days, 6 tutorials presented by experts, 4 days of exhibition with 10 suppliers of important products and services from the energy systems market.

- 2016 ***Regional South East European Conference 2016 - RSEEC 2016.*** The 3rd Edition had 160 registered participants from 12 countries. 44 articles presented during 3 days, 5 tutorials presented by experts, 3 days of exhibition with 8 suppliers of important products and services from the energy systems market.

- 2017 ***International Condition Monitoring Diagnosis and Maintenance Conference - CMDM 2017.*** The 4th Edition had 215 specialists from 22 countries. During the 3 days, 51 scientific papers and 6 tutorials were presented, in parallel with the development of the specialized exhibition, with 10 suppliers of products and services from the energy systems market.

- 2018 ***Regional South East European Conference 2018 - RSEEC 2018.*** The 4th Edition had 130 registered participants from 12 countries. 32 articles presented during 3 days, 6 tutorials presented by experts, 3 days of exhibition with 8 suppliers of important products and services from the energy systems market. A competition (Next Generation in Energetics) was organized for young students, master students and doctoral students with prizes awarded to the best 8 works.

- 2019 ***International Conference Condition Monitoring Diagnosis and Maintenance - CMDM 2019.*** The 5th Edition held in joint session with the CIGRE A3 Study Committee with the participation of the B3 Study Committee had 260 specialists from 26 countries. During the 3 days, 66 scientific papers and 6 tutorials were presented, in parallel with the specialized

exhibition, with 10 suppliers of products and services from the energy systems market.

Organizing conferences of the Romanian Study Committees

Within CNR – CIGRE, the observers and experts from the SC organized in Romania working groups with specialists in the fields of activity to present the topics discussed within the SC and at the CIGRE Conferences in Paris and to evaluate the possibilities of proposing reports with in view of the preferential topics approved by the CIGRE Technical Committee.

The reorganization of the CNR – CIGRE activity in 2010 ensures a better activity of the other study SCs in Romania as well. The Board of Directors organized during 2011 under the auspices of the CNR – CIGRE Association the following events:

- Martin Bercovici Symposium at UP Bucharest;

Implementation of the Automobile Electric project by designing and installing the first electric vehicle charging station in Romania and purchasing the first electric vehicle (Mitsubishi i-MiEV) sold in Romania.



Also, CNR-Cigre obtained in April 2012 at the Romanian Energy Awards Gala (by The Diplomat) the award "The most energy efficient and state of the art company / NGO" for the "Electric Car" project.



Romania's participation in the CIGRE Management Organizations

Between 1927 and 1939, engineer Constantin Bușila was vice-president of the CIGRE Bureau.

In the period 1948-1956, Professor Constantin Budeanu was a member of the CIGRE Board of Directors and vice-president of this Council.

Members of the CIGRE Administrative Council were:

- In the period 1972–1976 Adrian Georgescu;
- In the period 1976–1980 Dumitru Popescu;
- In the period 1991–2000, Dr. Călin Mihăileanu;
- In the period 2000–2010 Prof. Dr. Dorin Cristescu;
- In the period 2010–2020, Dr. Ciprian Diaconu.

Member of the CIGRE Technical Committee as representative of Administrative council:

- In the period 2018–2020, Dr. Ciprian Diaconu.

Romania's participation in the CIGRE Study Committees

Romanian specialists were members and observers in the International SCs of CIGRE as follows:

Title	Name of experts	Study Committee		Period
Prof. dr. ing.	Constantin Apetri	CS 17	Generators	1964–1968
Prof. dr. ing.	Corneliu Penescu	CS 4	Protections and relays	1964–1972
Ing.	Tiberiu Ciubotaru	CS 12	Transformers	1964–1968
Acad.prof.dr.ing	Gleb Dragan	CS 33	Insulation Coordination in Systems	1966–1974
Dr.ing.	Emil Constantinescu	CS 23	Substations	1970–1974
Ing.	Paul Petrescu	CS 21	High Voltage Insulated Cables	1970–1974
Prof.dr.doc.ing	Vasile Nitu	CS 23	Substations	1974–1978
Ing.	George Toma	CS 12	Transformers	1974–1978
Dr.ing.	Liviu Groza	CS 31	System Planing	1972–1980
Ing.	Aurelian Spanu	CS 35	Telecommunications	1972–1980
Prof.dr.ing.	Gheorghe Hortopan	CS 13	Switching equipments	1970–1978
Dr. ing.	Calin Mihaileanu	CS 19	Sudden Variation in Voltage	1964–1968
Dr. ing.	Calin Mihaileanu	CS 37	Planning and Development of Systems	1992–2000
Dr.ing.	Constantin Moldoveanu	CS A2	Transformers	1992–1998
Prof.dr.ing.	Mircea Eremia	CS 14	HVDC and Power Electronics	1996–2002
Dr. ing,	Constantin Radu	CS B3	Substations	1996– 2004
Dr. ing.	Stelian Gal	CS B5	Protection and Automation	1996–2004
Prof.dr.ing.	Ion Lungu	CS 13	Switching Equipment	1998–2002
Prof.dr.ing.	Florin Teodor Tanasescu	CS D1	Materials and Emerging Tests	2000–2004
Prof.dr.ing.	Stefan Gheorghe	CS C6	Distribution systems and Dispersed Generation	2000–2008
Dr. ing.	Anca Popescu	CS C1	System Development and Economics	2000–2008
Dr. ing.	Georgel Gheorghita	CS B2	Overhead Lines	2000–2008
Dr. ing.	Dan Zlatanovici	CS A1	Rotating Electrical Machines	2000–2008
Prof.dr.ing.	Andrei Marinescu	CS D1	Materials and Emerging Technologies	2002–2008
Prof.dr.ing.	Ion Lungu	CS C5	Electricity Markets and Regulations	2002–2010
Prof.dr.ing.	Dr. ing.	CS B4	HVDC and Power Electronic Equipment	2004–2010
Dr.ing.	Florin Balasiu	CS B5	Protection and Automation	2004–2012
Prof. dr. ing.	Petru Notingher	CS D1	Materials and Emerging Technologies	2004–2010
Ing.	Ion Merfu	CS C3	System Environmental Performance	2006–2012
Dr. ing.	Ciprian Diaconu	CS B3	Substations	2006–2014
Prof.dr.ing.	Ileana Baran	CS A3	High Voltage Equipment	2008–2012
Dr. ing.	Ioan Diaconu	CS A2	Transformers	2008–2012
Dr. ing.	Simona Voronca	CS C5	Electricity Markets and Regulations	2010–2018
Prof.dr. ing	Constantin Bulac	CS B4	HVDC and Power Electronics	2010–2014
Dr. ing.	Sorin Pispiris	CS B1	Insulated Cables	2010–2014
Dr.ing.	Constantin Moldoveanu	CS A2	Transformers	2012–2020
Dr. ing.	Ioan Hategan	CS A3	High Voltage Equipment	2012–2020
Dr. ing.	Paul Stroica	CS C3	System Environmental Performance	2012–2018
Dr. ing	Gheorghe Moraru	CS B5	Protection and Automation	2012–2020
Ing.	Rodica Zlatanovici	CS A1	Rotating Electrical Machines	2012–2014

Prof.dr.ing.	Mihaela Albu	CS C6	Distribution Systems and Dispersed Generation	2012–2014
Dr.ing .	Dan Preotescu	CS C1	System development and Economics	2012–2014
Dr. ing.	Doina Ilisiu	CS C4	System Technical Performance	2012–2014
Dr. ing.	Dorin Popa	CS D1	Materials and Emerging Test Techniques	2012–2016
Ing.	Ovidiu Codreanu	CS D2	Informations System and Telecomunications	2012–2014
Ing.	Marian Vaju	CS B2	Overhed Lines	2012–2018
Dr.ing.	Ciprian Diaconu	CS C1	System Developments and Economics	2014–2020
Dr. ing.	Doina Ilisiu	CS C2	System Operation and Control	2014-2020
Ing.	Bogdan Dumitrascu	CS B1	Insulated Cables	2014–2020
Dr. ing.	Marian Florea	CS B3	Substations	2014–2020
Conf.dr.ing.	Lucian Toma	CS B4	HVDC and Power Electronics	2014–2020
Dr.ing.	Paul Curiac	CS A1	Rotating Electrical Machines	2014–2016
Prof.dr.ing.	Calin Munteanu	CS C4	System Technical Performance	2014–2020
Dr. ing.	Dan Bordea	CS D2	Information System and Telecomunications	2014–2020
Dr. ing.	Daniela Bolborici	CS C6	Distribution Systems and Dispersed Generation	2014–2020
Dr. ing.	Mihai Plopeanu	CS D1	Materials and Emerging Tests Techniques	2018–2020
Ing.	Traian Tunescu	CS A1	Rotating Elactrical Machines	2018–2010
Dr. ing.	Simona Voronca	CS C3	System Environmental Performance	2018–2020
Dr. ing.	Paul Stroica	CS C5	Electricity Markets and Regulations	2018–2020

CIGRE distinctions awarded to Romanian experts after 1990

Within CIGRE, various distinctions are awarded in recognition of the contribution of members to the work of the Association.

Distinguished members:

- 1998 Prof. Dr. Dorin Cristescu
- 2004 Prof. Dr. Mircea Eremia
- 2006 Dr. Stelian Gal
- 2006 Dr. Georgel Gheorghiță
- 2006 Dr. Anca Popescu
- 2006 Dr. Dan Zlatanovici
- 2014 Dr. Ciprian Diaconu
- 2014 Dr. Constantin Moldoveanu
- 2018 Dr. Ioan Dorin Hategan
- 2020 Dr. Florin Grigore Balasiu

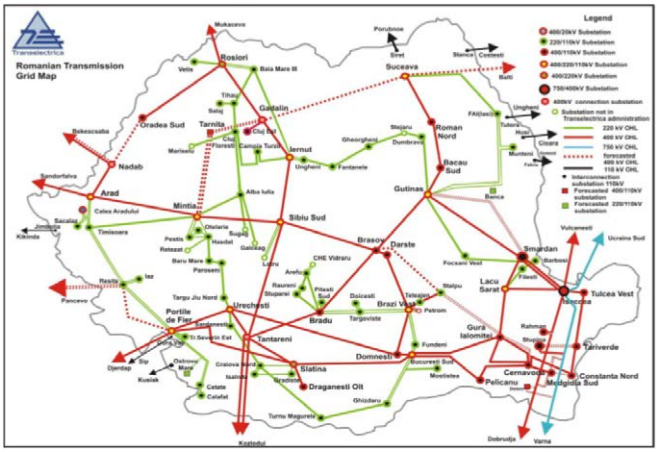
The CIGRE Technical Committee Award:

- 2004 Dr. Dan Zlatanovici from SC A1
- 2005 Dr. Anca Popescu from SC C1
- 2011 Dr. Ion Nedelcu from SC D2.

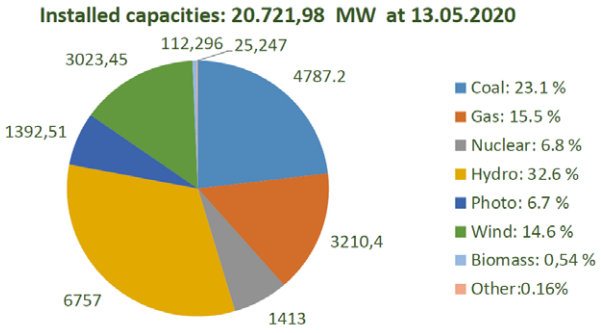
16.4 Romanian Electric Power System

Basic data	
Area	**238,397 km²**
Population	**19.71 million**
No. of electricity consumers	**9.15 million**
No. of TSOs	**1**
No. of DSOs	**8**
Peak load in 2019	**9,555 MW**
AIT (average interruption time) in 2019	**0.9047 min/a**

Transmission and Distribution grid		
Responsibility	**Voltage level**	**Total length**
TSO	750 kV	3.1 km
TSO	400 kV	4,971.7 km
TSO	220 kV	3,875.6 km
TSO	110 kV	40.4 km
DSO	≤ 110 kV	337,500 km



Romanian Transmission Grid in 2019



16.5 References

Ioan Dorin Hategan – RNC Cigre Secretary
e-mail: ioan.hategan100@gmail.com, mobile: +40744790526

17. NC CIGRE SERBIA

17.1 History of Electric Power sector

a) Early electrification – Direct current (DC)

The beginnings of modernization of Serbia are related to the early industrialization and first application of electric power for industrial purposes. Electricity was often produced only for a couple of hours a day.
Even though it was expensive, electricity was cheaper and more suitable for use and starting the engines than application of other modes as to starting thereof (e.g. belt transmission for loco-mobiles). The first industrial power plants were built in Paraćin, Kragujevac and Obilićevo near Kruševac.

The industrial electrical lighting was introduced into the new plant of bush-manufacturing section of the Military-Technical Institute in Kragujevac in 1884. The bush-manufacturing section was designed by the engineer Todor Selesković who had the merit for introduction of lighting in 1884 and later the motor drive. Electric power station was delivered in 1883 by the company Sigmund Schuckert, from Nürnberg. A dynamo machine of five HP was installed in the station for supplying 30 bulbs being of 16 candle-powers each and two arc lamps of 1,200 candle-powers. And while in 1885 electric lighting was introduced in all departments of the Institute, electric motors were not in use yet. Later on, there was installed a new steam machine of 45 HP which generated a lot more energy. Gradually the station was being expanded with four steam machines of 80 HP each. As of January 1st, 1946, the military factory in Kragujevac obtained name "Crvena zastava (Red Flag)", and by the decision dated August 26th, 1953 investments were made into the expansion of production capacities for car industry. The first turbine in Serbia was made in 1885 in this Institute for the needs of sawmill in Stolovi. The turbine was of Schwamkrug type and was constructed 35 years after it had appeared in Germany. Later, three more turbines were made for the needs of powder mill "Obilićevo". All the turbines were designed by engineer Selaković.
"The first Serbian privileged wool factory made by the Minch Brothers" in Paraćin, on the right bank of River Crnica started working in 1881. The first datum about the factory having electric lighting is from 1889, but given that the factory owners followed the innovations that led to modernizing and cost effective production,

it is probable that hydropower station had started working even before 1889. Electric lighting was installed in all departments of the factory by the end of 1890. In the domestic publications we can see also a datum that electric lighting was installed in the factory in Paraćin in 1882. The first electric bulb in Serbia started shining in Belgrade in the tavern "Hamburg" in 1880.

In the power station in Paraćin, there were installed a water turbine of 50 HP and a steam machine with power of 80 HP, each in belt coupling with a dynamo of 110 V. The power of one dynamo was enough for operating of 300 bulbs of 10 and 16 candle-powers and the power of both dynamo machines for the work of 800 bulbs, which exceeded the needs of the factory. This was the reason that both dynamo machines used to be turned on only when it was necessary to illuminate Paraćin during the king's visits. The textile factory with the power station was burnt out in a fire on June 22nd (July 4th), 1904. In its place the Prva Srpska Fabrika Stakla (First Serbian Glass Factory) was built in 1907.

On June 16th, 1889, in Kruševac it was decided that for the drive of the powder mill a hydropower plant on the Rasina River should be built. Works as to construction of the building and of the flume of the station started on May 31st, 1890. Design of all the facilities of the powder mill, dam, station, and installations was made out by the engineer Todor Selaković. Works performance was directed by the engineer Radosav Raka Mutavdžić from the Military-Technical Institute of Kragujevac.

The first turbine was put in trial operation on August 4th, 1891. The turbines were made as per the design and under the supervision of engineer Selaković and were manufactured in the Military-Technical Institute in Kragujevac. The biggest turbine was named "Momčilo" and was the pride of the designer and craftsmen. On September 15th, 1891 in the presence of King Aleksandar I the power plant was solemnly put into operation. As of 1908 the power plant was working as the alternating-current power plant. From 1936 to the beginning of World War II it was supplying Kruševac with electric power since the municipal thermal power station was put on standby in that period.

From DC to AC three phase system

The thermal power plant at Dorćol in Belgrade was the first public power plant in Serbia. She has been in office since September 23/5 October 1893 and in the period 1893–1924 was the only power plant in Belgrade to produce electricity for public needs. The electricity produced in this thermal power plant was used for lighting Belgrade, households of prominent citizens, starting trams, as well

as the work of the then rare industrial plants. She was in office until May 14, 1933, when her work was transferred to the Thermal Power Plant "Power and Light". Since 2005, the Museum of Science and Technology has been housed in the boiler room and engine room of the former thermal power plant.

In the sixties of the 19th century, the Belgrade municipality decided to procure 60 lanterns for street lighting. The owners of every cafe, tavern and inn were obliged to place a lantern in front of their shop. The lanterns had to burn until 10 o'clock in the evening. Special candles were used for municipal lanterns, which were lit in Vienna. Lanterns were taken care of by lanterns, which were climbed on poles, with the help of small ladders. The first gas lamps in Belgrade were installed on the occasion of the opening of the National Theater in 1869. The first electric lighting appeared in 1880. in the tavern "Hamburg", whose owner was Pera Jovanović Šapčanin, who for that purpose procured a locomotive and an electric motor , which was placed in the garden in front of the then National Assembly and from where the electricity was conducted by a conductor across street "Topčiderski drum" to the tavern, where Bogen lamp and Edison bulbs.

The contract for a concession for lighting was signed on August 3, 1891. The concessionaire undertook to build a power plant and start lighting the streets of Belgrade within two years after signing, i.e. in February 1893. In the more important streets, 65 Bogen lamps were to be installed in the length of 7 km, while in other streets, in the length of 55 km, 1,000 light bulbs were to be installed. All the light bulbs were supposed to be on by 11 o'clock in the evening, and the rest of the night, half of them. For a predetermined consumption of 185,200 kWh for street lighting the price was also determined, which would decrease in the event of an increase in consumption.

Although the motives and inspiration for Đorđe Stanojević's engagement were the ideas and works of Nikola Tesla, the equipment was still procured from the company of his opponent Thomas Edison, who built the first power plant in New York in 1882. At the time Nikola Tesla visited Belgrade, 1892, the headquarters in Belgrade was still under construction. Stanojević was already familiar with Tesla's polyphase alternating current system but feared that he would be forced to use direct current due to high resistance. This later affected the quality of lighting in Belgrade. Already Stanojević's next project, the Small Hydro Power Plant *"Pod gradom (Under the City)"* (1900), used a polyphase system of alternating currents.

The thermal power plant started operating on **September 23, 1893,** which marks the beginning of the electrification of Serbia, the same year that Nikola Tesla

illuminated the World's Fair in Chicago. The opening ceremony of the power plant was enhanced by the arrival in the city of one of the first Serbian steamships "Deligrad", which started the international navigation on the Danube in Serbia. All work was finally completed on January 15, 1894, and since then the Municipality has begun to pay for lighting. The photograph testifies to the rather modest appearance of the building and is dominated by a 38-meter-high chimney, built so that the smoke would not disturb the neighboring houses.
The maximum load of the power plant in the first year was 441.3 kW, direct current, and in the last year of operation 9,650 kW. Three steam boilers were installed in the plant, with a heating surface of 140 m². Initially, Silesian coal was used, which was later replaced by coal from Drenkovo on the Danube and the Senj mine. Three 2,600-horsepower steam engines powered 9 dynamo machines via transmission wheels, 6 of which were used for street lighting and private apartments, and 3 were used for arc lamps. The town's electrical network consisted of 62 km of cables, which was also the main drawback of this power plant, because the lighting on the periphery of the network was very dim or often interrupted.
The electricity produced in this thermal power plant was used for lighting Belgrade, households of prominent citizens, starting trams, as well as the work of the then rare industrial plants.
After the First World War, Belgrade was illuminated again for the New Year 1919, and the tram started operating on June 27, 1919.
The planned works on the power plant were carried out in the period 1924–1927. The power plant was a profitable company. Revenues from 1925 were invested in the expansion of the electricity network and the power plant. During 1927, a new 6,000 kW turbine was installed, the existing 67-meter chimney was built and another, 85 meters high, was erected, designed by Dimitrije Savić (since 1928 the head of the Mechanical Department, and from January 1930 also the head of the entire Mechanical Service). An elevator was also installed. Major construction works were carried out, in the engine room, furnace, and water station.
The old power plant on Dorćol is in the period 1893–1924 was the only power plant in Belgrade for the production of electricity for public needs. In 1924, the Thermal Power Plant in Makiš started operating, to supply the Sava water supply system in Makiš. From 1930, "Elektro Makiš" supplied electricity to Čukarica, Rakovica, Kneževac.
On June 5, 1929, the municipality of Belgrade made a decision to build a new

power plant on the right bank of the Danube. The new Thermal Power Plant "Power and Light", also on Dorćol, by air, only a few hundred meters away from the old one, started operating on November 26, 1932. It was gradually incorporated into the system, taking over the work of the Old Headquarters. With the new power plant in Belgrade, the replacement of the direct current system with the alternating current system began.
On May 14, 1933, the Old Headquarters ceased operations. Its employees mostly moved to work in the newly built plant, while Substation I was built next to the old plant, connecting the new plant to the existing network. The frequency was then switched from 42 to 50 Hz.
Shortly after the closure of the Old Power Plant, two of its turbogenerators (1,000 kW at 3 kV and 2,100 kW, 3 kV) were transferred to a thermal power plant built for the needs of the Resava mine in Ćuprija.
In 1946, the building of the old thermal power plant at Dorćol in Belgrade was completely emptied and both chimneys were demolished. Machines and boilers from the furnace were transferred to the Mali Kostolac thermal power plant. The former boiler room of the Old Belgrade headquarters was adapted in 1946 for the needs of the Electric Company of Serbia. Extensive work was carried out inside the plant, new windows and communications on the building were breached and warehouses, garages and workshops were moved in.
When the thermal power plant in Kostolac expanded its capacities, at the end of 1968, the equipment was replaced with a new one, and the old one was scrapped and sold in scrap metal.

b) Implementation of AC Three Phase system in Serbia

The small hydroelectric power plant "VUČJE" - IEEE Milestone
In the year 2005 this power plant was inscribed into the register of IEEE History Society.
Professor Đorđe Stanojevic, the founder of electrification in the Kingdom of Serbia, a friend of Nikola Tesla and a supporter of his inventions, chose the Vučjanka canyon for the construction of an "electricity factory". The Vucje hydroelectric plant began its work on 1903, December 24. It was the first in southern Serbia and the largest in the broader region. By transmitting alternating current multiphase system of 50 Hz at 7000 volts-high for the period over a distance of 17 km, a transmission line for electrification of the city was built

the first in the Kingdom of Serbia, it helped to transform the regional economy and. It remained in continual use for over a century. The plaque can be viewed at the Vucje Hydroelectric Plant, two kilometers upstream from the town of Vucje, in Serbia. The equipment, which includes the first transmission line in the Kingdom of Serbia - from Vučje to Leskovac (17 km) - was bought from the German company "Siemens & Halske", a well-known company from Germany at the time. Two generators were each capable of producing 139 kW. The turbines produced by J. M. Voith were 200 horsepower). The hydroelectric power plant captures water from the river through a canal about a kilometer (980 m) long, partially carved into high inaccessible rocks. This hydroelectric power plant was diverted during the Second World War. The construction was entrusted to Josif Granzan, originally from Veliki Bečkerek. The HPP started operating with 2 SIEMENS & HALSKE hydropower units of 139 kW each, and in 1931 the Vucje was expanded by adding a third generator, manufactured by the Swedish brand ASEA of 800 kW was put into operation. It increased the output to 1,078 kW (1 MW). Today, HPP Vučje is in the system of the Electric Power Industry of Serbia and produces about four million kilowatt-hours of electricity per year. In 2005, Vučje hydroelectric power plant is included in the world heritage of technology, which consists of only sixty buildings.
On 18th January 2012 it was registered as a property with monument qualifications.



Fig 17.1 Hydroelectric power plant "Vučje" near Leskovac, was put into operation in 1903.

c) Timeline of creation the Serbian Electric Power System

In 1894, Đorđe Stanojević published the work *"Nikola Tesla and His Discoveries"*. It was the first book about Tesla in Serbia and the second in the world.

- **1896,** Coal is dug in the Tvrdojevac pit, in Kolubara. In Kolubara pits, coal wagons have been dragged for a long time – horses!
- **1900,** Hydro power plant "Under the City" started operating in Uzice on Đetinja, the first power plant in Serbia under Tesla's alternating current principles, only four years after the start of operation of the hydro power plant in Niagara. Its installed capacity is 0.36 MW and possible annual output 0.26 GWh. Two generators for the production of three-phase current with a power of 32.8 kilowatts, 50 hertz and 2,000 volts, as well as switchboards with instruments for voltage control and regulation. Generators and equipment were purchased from Siemens & Halske. The manufacturer of the two turbines, 50 hp each with horizontal shaft and built-in regulator for water supply to turbines and two steel pipes for directing water from the channel into the turbines, was "Danubius-Maschinen Hartmann, ie Ganz & Co. Danubius Budapest". The power plant is still operating today.
- **1903,** Hydro power plant "Vučje" started operating in the village of the same name in Vučjanka. The first 17 km long power line in Serbia was built from this power plant to Leskovac. The hydropower plant is still in operation today.
- **1908,** The hydropower plant "Saint Petka", in Nišava, near Niš, is put into operation. It works today.
  At the same time, with the construction of the power plant, 8 kV transmission line, 25 km long with copper conductors were stretched on wooden poles, and 10 substations (transformer stations) with 50 kW transformers were installed on concrete stands, so that the planned works on electrification of the city of Nis were completed by the end of August 1908. Dam type: Concrete threshold in the river. Height: 4 m. Turbines: 3 turbines of 220 kW - a total of 660 kW, two Francis turbines - manufacturer "M. Voith Heidenheim" - 1908, one Pelton turbine - "manufacturer M. Voith Heidenheim" - 1931. Generators: 3 generators of alternating three-phase current of 200 kW - total power 600 kW, two generator manufacturers "Siemens-Schuckert Werke" Wien - 1908, one generator - manufacturer "Siemens-Schuckert" - 1927. Installed flow: 10.5 cubic meters per second.

Annual production: 3,10 GWh. In the city of Nis, streetlamps of the usual appearance were installed at that time - with curved brackets, shade, and built-in light bulbs. Light bulbs of 100 and 150 W were located at all transformer stations, squares, and intersections. In the center of the city, a lamp was installed on each low-voltage pole, and in other city streets, light bulbs were placed on every other pole.

The hydroelectric power plant "Sveta Petka", which was called "Villa on Nišava" by the locals, was put into trial operation on September 21, 1908 in the presence of the highest state and church authorities headed by Crown Prince George Karadjordjevic, who released it on the occasion. in the work of the central.

- **1909,** The Gamzigrad hydroelectric power plant on Timok, near Zajecar was built. The power plant is still in operation today. 1911 The Moravica hydroelectric power plant began to operate on the river of the same name in Ivanjica. It is currently out of operation.

  Work on the construction of the hydroelectric power plant began in March 1908. A place called Beljigovo was chosen for the construction of the hydroelectric power plant. At that place, on one side of the hill, Crni Timok flows in the form of a meander. On the other side of the hill, a dam was built on Timok, and a tunnel was dug through the hill, which brings Timok water from the dam to the power plant. The canal is 160 m long, of which the water of the last 60 m flows through a tunnel. The dam is made of masonry and is about 50 m long along the entire width of the river, while an overflow field is made on the right side of the dam. The project was developed by Ganz & Comp from Budapest. According to the project, the power plant building occupied 280 m^2, and another auxiliary building with an area of about 70 m^2 was designed, to accommodate the master. The construction work was carried out by the Milosevics, who hired the local population for that purpose. The machinery was delivered, which consisted of a water turbine of the Francis brand, 130 horsepower, horizontal shaft, with 240 revolutions per minute. The main drawback was the manual regulator. The turbine was connected to the shaft of a three-phase generator with a power of 100 kW, voltage 6,000 V and 11.5 V, via a belt.

  A year after the works started, the owner of the company "Uros Milosevic and Sons" and the town municipality of Zajecar signed a contract on "electric lighting of the town". According to the signed contract, the company accepted the obligation to install street lighting in the town. High-voltage

electricity was transmitted from the power plant by 10 km of overhead water, on wooden acacia and oak poles, with copper conductors. Seven transformers were installed in the city, which transformed the voltage of 6,000 V to 250 V. The town network initially consisted of five flaming lamps (Bogen lamps) and 190 light bulbs, covering only the main streets, and the network later gradually expanded.

After successful trial operation, the power plant began producing electricity on November 1, 1909.

Considering that after the war, due to the establishment of industrial plants and the introduction of electric motors in craft and trade shops and the introduction of electricity in households, electricity consumption increased significantly, the hydroelectric power plant with manual turbine regulation could no longer meet needs. The Milosevics then began modernizing the plant. In 1921, a new water turbine of the Francis brand was purchased, with 185 horsepower and an automatic regulator, as well as a 160 kVA generator with a voltage of 6,300 V, and in 1924 another generator and turbine of the same parameters were procured, so that the total power of the power plant was 320 kVA.

- **1911,** The small hydroelectric power plant Moravica or SHPP Moravica, In the town under mountain Golija in 1911, on St. Nicholas Day, one of the oldest hydroelectric power plants in Serbia was put into operation, which had a power of about 200 kilovolt amperes and illuminated the entire Ivanjica, and is considered the fifth hydroelectric power plant in Serbia. It is located in the center of Ivanjica and as a part of the Old Bazaar, it has been declared an immovable cultural asset of great importance. It includes an accumulation lake and a waterfall.

  In technical terms, the hydroelectric plant has retained its authentic appearance, including the Francis turbine, whose power is 300 rpm, to tools and generators, which are completely correct. The generator was manufactured by Siemens-Schuckert, which supplied and installed a mechanical and electrical plant in the power plant.

  The accumulation lake and the waterfall around the hydroelectric power plant are one of the symbols of Ivanjica, and the dam lost its authenticity over time, because it was originally built of wood, to be replaced by concrete in 1936, which was renovated in 2011 with complete revitalization of the plant. The machine part was repaired in 1987, and the facade was renovated in 1996.

  Although this hydroelectric power plant has a symbolic energy role be-

cause it produces as much electricity as Ivanjica consumes in two days, its historical role is much greater. She is also a museum. The power plant is in the system and serves as an auxiliary power supply to the buildings of the Municipal Assembly, the Ministry of the Interior and the Park Hotel.

- **1928,** The hydroelectric power plant "Jelašnica" is put into operation on the river of the same name near Vranje. It works today.
  SHPP "Jelašnica" works as a flow HPP, with a derivation channel. The power plant is connected to a 10 kV overhead line owned by ED Vranje (EDV) and is designed for both network operation and independent operation.
  The working pressure in the supply pipeline from the water level facility to the turbines is about 12.5 bar, which corresponds to a geodetic drop of about 125 m, so this power plant can be classified as a power plant with a high drop. As for the type of turbine, a Pelton turbine with one rotating wheel and two nozzles was installed.
  The generator is three-phase, and the transformation of the output voltage level of the generator 0.4 kV, to a medium 10 kV voltage is done using oil power transformers 10/0.4 kV.
- **1929,** The hydroelectric power plant "Turica" in Užice. Installed capacity of this power plant is 0.32 MW.
- **1931,** Hydro power plant "Sićevo" started operating. It is located a few kilometers downstream from the older HPP "Saint Petka" in Nišava, near Niš. Even today, it produces electricity.
  Preparatory works for the construction of the hydroelectric power plant "Sićevo" began in May 1921 after the engagement of engineer Deckler from Vienna, with the task of surveying the terrain and collecting the necessary data on the basis of which the company "Siemens-Schuckert" with which the contract was concluded.
  The construction of the construction part of the hydroelectric power plant, after the auction, was entrusted to the entrepreneur Milan Miljković from Zaječar. After all the previous procedures, the construction works began on October 8, 1928, with the planned completion date in the summer of 1929. However, the set deadline could not be met. Due to severe storms and floods, which took away most of the construction material and damaged most of the work already performed in 1929 and 1930, construction was completed in 1931 with a two-year delay, from the planned start of construction and nine years from the procurement of project documentation and equipment for its operation.

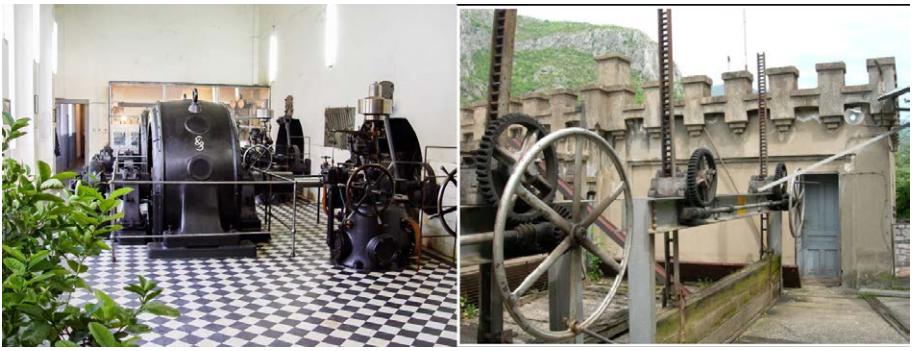


Fig 17.2 HPP "Sićevo" Niš, from 1928.

- **1932**, The Power and Light Thermal Power Plant, one of the largest power plants in the Balkans, was built in Belgrade.
- **1937,** The company "Elektro-Makis" built a thermal power plant in Vreoci, which was the backbone of the electric power system of Serbia at that time. The installed capacity of the thermal power plant was 12 MW. The coal for her work was dug in the Junkovac pit.
- **1940,** The hydroelectric power plant "Temac" near Pirot. Its installed capacity is 0.78 MW and its possible annual output 2.50 GWh. Dam type: Concrete threshold in the river. Height: 5 m. Turbines: Three Francis turbines, manufactured by "J. M. Voith Heidenheim" (1940, 1945, 1953). Generators: Three three-phase AC generators, power, 400 kW, manufacturer "Ganz" (1940), 224 kW, AEG (1945), 128 kW, manufacturer "Siemens" (1953). Installed flow: 4.65 cubic meters per second.

d) First regional electric power grid in Serbia (1931-1945)

In the period 1931–1945 number and configuration of electric power stations changed and local electric power centres were being gradually formed close to the bigger cities and industrial facilities. In such situation, at the An- nual Assembly of the Association of Electricity Enterprises of the Kingdom of Yugoslavia (SEP), held in 1934 in Zagreb, first ideas developed concerning necessity of creation of a single electric power system.
First regional electric power grid in Serbia was created in the period 1931–1945. This grid resulted from exploitation of two their small plants, "Power and Light" in Belgrade in 1932, and "Vreoci" at Vreoci in 1937 as well as from, for the first

time realized cost effective, safe and quality system of electric power supply. By action of two joint stock companies "Jelica" and "Elektromakiš" in Belgrade, there commenced connection of power plants and the scattered power sources so that electrification could be continued from the concentrated electric power sources. As of 1937 Company "Jelica" became part of "Elektromakiš" system. There started a period of construction of transmission lines which supplied the non-electrified settlements as well as those settlements which had their public local smaller power plants, operation of which was stopped with connection to the long-distance transmission line. Small local electric power plants became unprofitable. Purchase price of electric power from "Elektromakiš" was to a great extent lower than the generating price in small power plants, and the supply became more reliable.

In that period there arose strivings for the field of electric power industry to be regulated by the state. Thus, in Belgrade in 1920 a special committee of the Ministry of Transport had a session and was considering the issue of electrification of the country. It was proposed enactment of the law on electrification but due to different interests the proposal was not realised. In 1921 Ministry of Civil Engineering passed a directive on use of German VDE regulations in the field of electrical engineering.

In the period 1924–1928, within Ministry of Agriculture and Waters of the Kingdom of SCS there was formed a Đerdap Section with a task to make out a "Study on General Regulation of the Danube Sector named Đerdap (sailing and water power utilization)". The study making out was encouraged by the construction of the Rheine-Maine-Danube Channel, with expectation that there would be an interest of foreign capital for the Đerdap sector to be qualified for the same conveniences of sailing. Objective of the study was such that concurrently with solving of sailing issues, there would be also considered possibilities as to utilization of the energy potential of Đerdap. When the world economic crisis occurred already in the late thirties, the initiated negotiations on continuation of the activities concerning the study were suspended. Design of Đerdap was actualised after three decades.

In 1925, a long-distance transmission line of 7.5 kV from hydropower plant "Sveta Petka" to Niš was reconstructed. It was transferred to voltage of 25 kV which was the first long-distance transmission line for that voltage-level at that time. Until hydropower plant "Sićevo" was put into operation in 1931, the long-distance trans- mission line had been operating with 7.5 kV of voltage. In 1929 "Elektro-Makiš" J. S. C. Belgrade started electrification of Southern Srem

by placing a river cable of 6 kV over the Sava River near the sawmill "Makiš" and by building a transforming station 6/30 kV on the left bank of the Sava River. Here, for the first time an electric cable was placed along the river bed and energy was transmitted underwater. At the same time this is also the first application of 30 kV voltage.
Standardization of the type of current, frequency, as well as voltage, starts after the First World War and extends to the following decades. Introduction of the voltage of 3 x 380/220V in Belgrade was not simple because installations in the buildings had been adjusted to the voltage of 3x206/120V. Only in 1928 there started introduction of new voltage values, whereat the works lasted until 1940. In Belgrade, replacement of direct-current system by alternating-current system was done around 1932 and in other cities this replacement lasted until 1958. Frequency of 42 Hz was in use in Belgrade until 1933 when the Old Electricity Station at Dorćol stopped working.

Table 17.1 Situation in Serbia, in 1931

State in 1931	Number of power stations	Number of electrified settlements
Central Serbia	58	100
Vojvodina	44	154
Kosovo	6	6
Total	108	260

After the power plant at Vreoci had been constructed, there was carried out connection of Vreoci with Belgrade, Southern Srem and cities in Šumadija. In 1938 the "Elektromakiš" system started powering Čačak through a 35 kV transmission line "Kargujevac-Čačak". In October 1938, near Bresnica village, Kraljevo was also connected to the mentioned long-distance transmission line because of what a 35 kV transmission line "Kraljevo- Bresnica" was constructed. From Kraljevo, in 1939 mentioned transmission line was extended up to Vrnjačka Banja. By construction of 30 kV "Vreoci-Valjevo" transmission line, Valjevo was also connected to the system in 1940. In 1938, there were completed a 60 kV "Vreoci-Kragujevac" transmission line and 35 kV "Kragujevac-Jagodina" transmission line whereby supplies of Jagodina began. Thereby wider area of Kragujevac, which used to be supplied by the "Jelica" Company from Čačak, was connected to the "Elektromakiš" system.

e) Development of electric power grid in Serbia after 1945

- **1943,** The first surface mine in Kostolac opened in Serbia; after the Second World War it played a significant role in the industrialization of the country, the training of personnel and the application of new technology in coal production. The mine closed in 1980.
- In 1943, German engineers opened at Kostolac the first open-pit coal mine, which was going to be of great significance for electrification of the country after the Second World War. Until 1939, 29.8% households in Serbia were electrified. By the end of the Second World War number of electrified places, cities, towns and villages in Serbia amounted to 357.
- **1948,** The first hydroelectric power station after the Second World War, HPP "Sokolovica", in Timok near Čokonjar was built. The small hydroelectric power plant "Sokolovica" is the first hydroelectric power plant built after the Second World War. It was put into operation on Republic Day on November 29, 1948, on Veliki Timok near Čokonjar, 22 km downstream from Zaječar.

  It was of great importance for the entire Timok Krajina, especially for the economic development of that region. It was built as a dam plant at 100 meters above sea level. The dam is gravitational. The height of the dam in relation to the lowest elevation of the foundation is 18 meters, and in relation to the elevation of the terrain it is 17.5 meters and the total length is 100 meters. The projected volume of the accumulation lake is 1,100,000 m^3, and the maximum overflow capacity at the level of normal deceleration is 750 m^3/s. The first unit was installed in 1948. It is a Francis turbine from 1930. In those years, which is autonomous, it can start without hydropower generator excitation, while the second and third units were designed by the Yugoslav producers "Rade Končar" and "Litostroj". The average annual production is about 11 million kWh. When it was built, it was the largest in Eastern Serbia.

  Although of modest capacity by today's standards, this hydroelectric power plant, in the event of the collapse of the power system, which has happened twice so far, serves to raise the entire system. Since one of the turbines can be started manually, after reaching the full power of its generator, the other two can be started. All three together have enough power to start the generator in HPP Djerdap II , which can then start the generators in HPP Djerdap I , which would start everyone else.

HPP "Sokolovica" is one of the few in Serbia that has a so-called "fish path", ie the possibility of unimpeded passage of fish on both sides of the dam, which significantly helps to preserve the fish stock.

- **1948,** Thermal power plant of TPP "Mali Kostolac" is built. Mechanical equipment: turbines, generators and boilers, were transferred from the old Belgrade power plant (1893), partially reconstructed and installed in this power plant.

By the Regulation of the Government of the National Republic of Serbia dated 2 June 1945 an Electric Company of Serbia (EPS) was founded with its main office in Belgrade. Concurrently were founded branches of this company in the cities of Serbia where there were located, for that time significant electric power plants or transforming stations of 35 kV which had already been included in the electric power system or connection thereof was about to happen: Užice, Ivanjica, Čačak, Kragujevac, Vrnjačka Banja, Mataruška Banja, Valjevo, Kruševac, Trstenik, Novi Pazar and Vreoci. Basic tasks of the company were: to construct and exploit electric power plants, transforming stations and transmission lines, the existing facilities which had been nationalized and handed over to EPS for management; to provide, to supply and sell to the consumers sufficiently safe and cheap electric power; to help foundation of consumers' cooperatives as to electric power usage. Thereby, Government of PR of Serbia, as a founder, consolidated the electric power industry which had been partial by then and created a condition for technological improvement of the electric power industry and its growing out into a big modern technical system.

Following the Second World War end, the distribution grid was in the state of destruction and of different technical equipment as well as with application of several voltage levels. During the war, depending on the region, 15% to 60% of distribution grid of Serbia was destroyed. The network was conducted on poles of impregnated wood and on few reinforced-concrete poles. Transforming stations were equipped with devices of foreign manufacturers, without special automatics and often with crews composed of electricians and handlers. Applied was direct current voltage of 110 V and 220/110 V and alternating current voltage of 220 V/110 V and 380/220 V. At the level of high voltages following values were used: 2.1 kV, 3 kV, 5 kV, 6 kV, 7.5 kV, 10 kV, 15 kV, 20 kV, 30 kV, 35 kV and 60 kV. In 1952, high voltages were standardized in the way that scale of 10, 35 and 110 kV was prescribed. Voltages lower than 10 kV could be used only in mining industry and individual companies where it was technologically justified. Right after the war end, reconstruction of distribution grid was set

to. By the first five-year plan it was envisaged that consumption per capita in 1951 should achieve level of 272 kWh, in comparison with 71 kWh in 1939. In order that electricity generated in the power station could be sent to the end consumers, it was indispensable that distributive network be renewed and expanded. Distribution companies were founding their own workshops for mending and fabrication of transformers, calibration workshops for electricity meters, as well as workshops for fabrication of consoles and insulator bearings and other equipment. Mode of operation of distribution companies was not uniformed and standardized, yet every company used to work as per its own instructions and rules. In addition to that, there were frequent organizational changes of distribution companies which occasionally used to exist as utility service companies. Given that priority was given to construction of generating capacities, distribution capacities ware not developing proportionally with the development of generation and speed of consumption increase. Distribution companies did not dispose with financial funds which would be sufficient for maintenance, expansion, and construction of facilities. Regarding the lack of electric power, the consumers were appealed to decrease consumption and when savings results were weak, disconnections were carried out.

In December 1957 connection of all parts of Yugoslavia to the voltage of 110 kV was carried out, save for Macedonia and Kosovo and Metohija. Company for electric power transmission "Elektroistok" was formed in 1958 within the United Electric Power Industry of Serbia as a company for designing and construction of transmission system, transmission of electric power and transmission system management. Due to significant increase in consumption, as well as construction of new power plants in the period 1955–1960, an intensive study of network development was initiated. Introduction of transmission grid at the voltage of 220 kV commenced in 1960 with commissioning of HPP "Bistrica", first power plant in Yugoslavia connected to the transmission grid of 220 kV. HPP "Bistrica", and then long-distance transmission line that used to connect this hydroelectric power plant with transforming station "Belgrade 3" and transforming station "Belgrade 3", were the first 220 kV facilities in Serbia. In "Elektrosrbija", later on "Minel", first transformer of 35 kV was manufactured in 1961, first transformer of 110 kV was manufactured in 1967 and first transformer of 220 kV in 1975.

Table 17.2 Installed capacities of electric power plants and output of electric power in Yugoslavia in 1945

	Installed capacity (MW)			Output (GWh)			Utilization (h/year)
	HEPP	TPP	Total	HEPP	TPP	Total	
Bosnia and Herzegovina	11	40	51	19	43	62	1,216
Macedonia	6	4	10	12	2	14	1,400
Slovenia	90	50	140	198	160	358	2,557
Serbia	6	137	143	8	203	211	1,476
Croatia	87	81	178	79	92	171	960
Montenegro	0.3	1.2	1.5	0.3	0.5	0.8	533
Yugoslavia	210.3	313.2	523.5	316.3	500.5	816.8	1,560

f) Development of electric power system in Serbia after 1991

As the war began in Yugoslavia in 1991, functioning of the single electric power system of Yugoslavia was jeopardized. Ever since September 1991, the electric power system of Yugoslavia, Macedonia, Greece and Albania has been functioning as a discrete system, separated from the Western European connection UCPTE. After the years of maximal annual output, which was achieved in Serbia in 1989 and 1990, there followed years of output decrease due to impossibility of placement to other republics as well as due to impossibility of exporting.

The single electric power system of Serbia was created on 1st January 1992 by founding of Public Enterprise "Electric Power Industry of Serbia" (PE EPS). Single EPS was formed by integration of Electric Power Industry of Vojvodina, Kosovo and Metohija and United Electric Power Industry of Belgrade. In the NATO bombing the EPS electric power facilities suffered huge damages. Ever since 1st June 1999, EPS has not been managing capacities thereof in the area of Kosovo and Metohija.

After thirteen years of cessation from UCPTE, in October 2004 Serbia has been connected again to the first zone of UCPTE synchronic network.

Based on the Decision of the Government of the Republic of Serbia dated 1st July, 2005, from PE EPS disassociated was activity of electric power transmission.

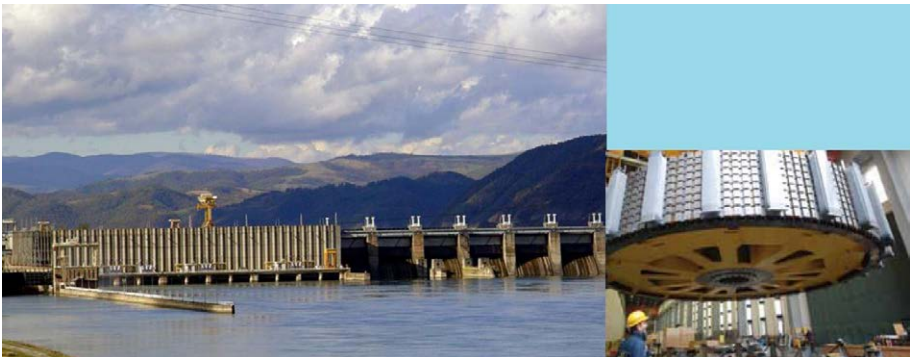
Thereby, there were formed two independent public enterprises, PE "Electric Power Industry of Serbia" and PE "Electric Network of Serbia" which took over the role of PE "Elektroistok" in the domain of electric power transmission and transmission system management.



PHPP "Bajina Bašta", Bajina Bašta
Basin/Water-course: Drina
Put into operation: 1982
Maximal capacity of the Electric Plant in the Generator regime is 614.00 MW
Maximal input capacity in the Pump regime is 620.00 MW



TPP "Nikola Tesla B", Obrenovac
Put into operation: 1983
Block B1, 1983; Block B2, 1985
Installed capacity: 1,240.00 MW



HPP “Djerdap 1”, Kladovo
Basin/Water-course: Danube
Put into operation: 1970, The entire facility was put into operation on May, 16th , 1972
Generating set 1, 1970; Generating set 2, 1970; Generating set 3, 1971; Generating set 4, 1971; Generating sets 5 and 6, 1972
Installed capacity: 1,026.00 MW



TPP “Nikola Tesla A”, Obrenovac
Put into operation: 1970
Block A1, 1970; Block A2, 1970; Block A3, 1976; Block A4, 1978; Block A5, 1979; Block A6, 1979
Installed capacity: 1,650.00 MW



HPP “Djerdap 1”, Kladovo
Basin/Water-course: Danube
Put into operation: 1985
Generating sets 3, 4, 5 and 6,1985; Generating sets 7 and 8, 1986; Generating sets 1 and 2, 1987; Generating set 10, 1998; Generating set 9, 2000
Installed capacity: 270.00 MW



Fig 17.3 Most important HPP and TPP in Serbia

TPP “Kostolac B”, Kostolac
Put into operation: 1987
Block B1, 1997; Block B2, 1991
Installed capacity: 697.00 MW



HPP "Bajina Bašta", Bajina Bašta
Basin/Water-course: Drina
Put into operation: 1966
Installed capacity: 368 MW

Table 17.3 Development of theelectricity energy sector in Serbia

POWER INDUSTY OF SERBIA		**1951**	**1958**	**2007**	**2019**
Capacity of the Power plants	MVA	188	511	8,355	7,664.90 8,931.90*
Produced electrical energy	GWh	581	1,685	38,897	39,639.86
Consumed electrical energy	GWh	491	1,463	37,785	33,607
Electrification of settlements	%	29.6	55.8	100	100
Joint Stock Company "Elektromreza Srbije" Belgrade - the Serbian TSO (Transmission System and Market Operator)		1951	1958	2007	2019
Length of transmission line	km	498	1,880	9,899.60	9,811.07 10,866.07*
Installed capacity of power transformers	MVA	3	393	17,385.10	16,041 17,624*
Transmission of electricity	GWh	511	1,484	46,606	38,834 38,834*

* with Kosovo

17.2 History of CIGRE

a) Yugoslav Committee CIGRE (1951–1991)

Foundation

The Yugoslav National Committee CIGRE (JUNAKO CIGRE) was founded in 1951, with its head office in Zagreb, Croatia. Numerous prominent experts from electric power system operators, universities, and manufacturers of electrical equipment of the time actively supported the initiation, formation, and application of the Yugoslav National Committee CIGRE, and subsequently also contributed to its operation.

The first president of JUNAKO CIGRE was Prof. Milan Vidmar, from the Technical Faculty of Ljubljana. Members of the first executive committee delegated from Serbia were Prof. Milivoje Rakić, from Faculty of Electrical Engineering, Belgrade, Prof. Vladimir Ljubojević, from Elektrobiro-Energoprojekt Beograd, and Ilija Obradović, from the Institute at the Ministry of Electricity.

The original name JUNAKO CIGRE was later contracted to JUKO CIGRE (Yugoslav Committee CIGRE).

Institutional Organization of the Electric Power Industry

From the foundation of JUKO CIGRE in 1951 to its transformation in 1991, the electric power industry of Yugoslavia, and that of Serbia as its part, changed a number of institutional organization forms. Under the Law in force at the time of formation of JUKO CIGRE, the functioning and operations of the electric power industry were managed by the Ministry of Electricity. Legislative amendments introduced in 1958 resulted in the formation of Republic-level Unions of Electric Power Enterprises, which were under an obligation to associate and form a Yugoslav Electric Power Union. The Republic-level Unions of Electric Power Enterprises included enterprises responsible for electricity generation and transmission. This organizational structure remained until 1962.

In 1966, duties and responsibilities for electricity supply were transferred from the Federation to its constituent Republics. At that time, Serbia formed the Associated Electric Power Enterprise of Serbia that included all existing generation and transmission enterprises, which acquired the status of Organizations within that associated enterprise.

Technical Issues

The Yugoslav National Committee CIGRE strived since its inception to keep abreast of new developments in electric power systems worldwide, essentially adhering to the issues addressed and the orientation affirmed by the international CIGRE organization. However, the dynamic developments in electrification of Yugoslavia due to its intensive industrialization after the end of World War II meant that the Committee also had to address a number of specific and current issues pertaining to the local needs of the country. This trend was subsequently continued, and it shaped the activities of the majority of individual and collective members and JUKO CIGRE itself as a national institution.

As virtually all major issues in connection with the design, construction and operation of the electric power system of Serbia were initiated, reviewed and resolved at sessions and other forms of work of JUKO CIGRE (CIGRE Serbia), the following key facts about the development of the Serbian electric power system in the period 1951–2007 bear perhaps the most eloquent and succinct testimony to the importance of JUKO CIGRE.

Furthermore, as an illustration of the activities of JUKO CIGRE, below is a selection of major issues and topics addressed at sessions of JUKO CIGRE and its bodies:

- Normalization and standardization of transmission line parameters for all voltage levels
- Selection of parameters and elements of transformer stations and substations
- Selection of unit powers of electricity transformers and generators and their parameters
- Issues of equipment standardization from the aspect of rationalization of spare parts
- ssues of parallel operation in normal circumstances and in circumstances of outage of transmission network facilities
- Issues of parallel operation with neighboring electric power systems
- Specific issues associated with plants such as: insulation coordination, overvoltages, functioning of protective devices, electricity dispatching, adoption of national and internal technical regulations and recommendations
- Modernization of dispatching
- Introduction of primary and secondary load regulation
- Introduction of a modern communication system

- Addressing the issue of shifting to higher voltage levels of 110, 220 and 400 kV
- Analysis of functioning of the electric power system from the aspect of its static and dynamic stability
- Issues of reactive power compensation in the system
- Analysis of status and development of short circuit power, etc.

Development of the National Committee CIGRE as an Institution

The development of the National Committee followed the pace of development of the electricity sector and the electric power system. To expert members of the National Committee, sessions held every odd year and symposia held every even year provided a valuable opportunity to publish their works, share priceless experiences and acquire knowledge on recent developments in the fields of development, design, construction and use of large electricity networks, thereby affirming their work and the firms that employed them.

The National Committee has its Statutes, harmonized with the CIGRE Statutes, and ancillary bylaws on study committees, on rewards, diplomas, and plaques and on organization of symposia and sessions. Sessions are attended by about 1000 participants with some 200 papers, while national symposia usually have 200–300 attendees who present about 50 papers. Membership was organized at level of JUKO CIGRE as well as international membership with CIGRE Paris. Organization of national Study Committees were as mirror to CIGRE mother. Focus of activity were on national SCs and national conferences which played a crucial role in development of electrification of Yugoslavia.

The number of individual and collective members in CIGRE Paris varied between 150–200 for individual and 20–40 for collective, respectively.

Prominent Contributors

Numerous renowned and distinguished individuals from all parts of Yugoslavia contributed to the operation and success of the Yugoslav National Committee CIGRE. Many professors from all Yugoslav universities in the field of electrical engineering, in particular those specialized in electric power industry, actively took part in the activity of JUKO CIGRE and CIGRE-Paris. Eminent experts from Institutes of electrical engineering, design organizations, electric power companies and generation and contractor organizations, each in their own specific way, both individually and collectively, gave invaluable contributions to the development of the Yugoslav National Committee CIGRE.

Contribution of our Experts to the international CIGRE activity

In the history of CIGRE before WW2 was mentioned participation of some individual experts from Yugoslavia, i.e. at 9th Session in Paris 1937, were recognized three experts from Yugoslavia, but their activities are not recorded. However, after establishing national committee JUKO CIGRE, activities raised.

The members of JUKO CIGRE, took part in all CIGRE sessions after WW2 and were actively involved in discussions on specific issues, achieving praiseworthy results.

Between 1951 and 1991, our members submitted 15 papers addressing various issues, including:

- *Automated control of time and load of generation units in an inter-connective system*
- *Impact of the electric power system on frequency management*
- *Interconnection of Djerdap Hydro Power Plant at 400 kV grid*
- *Decentralized approach to automated inter-connective system management*
- *Reduction of the silhouette of 400 kV overhead line towers.*
- *In addition to their contribution through submission of papers and discussions, our experts also participated in CIGRE colloquia and symposia and served as members of many international working groups.*

b) Serbian National Committee CIGRE (period 1991–2019)

Foundation

In 1991 and 1992, Yugoslavia as a joint state broke up. The events associated with this also brought about to a transformation of the former Yugoslav National Committee CIGRE. The new state union, which continued under the name of Yugoslavia, included only Serbia and Montenegro of the six former Republics. Aware of the importance of and the need for continued operation and participation in the activities of CIGRE, experts from the remaining two Republics launched an initiative for continuation of JUKO CIGRE. They sought and obtained approval from CIGRE bodies for the new national committee, which retained the former name – Yugoslav National Committee CIGRE or JUKO CIGRE in the abbreviated form – to be accepted as the successor to the former Yugoslav National Committee CIGRE.

Later, in 1997, the new national committee was acceded by experts and stakeholders from the Republic of Srpska (Bosnia and Herzegovina). The session of JUKO CIGRE in its new convocation was held under the title "21st JUKO CIGRE Session" in October 1993.

After the secession of the Republic of Montenegro from the joint state (in the meantime renamed Serbia and Montenegro), Montenegrin experts formed their own national CIGRE committee, and consequently the name of JUKO CIGRE was changed to CIGRE Serbia (2007). This organization retained continuity with the original Committee formed in 1951.

Reorganization of the Electric Power Industry

Although JUKO CIGRE included Montenegro until 2007 and still includes the Republic of Srpska, this text deals only with the organization of the Serbian electric power industry.

Reorganization of the electric power industry in Serbia was launched in 1989 and completed in 2005. Pursuant to the provisions of the Law on Electric Power Industry (1989), the Law on Public Enterprises (1990) and the Energy Law (2004), the electric power industry is organized in two public, State-owned enterprises, namely:

- Public Enterprise for Power Electricity Generation, Distribution and Trade "Elektroprivreda Srbije", Belgrade, and
- Joint Stock Company for Power Electricity Transmission System and Market Operator "Elektromreža Srbije", Belgrade.

This organizational structure remains in force to this day.

Technical Issues

In its operations, JUKO CIGRE made efforts to keep pace with the situation and development in large electricity networks worldwide through the participation of its members in CIGRE Sessions, its standing and ad hoc working groups, various hard and soft copy information provided by CIGRE, attendance of regional meetings etc. It chose preferential topics for its sessions, symposia, and round tables according to the current issues faced by the Serbian electric power system.

The new organization of CIGRE in 2002, with supplemented and reorganized topics addressed by specific study committees, has been reflected in the operations of JUKO CIGRE. As an illustration, below is a selection of issues addressed by JUKO CIGRE between 1991 and 2007:

- Issues concerning the operation of hydro and turbo generators; replacement of turbo generator coils; problems involved in the purchase of hydro generator actuating system; introduction of partial discharge monitoring in hydro generator coils

- Diagnostic methods, supervision technique, revitalization, testing of transformers; installation of transformers on site; transformer loading, ageing of insulation system, useful life of transformers; construction, manufacture, testing and supervision of measurement transformers
- Utilization of experiences and maintenance of circuit-breaking equipment; numeric methods of circuit breaker stimulation; characteristics of new devices and their comparison with the existing ones
- Current situation and tendencies in the development of high-voltage direct current power transmission systems; energy converters and regulators
- Application of new technologies and materials in the construction of new power lines; analysis of existing regulations pertaining to overhead power lines; problems associated with the repair of power lines damaged during the war; analysis of powering occurrences related to transmission line breakdowns; overloading of conduits; earthing issues
- Short circuits at plants; earthing and safety measures; reliability, maintenance and use of plants; SF6 gas-insulated plants; revitalization of plants
- Coordination of system insulation
- New equipment and plant protection systems; arc fault detection on transmission lines; commissioning of the first microprocessor protection; revitalization of the existing protection and management system
- Analysis of telecommunications routes; analysis of proposes telecommunications system solutions; new telecommunications equipment; OPGW cables
- Analysis of operation of the electric power system - EPS; measures and activities aimed at enhancing the power factor; calculation of electricity losses; EPS voltage and power flow analysis
- Modernization of dispatching; problems associated with the operation of Serbian EPS in the Balkans Interconnection
- Contribution to the preparation of the National Integral Cadaster of Polluters
- Regional electricity market in Southeastern Europe
- Calculation of electricity losses in the transmission network of Serbian EPS
- Integration Renewable sources (RES) of Power System in Serbia
- Analysis for Design and Construction of Storage of Electrical Energy in Power System in Serbia.

Development of the National Committee CIGRE as an Institution

After the secession of Montenegro from JUKO CIGRE (2007), the former name of the Committee was changed to CIGRE of Serbia. This National Committee includes as its members experts and organizations from the Republic of Serbia and the Republic of Srpska (Bosnia and Herzegovina).

CIGRE Serbia operates as an association founded by the Ministry of Public Administration under law of the Republic of Serbia. NC CIGRE Serbia is a non-profit, non-governmental organization with the following bodies: Executive Committee, Supervisory Committee and Assembly.

Table 17.4 Presidents of NC CIGRE of Serbia

Period	President
1993 – 2001	Vojisav Milić
2001 – 2010	Radomir Naumov
2010 – 2018	Gojko Dotlić
2018 –	Nebojša Petrović

Contribution of our Experts to the Operation of CIGRE International

From 1991 to 2019, the experts of JUKO CIGRE (CIGRE Serbia) took part in all CIGRE Sessions in Paris, contributed to the operation of international working parties and study committees as regular or observing members, submitted reports in writing on the activities of the National Committee at the Forum of National Committees, ensured the payment and distribution of the ELECTRA magazine to a number of JUKO CIGRE members, proposed the distribution and distributed the ELECTRA magazine to students of electrical engineering university schools and provided papers and other materials from CIGRE files to interested experts.

In addition to the above activities, JUKO CIGRE also participated in the "Large Disturbances" Workshop (2000) with a contribution on devastation and recovery of the electric power system destroyed by the NATO bombing campaign in 1999.

In 2001, JUKO CIGRE was a co-organizer (together with Greece) of CIGRE Black Sea El Net, organized by the Romanian National Committee.

In May 2003, Belgrade hosted the International Colloquium on Overhead Lines Revitalization. A report from this international meeting was published in the ELECTRA issue number 214.

As a key contribution of experts of CIGRE Serbia in this period, CIGRE accepted 20 papers prepared by CIGRE Serbia and included it in its Session materials. Below is a selection of topics addressed by those papers:

- Rapid aging of transformer insulation
- Lifecycle management and impact on its extension for hydro generators of Đerdap Hydro Power Plant
- Operator performance requirements and training needs in a commercial environment
- Measurement and fee payment in electric power plants regulation in decentralized electric power industries
- Development and application of overhead power line revitalization methodology
- Thermal monitoring of high-voltage cables.

Table 17.5 Serbian Members in Study Committees CIGRE, 2000–2022

	Name and Surname	Company/City	SC	Status	Mandates
1.	Vojislav Škundrić	EPS Beograd	A1	O RM	2000–2006 2006–2010
2.	Prof. dr Ljubomir Gerić	FTN Novi Sad	B3	O	2000–2006
3.	Mr Đorđe Golubović	EMS Beograd	B5	O	2000–2002
4.	Mr Jovanka Gajica	Institut Mihajlo Pupin Beograd	D2	O	2000–2010
5.	Prof. dr Vladimir Katić	FTN Novi Sad	C4	O	2000–2010
6.	Prof. dr Nešo Mijušković	EMS Beograd	C2	O	2000–2006
7.	Radivoje Crnjin	Elektroistok Projektni biro Beograd	B3	O	2006–2014
8.	Dr Ninel Čukalevski	Institut Mihajlo Pupin Beograd	C2	RM	2006–2014
9.	Dušan Arnautović	Institut Nikola Tesla Beograd	A1	O	2010–2016
10.	Jelena Milosavljević	EPS Beograd	C5	O RM	2010–2014 2014–2018
11.	Aleksandar Car	Institut Mihajlo Pupin Beograd	D2	O RM	2010–2014 2014–2018
12.	Mr Goran Jakupović	Institut Mihajlo Pupin Beograd	C2	O	2014–2020
13.	Nemanja Milojčić	Institut Nikola Tesla Beograd	A1	O	2016–2020
14.	Jelena Lukić	Institut Nikola Tesla Beograd	A2	O	2018–2020
15.	Mladen Apostolović	EFT Trade Beograd	C5	O	2018–2020
16.	Dr Jasmina Mandić Lukić	Energoprojekt ENTEL	D2	O	2018–2020

LEGEND: RM - Regular Member, O - Observer

17.3 Activities and achievements of NC CIGRE in Serbia

Challenges and Objectives Ahead

CIGRE Serbia will continue the years-long close cooperation with CIGRE, making its contribution within the available means. At the same time, it will be very interested in the contributions and experiences of other national committees and regional experts and institutions, to transpose their positive experiences in its practice.

Aware of current global tendencies, particularly in the field of electric power industry theory and practice, in 2003 we adopted the new organizational structure and spheres of interest of specific CIGRE committees and we developed their activities accordingly.

The reorganization of power utility companies of Serbia and the Republic of Srpska ("Elektroprivreda Srbije" and "Elektroprivreda Republike Srpske", respectively) and their closer ties will open a whole range of issues in connection with their joint operation.

Strengthening of existing relations – technical and economic – and establishment of new ones with the electric power industries of the neighboring countries will be a crucial field of activity for CIGRE Serbia.

The issues of environment protection, economic aspects of electricity generation, transmission and distribution and safety of supply of sufficient quantities of good quality electricity to consumers expand the scope of interest and engagement of experts at CIGRE Serbia.

Alternative sources of energy, use of available hydro potential and rational electricity consumption are emerging as unavoidable issues of interest for the wider research and development community in the country, and thus also for the expert members of CIGRE Serbia.

CIGRE Serbia, on its behalf, expects even higher commitment and organizational, financial and moral support and assistance from competent commercial and public authorities for the purpose of its improved performance and, above all, in the practical application of the results achieved by this organization in its highly committed and useful efforts.

Table 17.6 Biennial Sessions of JUKO CIGRE/CIGRE Serbia, 1993 – 2020

Session	Place of Session	Year	Nomber of participants	Number of papers
JUKO CIGRE				
21.	Vrnjačka Banja	1993	746	168
22.	Vrnjačka Banja	1995	1160	187
23.	Herceg Novi	1997	1326	207
24.	Vrnjačka Banja	1999	1000	186
25.	Herceg Novi	2001	1000	163
26.	Banja Vrućica	2003	700	184
27.	Zlatibor	2005	1000	209
28.	Vrnjačka Banja	2007	1000	206
CIGRE SERBIA				
29.	Zlatibor	2009	1000	200
30.	Zlatibor	2011	1000	200
31.	Zlatibor	2013	1000	198
32.	Zlatibor	2015	1000	170
33.	Zlatibor	2017	1000–1200	200
34.	Vrnjačka Banja	2019	1000	175

Table 17.7 Symposia on Cables, 1994–2020

Symposium	Place of Symposium	Year	Number of participants	Number of papers
JUKO CIGRE/CIGRE SERBIA				
13.	Donji Milanovac	1994	280	28
14.	Jagodina	1996	246	28
15.	Novi Sad	1998	250	33
16.	Sokobanja	2000	260	40
17.	Zlatibor	2002	200	31
18.	Zlatibor	2004	135	23
19.	Tara	2006	150	21

Table 17.8 Symposia on System operation and Telecommunication, 1994–2020

Symposium	Place of Symposium	Year	Number of participants	Number of papers
JUKO CIGRE				
9.	Herceg Novi	1998	220	37
10.	Herceg Novi	2000	219	56
11.	Herceg Novi	2002	250	50
12.	Bečići	2004	260	51
13.	Tara	2006.	300	56
CIGRE Serbia				
14.	Tara	2008	200	25
15.	Donji Milanovac	2012	80	25
16.	Kladovo	2014	100	29
17.	Vršac	2016	100	32
18.	Zrenjanin	2018	100	33
19.	Bajina Bašta	2020		

Table 17.9 Colloquiums of JUKO CIGRE/CIGRE Serbia, 1991–2020

Colloquium	Place of Colloquium	Year	Nomber of participants	Number of papers
JUKO CIGRE				
Electricity quality in distribution networks	Vrnjačka Banja	1992	320	20
Temporary overvoltages in high voltage networks	Belgrade	1994	120	8
Use of electricity distribution networks in winter and emergency conditions	Zlatibor	1994	400	29
I Load management in power distribution networks	Aranđelovac	1996	350	49
II Information systems in the electricity distribution system				
Colloquium on revitalization of overhead lines	Belgrade	2003	200	31
CIGRE Serbia				
Colloquium STK D2 - Information systems and telecommunications Colloquium STK C2 - Power system management and operation	Belgrade	2010	150	21

Distinguished Member Awards of CIGRE

Table 17.10 Serbian Distinguished Members of CIGRE

No.	Family and Firs Name	Year of Award
1	Škundrić Vojislav	2018
2	Turković Emilija	2014
3	Gajica Jovanka	2012
4	Čukalevski Ninel	2010
5	Naumov Radomir	2008
6	Mijušković Nešo	2008
7	Vučinić Nikola	1998

AWARDS for life work for the National Committee of CIGRE Serbia, 2011–2019

Table 17.11 Serbian Distinguished Members of CIGRE

Serial number	First and Family Name	SC
1	Prof. Mihajlo Golubović	2011
2	Prof. dr Milan Ćalović	2013
3	Prof. dr Milan Savić	2015
4	Radomir Naumov	2015
5	Prof. dr Jovan Nahman	2017
6	dr Jovan Štarklj	2019



Fig. 17.3 34th Session of NC CIGRE in 2019 attended about 1000 participants

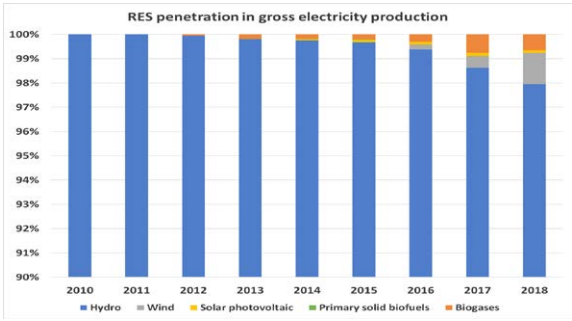


Fig. 17.4 Opening Ceremony of 34th Session of NC CIGRE Serbia, in 2019

17.4 Country electric power profile / RES vision

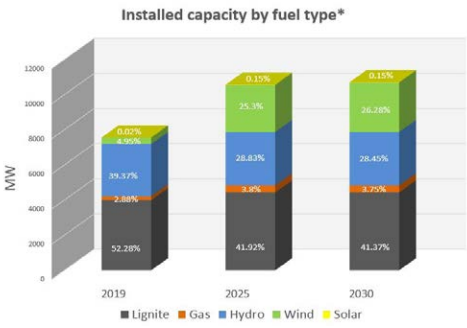
RES (Renewable sources) goals

- Objective: RES share in the gross final energy consumption in 2020 of 27%
- Production of electricity from RES reduced by 8% in the period from 2010–2018
- Revised RES Directive by EC shall be transposed via EnC to Serbia
- National Energy and Climate Plan still to be prepared (covering the period from 2021 to 2030)
- TSO goal: secure the stability of the transmission system with high RES generation



Installed capacities development

- Significant increase of wind capacities by 2025 (2650 MW)
- Moderate increase of lignite TPP by 2025 (new units are more environmentally friendly)
- No large PV projects planned
- Flue gas desulphurization projects (PE EPS)
- Potential balancing issues due to large penetration of RES



Overview of the transmission lines of the Serbian TSO (Transmission System and Market Operator)

Transmission lines EMS JSC		**31. 12 .2019**
400 kV	Number of transmission lines	38
	Length of transmission line (km)	1,798.14
220 kV	Number of transmission lines	48
	Length of transmission line (km)	1,847.14
110 kV	Number of transmission lines	370
	Length of transmission line (km)	5,902.17
110 kV	Number of cables	11
	Length of cable (km))	42.99
<110 kV	Number of transmission lines	10
	Length of transmission line (km)	220.63
TOTAL	Number of transmission lines	477
	Length of transmission line (km)	**9,811.07**
TOTAL with Kosovo	Number of transmission lines	527
	Length of transmission line (km)	10,866.07

Overview of the substations and switchyards of the Serbian TSO (Transmission System and Market Operator)

Substations and Switchyards EMC JSC		**31. 12. 2019**
400/x kV/kV	Number of substations	20
	Number of transformers	30
	Installed capacity (MVA)	9,750
220/x kV/kV	Number of substations	14
	Number of transformers	30
	Installed capacity (MVA)	5,631.5
110/x kV/kV	Number of substations	8
	Number of transformers	14
	Installed capacity (MVA)	659.5

TOTAL	Number of substations	42
	Number of transformers	74
	Installed capacity (MVA)	**16,041**
IN TOTAL with KandM*	Number of substations	46
	Number of transformers	86
	Installed capacity (MVA)	17,624

Overview of transmission capacity of users of the transmission system

Transmission lines of users of the transmission system		**31. 12. 2019**	**31. 12. 2019**
Production	Number of transmission lines	12	
	Length of transmission lines (km)	58.6	
	Number of substations		20.0
	Number of transformers		40.0
	Installed capacity (MVA)		1,159.5
Distribution system operator	Number of transmission lines	3	
	Length of transmission lines (km)	44.3	
	Number of cables	2	
	Length of cables (km)	5.8	
	Number of substations		193
	Number of transformers		348
	Installed capacity (MVA)		10,751.5
Others	Number of transmission lines	22	
	Length of transmission lines (km)	73.2	
	Number of substations		42
	Number of transformers		92
	Installed capacity (MVA)		2,295
Total of transmission lines	Number of lines	39	
	Length of transmission line (km)	181.9	
Total of substations	Number of substations		259



17.5 References

1. The History of CIGRE (International Council on Large Electric Systems), A key player in the development of electric power systems since 1921, ISBN.978-2-85873-166-4, Paris, 2011.
2. The History of CIGRE National Committees, A major contribution to the International history of CIGRE: Creation and Development of National Committees since the 1920s. Paris, 2013.
3. 18.3V.K. Ishkin, International Council on Large Electric Systems, 85 years, 1921–2006, Orgenergo-servis, 2006.

18. NC CIGRE SLOVENIA

18.1 History of electric power sector

a) Early time of DC electricity

First public presentation of electric light in the territory of Slovenia, happened in Ljubljana, on 25th May 1881, between 8 and 10 PM. At the end of the local newspaper called *"Slovenski narod" (Slovenian people) no. 120*, it was written that Carniolan Technical Society made successful demonstration of a great innovation for all mankind – electrical light. At that time Slovenia was under the Austro-Hungarian Empire. On the 10th May, marriage of Prince Rudolf Habsburg with Princess Stephanie of Belgium was announced, and in honour of this event, all authorities of municipalities in the Empire invited people to celebrate it, with a great illumination on the main squares. E.g. in honour of this occasion, the Vienna Gas company organized a gigantic triumphal arch illumination with many small gas flames put up on the Ringstrasse boulevard in Vienna /R 18.9/. In Ljubljana people demonstrated an electrical illumination. On the evening of 9th May, the attempt of generating electricity from locomobile was not possible, because of heavy rain. However, Technical society repeated it successfully two weeks later, on 25th May 1881. The newspaper said, that it was significantly crowded event, where people stood enraptured with electric light, which was strong like daylight in comparison to existing public gas lights, and that it was possible to read newspaper far away from the arc light. People were feeling overwhelmed by the new technology.

Consequently, other cases of electrification followed in 1882, starting with the renewed and modernized Thermal Bath in Laško (at that time called Tüffer, Styria region), where owner Theodor Gunkel from Vienna, installed two 5 kW DC dynamos to a wooden waterwheel at the nearby stream. This installation produced electrical light in the surrounding promenade and also pumped the thermal water in between the bathing pools. This was one of the world's first installations for using hydro power as an electricity generator and water pumping at the same time.

Third World Electrical Exhibition in Vienna in 1883 brought /R 18.10/ many innovations in electrical technology. The Vienna exhibition lasted 108 days with 15,000 visitors per day. The immense influence of this exhibition spread through-

out the Region. In April 1883, in Maribor, Miller Karl Scherbaum installed a 5 kW dynamo to his steam mill, with a purpose to demonstrate electrical illumination with 36 incandescent lamps. It is also a well-known fact, that famous inventor Nikola Tesla had his first job in Maribor in 1879, as an assistant engineer in one of the newly establishing electro-mechanical workshops. In 1888, Slovenia started using DC electricity for industrial use, firstly in a town workshop of Litija.

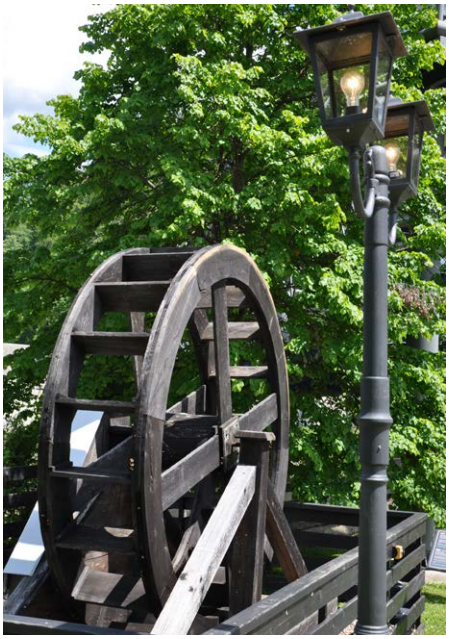


Fig. 18.1 Replica of a wooden waterwheel by Lasko Thermal complex, located in the same place as the original in 1883.



Fig. 18.2 First public HPP Završnica from 1914.2 x 1.25 MVA, marks the beginning of the 10 kV public electrification supply network.

b) First use of AC three phase electricity

The first use of AC electricity was incorporated in a hydro power plant on river Ljubljanica, in the nearby city of Ljubljana, for a paper factory, which started operating on April 14th 1897. Hydro Power Plant (HPP) had two Jonval-Girardi turbines, connected to 650 kVA three-phase generators, with 170 revolutions per minute. Those generators used step-up transformers to 3 kV rated voltage and the frequency of 42 Hz. From HPP to industrial plant Vevče ran the first

overhead line (OHL) in Slovenia, 3 km long with 87 poles. This happened only two years after Niagara Power Station 2 in the USA, which already used AC multi-phase systems instead of DC systems. In the year 1900, there were all together 35 electrical power plants in Slovenia, with the installed power of 2960 kW (30 DC and 5 AC power plants).

In 1901, at beginning of 20th century, the level of the world's electric power generation was about 12 TWh, and at the end of the century about 13.100 TWh. Thus, global electricity growth in one hundred years was about 1000-times higher and the average annual rising rate was 7.25%.

In the first decade of the 20th century, Slovenia constructed another 30 electrical power plants with the installed power of 12 MW, with the majority of AC facilities. In 1910, a 150 kVA generator with the frequency of 50 Hz was introduced in small HPP. All electrification projects until 1910 were on the individual level. In 1914 however, public electrification in Carniolan region began with the first HPP called Završnica (2 x 1.25 MVA). Dr. Evgen Lampe, a political leader of People's Party, in 1908 established a Carniolan Provincial power company (named KDE – *Kranjske deželne elektrarne*), which actually began with public electrification of Carniolan region. KDE developed a 10 kV network system in the Northwest part of Slovenia, connecting HPP Završnica with consumers in Bled and nearby villages. Up to the end of Great War (WWI) in 1918, 66 additional power plants were constructed in Slovenia with 43 MW installation power. Thus, before Slovenian territory became part of the newly established country, there were 191 power plants altogether (52 MW, 90% of them AC). The largest one was HPP Fala, with 34.5 MW on Drava River, which was one of biggest in Europe at that time /R 18.11/. Swiss capital was invested in Hydro power plant Fala with the intention to supply electricity to Maribor and Graz, but after new border was made between Austria and Slovenia after WWI, investors changed previous plans.

c) Development of Electric Power System

In the period of first Yugoslavia, from 1919 to 1941, the construction of electrical network and power stations began in Slovenia alongside of power stations. Up to 1941, there were 642 new plants constructed, which was in total 833 power plants with 160 MW of installed power. The network consisted of almost 2000 km of different voltage levels from 132 kV, 80 kV, 35 kV, 10 kV and 5 kV. The

low-voltage network was also around 2000 km long. The parallel operation started in 1925 after the construction of 80 kV OHL between HPP Fala and substation Laško 80/35 kV. It connected 35 kV OHLs to Trbovlje mine and city of Celje as well. The characteristics of electrification in the early phase was lack of public interest and regional coordination. The reason for the lack of interest in public sector were the high prices of electricity, electrical equipment, economic depression, as well as the lack of the long-term vision in the development of the electricity sector. Industrial and small craft plants prevailed, operating in island mode. Only a few power plants exported surplus electricity production to public consumption (e.g. town of Škofja Loka, which first had public lighting in 1894).

Territory of Slovenia was part of Austro–Hungarian Empire at the beginning of electrification (before October 29, 1918). On October 29, 1918 State of Slovenes, Croats, and Serbs was established as a new country, which was re-named one month later on December 1, 1918 to Kingdom of Serbs, Croats and Slovenes. On October 3, 1929 country was renamed to Kingdom of Yugoslavia (also first Yugoslavia) lasting up to 1941, beginning of Second World War (WW2). From August 1945 to November 1945, a new state called Democratic Federal Yugoslavia was established, which was renamed on November 29, 1945 to Federal People's Republic of Yugoslavia (also second Yugoslavia). On April 7, 1963 country was renamed to Socialist Federal Republic of Yugoslavia, which lasted up to 1991. Independent Republic of Slovenia was established in 1991.

However, the electrification in the period from 1918 to 1941, was different than before. The impact of the newly created Yugoslav state and the unstable general global economy, also characterized electrification growth. Especially, it struggled between two competitive companies: Carniolan Provincial power utility (KDE), which represented public interest and had an impact on the area of central Slovenia, and FALA (joint-stock company), which had an impact on electrification of the northeast part of Slovenia. In the western area (region Primorska), which was under Italy, the process of electrification was separate, using different frequency (42 Hz) and voltage levels.



Fig. 18.3 HPP FALA (5 x 5.2 MVA) was the first large power plant in Slovenia, which began operating in 1918.

In 1939, connection between two sub-systems, public KDE (central/west part of Slovenia) and private FALA (northern/east part of Slovenia) was made, with 60 kV overhead line between substations Trbovlje and Podlog. Thus, Slovenian territory established fully connected electric power system before Second World War (WW2).
During the WW2, German army build first 110 kV overhead line and Hydro Power Plant Dravograd on Drava River connecting it to Thermal power plant in Velenje.
After the WW2 in 1945, private properties became nationalized by a new established communist ruler, thus new utility named State Electric Power Plants of Slovenia (DES) was established on Slovenian territory, unifying all production of electricity in the Slovenian electric power system. All facilities became publicly owned. Fig. 18.4 shows development of generation in Hydro vs. Thermal power plants, between 1945 and 2005. After 1974 thermal power units predominated over hydro units, due to great increasing needs of electric energy in Slovenia.

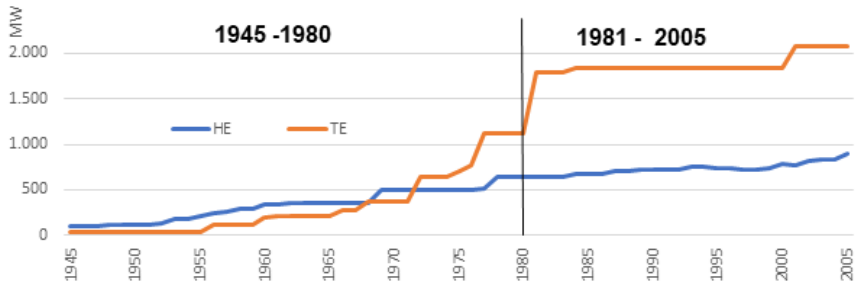


Fig. 18.4 Development of Hydro and Thermal generation in Slovenia
HE ... Hydro power plants, TE ... Thermal power plants

In 1950, the installed power of the public power plants in Slovenia was 214 MW with total generation of 937 GWh, what was almost 40% of all electricity generated at that time in Yugoslavia. That time was characterized with intensive development of electricity network. Annual rate of electricity demand was over 7.5%.
In 1951, UCPTE *(Union pour la Coordination de la Production et du Transport de l'Électricité*) was established by 8 countries: Belgium, Germany, France, Italy, Luxembourg, Netherlands, Austria, and Switzerland, who created Western European Transmission as synchronous interconnection system. This had impact on the way of thinking about the further development of electric power system in all regions. Quality of supply became of value.

Electric power system in Slovenia was growing fast. 614 MW of generated power was produced in 1960, which was 4-times more than in 1945. In the period between 1965 and 1975, several re-organizations in electricity sector were made, with the aim to find the best solution for rapid development of electric supply industry. Finally, Slovenian Joint Enterprise for Electric Power (SOZD EGS) with headquarters in Maribor, unified all electricity sector and very successfully organized development of electric power system for the next 15 years, although new principles for self-management business approach were implemented. Those 15 years, were the most successful in history of Slovenian Electric supply industry. During this period construction of 220 kV network, construction of new 400 kV network was made, the largest unit 5 in Thermal power plant Šoštanj, Nuclear power plant Krško (shared with Croatia) and numerous facilities in Slovenian distribution had been completed. The benefits of the build infrastructure from that period (1974–1990) are still reaped today.

Nevertheless, one more aspect of electricity sector must be emphasized. That is the interconnection with UCPTE network. In the 1964, SUDEL (an initiative group to connect the electricity networks of Austria, Yugoslavia, and Italy) was set up with a political support. First time after the WW2 and during the Cold War, between the blocks, members of SUDEL developed an idea of connecting electricity network between two politically different systems into a single technical system, which was unique for that political time in Europe. After many technical discussions and studies, the first of 220 kV OHL of SUDEL loop with Italian system was realized on **September 16, 1974.** In June 1975, OHL Obersielach (AT) - Podlog (SI) was connected, which means that SUDEL loop of 220 kV OHLs was integrated into Yugoslav EPS and to the European synchronous UCPTE interconnection. Later, in 1981 SEDEL loop was upgraded with 400 kV connection to Italy and in 1991with Austria with 2 x 400 kV line. In 1981, the latter countries also approved integration of Greek Electric Power system to UCPTE.

CONSUMPTION DEVELOPMENT IN SLOVENIA FROM 1950

YEAR	**GWh**
1950	937
1970	4 661
1990	9 833
2010	12 158
2018	13 485



Fig. 18.5 Nuclear power plant KRŠKO in operation from 1981

In 1999, the National Assembly adopted the Energy law, which was consistent with the European Union's orientations, and opened a new chapter in the development of the Slovenian national Electric Power System. Integration with the European internal market and the new market-oriented organization of the electrical system, profoundly altered the conditions of planning, development, and operation in the electricity market.

18.2 History of CIGRE

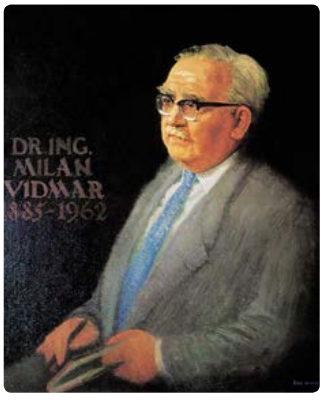


Fig. 18.6 Milan Vidmar

Before WW2, some Yugoslav experts participated in about 10 CIGRE sessions in Paris /R 18.3/, but details about it were not noted in our archive. Registered CIGRE activity really started in second Yugoslavia in 1950, with the help of University professor Milan Vidmar, who was at that time, world renowned electrical engineer. In 1948, during the 12th CIGRE Session in Paris, which M. Vidmar attended, the delegate general and vice-president of CIGRE, Jean Tribot Laspiere invited Slovenian professor Milan Vidmar to establish Yugoslav National Committee of CIGRE. Professor Vidmar started this procedure with a careful step of asking for an invitation letter, being aware of the communist

regime in his country and delicacy of cooperation with the foreign institution. After receiving the invitation letter, Milan Vidmar informed minister of electricity about this initiative from Paris. Regarding the political time the procedure for establishing National Committee of CIGRE lasted almost three years. In the meantime, CIGRE Central office already considered Yugoslav Committee as one of the 34 NCs in CIGRE family.

Milan Vidmar was a managing director of the first Institute for electrification in Yugoslavia, located in Ljubljana, and author of many technical books on electricity issues (i.e. his book *"Die Transformatoren"*, second edition from 1932, in German language, was translated to French and Russian language and was very known in many universities in Europe). His interest in transformers came from his work in the beginning of his career with Ottó Titusz Bláthy, Hungarian electrical engineer, who worked with Ganz Company, and was known in 1885, as one of the three inventors of "Transformer", who gave its name. Before that, it was called a "secondary generator". Milan Vidmar was also known worldwide as one of the best chess players. In 1948, he was the chief arbiter for World Chess Championship, so he was the one to announce Mikail Botvinik for 6th World Chess champion in Moscow. Such reputation has also brought him certain advantages. To summarize, current chapter is focused on two parts of CIGRE activities in Slovenia:

a. 1951–1991 ... Slovenian participation in former Yugoslav CIGRE Committee activities
b. 1992–2020 ... Short history of the Slovenian National Committee of CIGRE.

Slovenian participation in the former Yugoslav CIGRE Committee activities (1953 – 1991)

After the initial difficulties, the Yugoslav National Committee of CIGRE (abbreviated to JUNAKO and later JUKO CIGRE), came to life on December 3, 1951, in Zagreb, during the Founding General Assembly, which approved Statute, Working program and leading councils. First president was named Milan Vidmar from Ljubljana, Vice-president Milivoje Rakić from Belgrade and Secretary General Herman Mattes, from Zagreb, who played a crucial role in solving administrative obstacles and preparing documents for establishing association. The organisation was officially registered as a non-governmental professional association of Yugoslav electric power engineers, based in Zagreb, where central office of the JUKO CIGRE was located, until the dissolution in 1991. On the proposal of the first President Milan Vidmar, the first CIGRE Conference was

convened in Ljubljana. Thus, first conference held from 25th to 27th May, 1953 in Ljubljana, Slovenia, welcomed exactly 100 participating experts, who presented 21 papers. Table 18.1 shows statistics of all 20 Yugoslav CIGRE conferences, with the number of papers from Slovenia.

Table 18.1 The list of conferences organized by Yugoslav National Committee of CIGRE in period 1953 to 1991

Number of conferences	Location	Republic	Year	Number of participants	Number of papers	Papers from Slovenia
1	Ljubljana	**Slovenia**	1953	100	21	2
2	Sarajevo	Bosnia & Herzg.	1954	135	23	2
3	Niška Banja	Serbia	1956	205	35	4
4	Opatija	Croatia	1958	253	30	3
5	Ohrid	Macedonia	1960	291	46	4
6	Budva	Montenegro	1962	350	77	18
7	Bled	**Slovenia**	1964	550	93	23
8	Mostar	Bosnia & Herzg.	1966	650	102	11
9	Vrnjacka Banja	Serbia	1968	713	99	11
10	Dubrovnik	Croatia	1970	830	163	20
11	Ohrid	Macedonia	1972	860	152	31
12	Budva	Montenegro	1975	1091	193	34
13	Bled	**Slovenia**	1977	1170	180	25
14	Sarajevo	Bosnia & Herzg.	1979	1058	185	24
15	Beograd	Serbia	1981	1016	215	32
16	Opatija	Croatia	1983	1023	255	21
17	Struga	Macedonia	1985	1110	262	29
18	Bečiči	Montenegro	1987	1330	271	21
19	Bled	**Slovenia**	1989	1210	283	36
20	Neum	Bosnia & Herzg.	1991	Not available	216	23
	Total				**2899**	**374**

It is important to underline, that JUKO CIGRE biennial conferences were the main event for electricity experts in Yugoslavia for many years, where they discussed crucial technical solutions, technology decisions, standards improvements and developments of energy sector in the period of country's growing electrification. CIGRE activities in Yugoslavia were similar to the ones in Paris, stressing on the important topics for ongoing electrification projects in the country. Participation of Yugoslav CIGRE members at CIGRE Sessions in Paris, as well as in international WGs, was not so active as after the year 1991, which is expected due to the political situation at that time. However, first organized participation of Yugoslav experts at CIGRE was on the 13th CIGRE Session in Paris in 1950. There, Professor Milan Vidmar from University of Ljubljana, Slovenia wrote and presented: *"Aluminium Transmission Conductors without mechanical reinforcements"* and *"Automatic Control of time and load division among generating stations in interconnected systems"* written by Dr. Ilija Obradovic from Belgrade, Serbia.



Fig. 18.7 JUKO CIGRE hosted the meeting of SC 34 Protection, in Dubrovnik 1988.

Professor Anton Ogorelec from Slovenia organized the first international Colloquium on protection in Ljubljana in 1960. It was well accepted by many experts, particularly protection manufacturers, who wanted a closer relationship with the industry. As an active member of SC 34 and a well-known expert for protection, Ogorelec organized also the second CIGRE international colloquium in 1988, in Dubrovnik (see fig. 18.7).

Slovenian authors participated with 4 papers at Paris sessions from 1950–1990 and 374 papers (13%) in 20 Yugoslav National CIGRE conferences from 1953 to 1991.

In 1991, only two members of international CIGRE Study Committees from Slovenia and nominated by JUKO CIGRE were Kresimir Bakic *(SC37 – Planning and Development of Power Systems)* and Ferdinand Gubina *(SC 39 – Operation and*

Control of Power Systems). Nevertheless, CIGRE activities in JUKO CIGRE organization in the period from 1951 to 1991, paved the way for later established seven national committees, born from former one.

a) Short history of the Slovenian National Committee of CIGRE

In February 1992, a group of "old CIGRE-ans" organized a committee for establishing the assembly of Slovenian National Committee of CIGRE. The interest of the Slovenian energy experts was immense. Establishing assembly was held on March 17, 1992 with 106 experts and 21 utilities present. For the first president Prof. Dr. Ferdinand Gubina was elected, and two vice-presidents Kresimir Bakic and Maks Babuder. K. Bakic was responsible for the development of society within Slovenia and M. Babuder for activities abroad. From the beginning the Slovenian National Committee organization mirrored the one in Paris with 12 National Study Committees. 200 experts expressed a desire to participate in the activities of National CIGRE as well as in international activities. Two months later, new Association of electric power engineers called SLOKO CIGRE was registered, in accordance with the Slovenian law.
At the next CIGRE Session in Paris, Administrative Council of CIGRE on August 30, 1992 recognized Slovenian National Committee of CIGRE as a new member of CIGRE family.
For a small country as Slovenia, it was especially important to cooperate, exchange information and knowledge in the international community. For this reason, organization of CIGRE in Slovenia is well accepted and represents new academy for electricity sector.

Table 18.2 List of leaders in the Slovenian NC CIGRE 1992–2020

	President	**Vice-presidents**	**Secretary**
1992–2001	Ferdinand Gubina	Maks Babuder, Kresimir Bakic	Kresimir Bakic
2001–2005	Vekoslav V. Korošec	Lado Tomšič, Jože Voršič, Marko Senčar, Franc Jakl, Franc Leskovec	Kresimir Bakic
2005–2017	Krešimir Bakic	Marko Hrast, Matjaž Osvald, Drago Polak, Marko Senčar, Igor Papič	Miloš Pantoš, Matej Čoga, Miha Bečan
2017–2021	Marko Hrast	Uroš Salobir, Andrej Tumpej, Jože Pihler, Matjaž Osvald, Bojan Kuzmič	Leon Maruša

The main challenge of the organization of national technical society, was how to organize independent technical organization in the spirit of CIGRE and its approach to develop *"free technical thinking"*. To achieve that, there were three main objectives:

a. to create financially independent organization,
b. to motivate electrical engineers for massive participation on national conferences and invite sponsors to participate and meet key persons from utilities, and
c. to develop voluntary work value. After 27 years of experiences, it can be said, that all was achieved.

Organization of national CIGRE conferences, workshops, publishing technical books, intensive cooperation with international Study committees and WGs, involving young engineers for cooperation in CIGRE, increasing activity to distribution and generation interested areas, and new model of institutional arrangements, made Slovenian NC CIGRE successful as an association and one of the best recognized technical society in Slovenia. All this is possible, despite the low number of power engineers (about 10 thousand employees in all Slovenian electric power sector).
From 1993 to 1999, distribution companies and its engineers participated in a separate Study Committee No.31 in NC CIGRE, named Distribution network (following the practice from JUKO CIGRE). However, engineers from Distribution utilities insisted to extend activities in this area of distribution connecting to CIRED. They were looking for possibilities to be in same National Committee/ Technical Society. After the discussion (in 1999), independent association of NC CIGRE established separate section for distribution activities, and submitted the first paper to CIRED conference in Nice (France). Thus, after year 2000, Association changed its name to Slovenian Association of Electrical Power Engineers, CIGRE and CIRED, covering full activities of both organizations. Association operates as an independent technical organization. From 2001, all National biennial conferences were organized in two sections: section CIGRE and section CIRED.

Association combines about 250 individual members and 40 collective members. In international CIGRE community membership, Slovenian NC CIGRE lies in average with 54 individual members and 8 collective members, which leads up to 102 equivalent members. Comparing the size of the country and number of employees, rate of CIGRE membership is very high.

In 2002, CIGRE made structural changes, dividing Study Committees into A, B, C and D groups. Later, in 2016, in accordance with global transition of electric power system, CIGRE changed the strategy and business model with an extension of technical activities to all voltage levels of the Electric Power System. Slovenian NC CIGRE participated in almost all Study Committees. From 2014, Slovenian NC CIGRE has participated in all activities of newly established South East European Region of CIGRE (SEERC).

18.3 Activities and achievements of NC CIGRE in Slovenia

a) National Cigre Conferences, Workshops, Colloquiums

Slovenian NC CIGRE continued with a good practice and tradition from former Yugoslavia, with biennial National CIGRE conferences in odd years. First national conference was launched on 25th May 1993 in Ljubljana. It was a nice coincidence, that exactly 40 years, after the first Yugoslav CIGRE conference in Ljubljana was held, the first Slovenian National CIGRE conference was organized on the same day and in same the city. From 1993 to 2019, Slovenian NC CIGRE organized 14 biennial national conferences (Table 18.3). Attendance at the conferences was always very high (with over 500 experts) and on average 127 CIGRE papers per conference or 167 papers in both sections (CIGRE and CIRED section). Considering the size of the event and limited number of experts, CIGRE events are always of high interest. Slovenian electricity engineers expressed a request to exchange mutual information and improvements of the system through CIGRE activity. Participation and contribution of papers by Slovenian experts in the new National CIGRE association became seven times larger, than in previous Yugoslav CIGRE organization.

Table 18.3 The list of the conferences of Slovenian NC Cigre from 1993–2019

National CIGRE Conferences	Location	Year	Number of papers
1	Ljubljana	1993	83
2	Maribor	1995	90
3	Nova Gorica	1997	122
4	Thermal Spa Rogaška	1999	118
5	Bled	2001	108
6	Portorož	2003	121
7	Velenje	2005	136
8	Thermal Spa Čatež	2007	122
9	Kranjska Gora	2009	108
10	Ljubljana	2011	141
11	Thermal Spa Laško	2013	184
12	Portorož - Bernardin	2015	171
13	Thermal Spa Habakuk, Maribor	2017	149
14	Thermal Spa Laško	2019	131
TOTAL			**1784**

Moreover, similar situation occurred with the increased participation in activities at CIGRE Paris. Between 1952 and 1991, Slovenian engineers representing JUKO CIGRE contributed only four papers to CIGRE General Sessions in Paris vs. 51 papers in the period 1992–2020, after establishing our own National Committee (which means 12 times more, after establishing Slovenian National Committee).

Biennial National CIGRE conferences in Slovenia are organized in May, every odd year. Preferential subjects (PS) for each conference are selected by leaders of each Study Committee on the national level. Majority of PSs are selected with consideration to national aspects and needs. Papers are reviewed by at least one reviewer, who must prepare questions for authors and the audience. After presentations, every Study Committee has a task to select the best paper of group. 95% of approved papers come from Slovenian authors and other from abroad. Each paper must be orally presented in Slovenian or English language. Beside paper discussion, every conference organizes 2–3 panels on interesting topics with international participation *(e.g. from 2019: Application of chemical bat-*



Fig. 18.8 The first national conference in Slovenia, 25 May 1993.

teries in Power systems and Transportation; National energy strategy up to 2030; and Big data analytics in Power systems). Among those, there is also a Student competition for the best paper, which became also remarkably interesting between students and young engineers. Winner of the best student paper receives a PC or a tablet.

At the same time, NC CIGRE also organizes Exhibition of products and services for Electric Power System, with over 30 sponsors. All exhibition booths are booked one-year in advance. Beside National conferences, NC CIGRE organizes a special workshop CIGRE after CIGRE (after CIGRE session in Paris) and one-day traditional conference on Maintenance in Distribution, Transmission and Generation part of system in even years. This conference is always in the middle of November with 150–200 attendees.

b) Contributions to international activities of Cigre after 1992

Cooperation in Study Committees

After the establishment of our National Committee, the activities of the Slovenian experts in CIGRE Study Committees became much more active in SCs and WGs. In 1992, it began with only two SC members from Slovenia (F. Gubina, K. Bakic). In 2010–2012, Slovenia participated in all 16 Study Committees (3 regular and 13 observers). In 2019–2020, NC CIGRE Slovenia participated with 14 members in SCs.

Table 18.4 presents increase of SC's members from the Slovenian NC CIGRE in the period from 1992 up to 2020.

Table 18.4 Number of members in Study Committees from NC CIGRE Slovenia in the period 1992–2020

Year	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
All Members	2	4	6	6	6	8	8	10	9	16	16	14	13	14
Regular Members	1	1	2	2	2	2	2	1	1	3	3	3	2	3

Many other experts from Slovenia participated in number of working groups as conveners or active members.

Slovenian member of Administrative Council Ferdinand Gubina was nominated in period 2002–2004 as member of the Technical Council of CIGRE representing Administrative Council.

From 2008–2010, Kresimir Bakic was nominated as a member of Technical Council of CIGRE representing Administrative Council.

During the Panel Electric Power Engineering Education in 2002, Professor Ferdinand Gubina was appointed as convener and chairman of a Panel. In 2014, Krešimir Bakič was a chairman of the Forum of National Committees during Paris General Session.

Slovenian member Kresimir Bakic was Special reporter at three CIGRE Symposiums:

- 1997, Neptune (Romania), Symposium on Impact of DSM, IRP, and Distributed generation on Power System,
- 2005, Athens (Greece), Symposium on Power Systems and Dispersed Generation, Technologies, Impacts on Development, Operation and Performances, and
- 2013, Lisbon (Portugal), Symposium on Smarts Grids: Next Generation Grids for New Energy Trends. This Symposium was organized together with CIGRE and CIRED.

Later, Special Reporters at CIGRE General Sessions in Paris after 2014, were the following CIGRE members:

- 2014, Krešimir Bakič in the SC B2, Overhead lines,
- 2016, Aleš Kregar in the SC C3, System Environmental Performance,
- 2018, Igor Papič in the SC C4, Power System Technical Performance.

Members of the Slovenian NC CIGRE in the period from 1992 to 2020, contributed 51 papers at CIGRE General Sessions. 30 of them were in the National (N) and 21 in International (I) quota, as presented below in the Table 18.5.

Table 18.5 Number of Slovenian papers at CIGRE General Sessions in Paris, in period 1992–2020:

Year	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
N-papers	-	1	2	1	2	1	1	3	2	-	2	2	2	2	9
I-papers	2	1	2	-	2	2	3	3	1	1	-	1	-	2	1

First paper of the Slovenian NC CIGRE from national quota was in 1994 *"Economical, planning and operational aspects of East West power transmission over the Slovenian power network"* by F. Gubina, K. Bakic, P. Omahen, J. Hrovatin, F. Jakl, which highlighted problems in Europe about extension of synchronized interconnection system of UCPTE and connection of 400 kV transmission line between Slovenia and Hungary. Now, 26 years later, this transmission line finally started with construction. In the meantime, many environmental and social problems had to be solved.

c) Organization of CIGRE Symposia in Slovenia

Slovenian NC CIGRE organized Symposium CIGRE in Ljubljana, in 2004. This symposium replaced Symposium in China 2003 (Shanghai), which was canceled due to SARS (severe acute respiratory syndrome). Secretary General of CIGRE, Jean Kowal, asked K. Bakic in autumn 2003 about replacing the location of this event to Ljubljana, in April 2004. Symposium was titled ***"Development and operation of interconnection in a restructuring context"*** and included four SC's: C1, C2, B2 and B4. Despite time shortage, symposium was very well organized with over 300 participants from all five continents. At that symposium, there were many discussions on crucial global restructuring issues as regulation, planning and operation.



Fig. 18.9 President of CIGRE Mr. David Croft at the opening session of CIGRE Symposium 2004 in Ljubljana

Slovenian NC CIGRE is about to organize next CIGRE Symposium, 1st–4th June 2021, celebrating 100 years of CIGRE and 40 years of the first CIGRE International Symposium. Symposium titled ***"Reshaping the Electric Power System Infrastructure"*** will cover 10 SCs (A1, A2, A3, B1, B2, B3, B4, B5, C3 and D1) and will focus on the future transformation of the electricity sector, the new framework of generation, transmission, distribution, and demand side.
In 2010 Slovenian NC CIGRE during the mandate of Kresimir Bakic in the Technical Council CIGRE, organized annual TC meeting in Bled, Slovenia (Fig. 18.10).



Fig. 18.10 Members of TC CIGRE 2010 on the trip to small island of Lake Bled

d) CIGRE Awards

A. CIGRE central Office Paris bestowed following awards to Slovenian members:

- **CIGRE Honorary Member:**
  - 2018 – Kresimir Bakic
- **CIGRE Technical Committee Awards:**
  - 2004 – Kresimir Bakic
    (SC C1 – Development and economy of the system)
  - 2012 – Janez Zakonjsek
    (SC B5 – Protection and Automation)
- **CIGRE Distinguished Member:**
  - 1998 – Anton Ogorelec,
  - 2000 – Ferdinand Gubina,
  - 2002 – Krešimir Bakič,

- 2004 – Maks Babuder, Franc Jakl,
- 2010 – Ivan Leban, Maja Koncan-Gradnik
- 2012 – Jože Voršič
- 2014 – Ladislav Tomšič
- 2016 – Rafael Mihalič
- 2018 – Jože Pihler
- 2020 – Igor Papič

B. NC CIGRE Awards

Slovenian National Committee every two years, during National CIGRE Conferences, assigns different levels of Awards on national, and as well on the international level. Awards on a National level are e.g. Life Achievement Award, Award for extraordinary contribution to the work of CIGRE, Award for excellent work in certain national electricity project, a Prize for best journalist reporting on energy sector, Prizes for best doctoral theses, masters, and university diplomas and for the Best Study Committee paper.

From 2010 Slovenian NC CIGRE introduced a new award on the international level called the **Ambassador of CIGRE,** and is given to members, who participated in broadening CIGRE importance worldwide. The winners were:

- 2010 - Jean Kowal, France, and Anton Ogorelec, Slovenia
- 2013 – Andre Merlin, France
- 2016 – Klaus Fröhlich, Switzerland
- 2017 – Krešimir Bakič, Slovenia.



Fig. 18.11 Former President of CIGRE Andre Merlin received a title "Ambassador of CIGRE" in the presence of the Slovenian President, Mr. Borut Pahor, who participated as a special guest at the 11th National CIGRE Conference in Laško.

18.4 Country electric power profile / RES vision

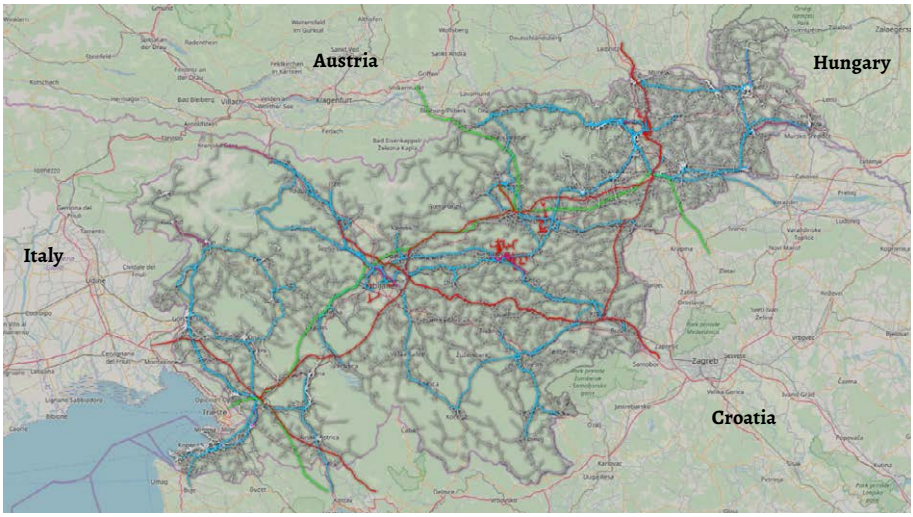


Fig. 18.12 Geographical layout of the Slovenian transmission and distribution network, in 2020

TRANSMISSION GRID (ELES TSO):	
Overhead Lines (400 kV, 220 kV, 110 kV)	2852 km
Cables (110 kV):	13 km

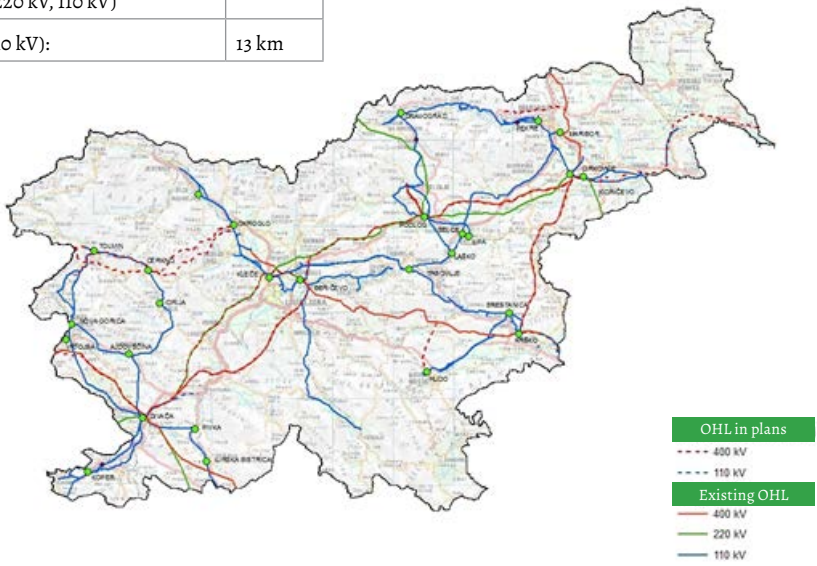


Fig. 18.13 The Slovenian transmission network of the existing and planned

Generation of electricity in Slovenia 2019	
Fossil power plants	4,589 GWh (30 %)
Nuclear power	5,423 GWh (36 %)
RES - Hydro - Soalr -Wind - Other	5,221 GWh (34 %) 4,677 GWh 235 GWh 6 GWh 304 GWh

Total electricity consumption	14 173 GWh
Household consumption	3 260 GWh
T&D losses 6.2%	6.2 %
Peak Load (2019) 2050 MW	

DISTRIBUTION GRID (SODO DSO) Overhead (44 346 km)	
110 kV	850 km
1–35 V	13,424 km
0.4 kV	30,072 km
Cables (20 200 km)	
1–35 kV	4,000 km
0.4–1 kV	16,200 km

Population 2019	2.06 million
Area	20,273 km^2
BDP/capita	21,267 EURO

SLOVENIA FINAL ENERGY	TWh
2019	56

SLOVENIAN RENEWABLE ENERGY RESOURCES (RES) IN PLANS	%
2019 - existing	19.5
2030 - plans	27

In Slovenia **72%** of electrical grid (T&D) are overhead lines

18.5 References

1. The History of CIGRE (International Council on Large Electric Systems), A key player in the development of electric power systems since 1921, ISBN.978-2-85873-166-4, Paris, 2011.
2. The History of CIGRE National Committees, A major contribution to the International history of CIGRE: Creation and Development of National Committees since the 1920s. Paris, 2013.
3. V. Kh. Ishkin, International Council on Large Electric Systems: Cigre History activity 1921 – 2006, UDK 621.311, Moscow, 2006.
4. JUKO CIGRE, 40 GODINA RADA 1951 – 1991. Zagreb, 1991.
5. Pedeset godina djelovanja CIGRE u Hrvatskoj (*"50 years of CIGRE in Croatia"*), 1951–2001, Deset godina Hrvatskog Komiteta Cigre *("10 years of NC Cigre Croatia")*, 1991 – 2001, Zagreb, 2001.
6. K. Bakic, et al: Življenje elektroenergetske stroke v samostojni Sloveniji *("Life of electric power society in independence Slovenia"), 65/25: 65 years of CIGRE in Slovenia and 25 years of NC CIGRE, Ljubljana,* Slovenian Society of CIGRE & CIRED, 2018.
7. Slovenski narod ("Slovenian People") Daily news, No.120, XIV, Ljubljana, Saturday, 28 May1881.
8. K. G. Beauchamp, Exhibiting Electricity, The Institution of Electrical Engineers, London, UK, 1997.

9. Slovenski narod ("Slovenian People") Daily news, No.120, XIV, Ljubljana, Saturday, 28 May1881.
10. K. G. Beauchamp, Exhibiting Electricity, The Institution of Electrical Engineers, London, UK, 1997.
11. C. Linsboth, Let there be light, Gas and electricity light up Vienna, The Monarchy Becomes Modern1815–1913, https://www.habsburger.net/
12. The Vienna International Electric Exhibition, *Nature, Volume 29, pages 42–43, 1883.*
13. S. Fras, et al: Razvoj elektroenergetike Slovenije do 1945. *("Development of Electric Power sector in Slovenia up to 1945")*, Tehnična založba Slovenije, Ljubljana, 1976.
14. F. Holz, et al, Razvoj elektroenergetike Slovenije 1945 – 1980. *("Development of Electric Power sector in Slovenia between 1945 and 1980")*, Tehnična založba Slovenije, Ljubljana, 1982.
15. J. Hrovatin, et al, Zgodovina slovenskega elektrogospodarstva. *("History of the Slovenian Electric Power sector")*, Elektrotehniška zveza Slovenije, Ljubljana, 2007.
16. F. Jakl, Thirty Years of Synchronous Operation with Europe, ISBN 961-91382-0-1, Elektro-Slovenija, 2004.

All photos used in this chapter are published by credit of NC CIGRE Slovenia.

For further information contact:
NC CIGRE Slovenia
Tehnoloski park 20C
1000 Ljubljana, Slovenia
NC CIGRE website: www.cigre-cired.si
e-mail: info@cigre-cired.si
Phone: ++386059972842

19. NC CIGRE TURKEY

19.1 History of Electric Power Sector

a) The First Power Plants

During Ottoman period, **the first electricity generation by an urban power plant** had started in Tarsus in 1910 in Southern Anatolia by upgrading of a 2 kW DC dynamo that was connected to a water mill owned by a Swiss-Italian company. Between 1906–1910 this facility had been upgraded to an urban power scale plant with a 75 kW generator. With the completion of the distribution lines by the municipality, on 8 February 1910, the plant supplied electricity for lighting of streets in Tarsus. It had been operated by the Tarsus Municipality until 1923, and by a private company until its nationalization in 1937.



Fig. 19.1 Silahtarağa PP Turbine Hall

The **first urban-scale power plant** in İstanbul, the Silahtarağa (Silahtar, Silihtar or Silighdar) Power Plant (PP), constructed by Budapest based Ganz Electricity Company, started operation in 1914. With an initial installed capacity of 3 x 5,000 kW, the plant supplied electricity for trams and lighting of main streets. The hard coal for the plant had been shipped from Zonguldak. With several generator upgrades and expansions, up to 120,000 kW max capacity, the plant had been in operation until 1983. In 2007, as an industrial heritage site, it has been converted to an arts and culture center under name Santralistanbul and it includes an Energy Museum. In 1926, in order to transfer the electricity generation of the Silahtar PP to the Anatolian side of Istanbul, two submarine cables, 10 kV voltage level and 2,500 m in length, that were manufactured by the Jeumont Cablein France, were laid under the Bosphorus, and as a result, the Asiatic and European sides of İstanbul were connected to each other. In 1931 and 1932, Buyukada and Heybeliada islands in Istanbul were electrified.

b] The Imperial Shipyard (Tersane-i Amire) Electric Factory

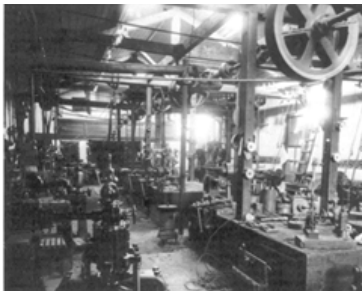


Fig. 19.2 Tersane-i Amire Elektrik Fabrikası

Despite that the urban-scale generation had commenced in İstanbul in 1914 and in 1910 in Tarsus, prior that, in the last quarter of the 19th century, there had been an Electric Factory in the Imperial Shipyard *(Tersane-i Amire Elektrik Fabrikası)* manufacturing electrical equipment, electric dynamos and projectors for the Ottoman navy and Ottoman Palaces. The Ottoman Officer, French engineer, Emile Lakvan Efendi (or fr. *Lacoine Effendi*) (1835–1899) had a huge role in the development of telegraph and electricity during Ottoman Period. He acted as the Electrical Advisor of the Ottoman Government, Head of the Technical Service of the Telegraphs of Turkey, and helped the Turkish telegraph network extend to Asia, worked in many applications of electricity and in the electric lighting of the Ottoman palaces. He participated on behalf of Ottoman Government to the Third World Electrical Exhibition in Vienna and in the Scientific Commission of the Exhibition in 1883.

c] The Development of Energy Organizations in Turkish Republic

During the Ottoman period and the Turkish Republic until 1937, in İstanbul, Ankara and in some other electrified Anatolian provinces, the electrical services (generation, distribution, lighting) had been carried by foreign invested companies under concession contracts. In that period also, auto producers are allowed for their electricity needs in their manufacturing facilities.
After foundation of Turkish Republic in 1923, the electrification of Turkey had become a major target. In 1935, for the exploitation of domestic energy resources two new administration had been established: The Electrical Power Resources Administration *(EIE - Enerji İşleri Etüt İdaresi)* for the survey-project phase, and, the Etibank for the construction-operation phase.
The Etibank had been given the responsibility of constructing and operation of new generation facilities and T/D lines. The establishment of Etibank could be considered as the first step to a consolidated structure for the electricity planning of Turkey.

Also, in 1935, a scientific institution, General Directorate of the Mineral Research & Exploration (MTA - *Maden Tetkik Arama*) had been established for the geological and geophysical survey of natural resources in Turkey. In 1953, General Directorate of State Water Affairs (DSİ - *Devlet Su İşleri*) had been established and assigned the duty of basin planning, constructing dams and cooperating with EIE for energy production. DSI, in years, had become the principal planner, constructor and operator of large dams of Turkey.
In line with the statist policies of the time, between 1939 and 1945, the electrical companies that were carrying out the distribution/generation services in İstanbul, İzmir, Ankara and some other Anatolian provinces under concession contracts were purchased from their owners and nationalized.
In 1963, Turkish Ministry of Energy and Natural Resources has been established.
In 1970, in accordance with *The Second Five Year Development Plan (1968–1972)* of The State Planning Organization (DPT - Devlet Planlama Teşkilatı), the vertically integrated Turkish Electricity Authority (TEK - *Türkiye Elektrik Kurumu*) was established and all electrical services, namely, the generation, transmission, distribution and the sale of electricity were consolidated with a few municipal exceptions. In 1982, those electricity services of the municipalities are also transferred to TEK.

d) Development of the Interconnected Grid

In 1948, the first urban-scale hard-coal thermal power plant of the Turkish Republic, *Çatalağzı Thermal PP* started operation with a capacity of 3 x 20 MW and upgraded to 6 x 20 MW in 1955.
In 1952, **the first high voltage line,** 154 kV, 238 km single-circuit overhead line was put in service between Ereğli (Zonguldak) and Ümraniye (İstanbul) over Adapazarı and İzmit substations. With this OHL, Çatalağzı PP and Silahtar PP was connected to each other. The excess power of Çatalağzı PP could be transferred to İstanbul. This OHL is the first piece of the interconnected grid.
In 1956, lignite fueled *Tuncbilek Thermal PP* (2 x 32 + 65 = 129 WM), and in 1957 *Soma PP* (40 MW) commissioned. In 1956, near Ankara, the first large reservoir type hydro power plant *Sarıyar HPP* (4 x 40 MW), and in 1959 *Hirfanlı HPP* (192 MW) had been completed and started operation.
In 1956, several 154 kV OHLs were completed in the northwestern Turkey: Sarıyar HPP, and Hirfanlı HPP was connected to Ankara; *Çatalağzı PP* connected to

Ankara over Kırıkkale. Following the connection of Adapazarı to Sarıyar HPP, the first loop of 154 kV grid was realized.
The **first OHL crossing over the Bosphorus,** 154 kV 795 MCM double circuit lines with 360 MVA in total capacity, was completed between 1957–1959 by Etibank. The tower on each side, having 133 m height and 180 tons weight, had been manufactured by Societa Anonima Elettrificazione S.p.A..

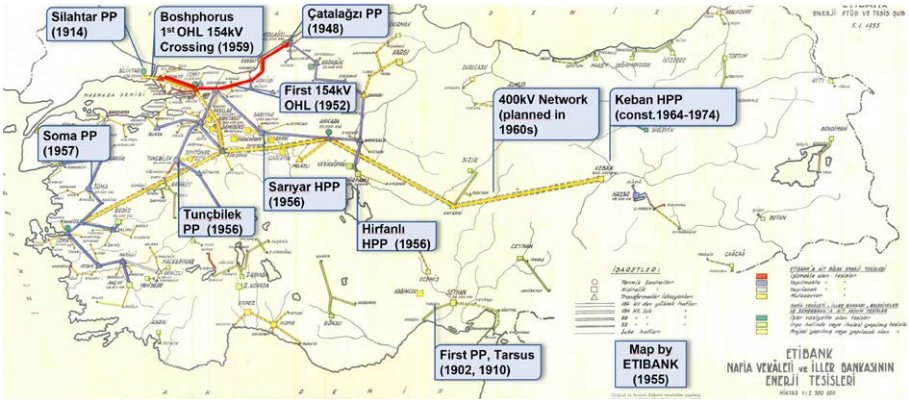


Fig. 19.3 Map of First Interconnected Turkish Grid in 1950s

For the operation of grid and PP's in that region, "Etibank Northwestern Anatolia Electricity Generation and Distribution Organization" *(Etibank Kuzeybati Anadolu Elektrik İstihsal ve Tevzi Müessesi)* had been established, which could be considered as the first system operator (bundled TSO/DSO) in Turkey.
In Western Anatolia, Soma PP, İzmir, Balıkesir, Aydın substations formed the Western Anatolian grid. In 1963, following the connection of Balıkesir to Bursa via 154 kV line, all 154 kV lines formed a complete system. The major power plants of Turkish grid could serve both İstanbul and Ankara, İzmir, Bursa securely.
At the end of the year 1959, 1,860 km of 154 kV, 625 km of 66 kV, 570 km of 33 kV, 255 km of 22 kV (or below) lines were in operation.
In the late 1960s and 1970s, for the exploitation of the large hydro and lignite sources, Keban HPP (1330 MW), and Elbistan PP (1,360 MW), Gökçekaya HPP (278 MW) and Seyitömer PP (600MW) had started operation.
Between 1971 and 1976, in order to transfer the power of those PP's to load centers, 2,529 km of 380 kV OHL has constructed as part of the first **Turkish 380 kV EHV grid.**

Also in the 1980s, the 380 grid was extended for the integration of Altınkaya HPP (700 MW), H. Ugurlu (500 MW), Karakaya HPP (1800), Atatürk HPP (2400 MW), Yatagan PP (730 MW).

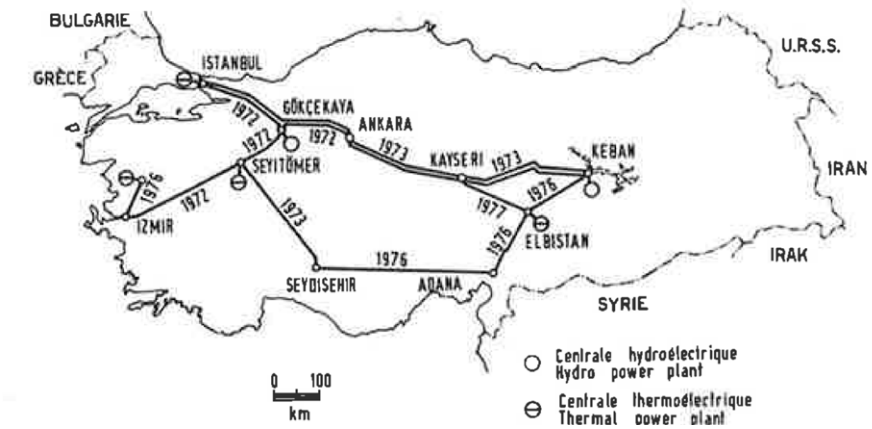


Fig. 19.4 First OHLs of the Turkish 380 kV Network in 1977

The **second OHL crossing over Bosphorus** (the 400 kV, double circuit lines with 2800 MVA in total capacity) have been completed in 1983 by TEK. The tower on each side, having 124 m height and 230 tons weight, had been manufactured by Siemens AG - MİTAŞ Consortium. **The third OHL crossing over Bosphorus** (400 kV, 4 circuit lines with 5,600 MVA in total capacity) have been completed in 2000 by TEAS. The tower on each side, having 160 m height and 460 tons weight, had been manufactured by Siemens - STFA Enerkom Consortium. The towers had been designed for also 800 kV voltage level, so the four-circuit 400 kV crossing can be converted two-circuit 800 kV crossing with minor revisions.



Fig. 19.5 The 2nd and 3rd Bosphorus OHL Crossings

With installation 400 kV and 154 kV transmission lines and substations over the years, Turkish electricity network now covers all over the country. The total length of transmission lines reached to 90,034 km and number of substations connected to the transmission system approached to 1,300 (748 TEIAS substations and 535 other) as of end of 2019.

According to 2018 figures, the total length of Medium Voltage (34.5 kV, 15.8 kV, 10.5 kV and 6.3 kV) and Low Voltage distribution lines exceed 1,150,000 km and total number of electricity customers in Turkey exceeded 43.46 Million.

The power generation installed capacity in Turkey continued to increase over the years and reached to 91,267 MW at the end of 2019. Electricity generation and consumption became 304.3 TWh and 303.7 TWh respectively in 2019. In 2019, approx. 69.6% of the total electricity generation was done by Independent Power Producers (IPPs), around 17.6% by the Build Operate (BO), Build Operate Transfer (BOT) and Transfer Of Operation Right (TOOR) power plants under long-term energy purchase contracts, and around 19.5% by the state owned generation company EÜAŞ and the remaining 3.3% by the small power plants which do not need a generation license.

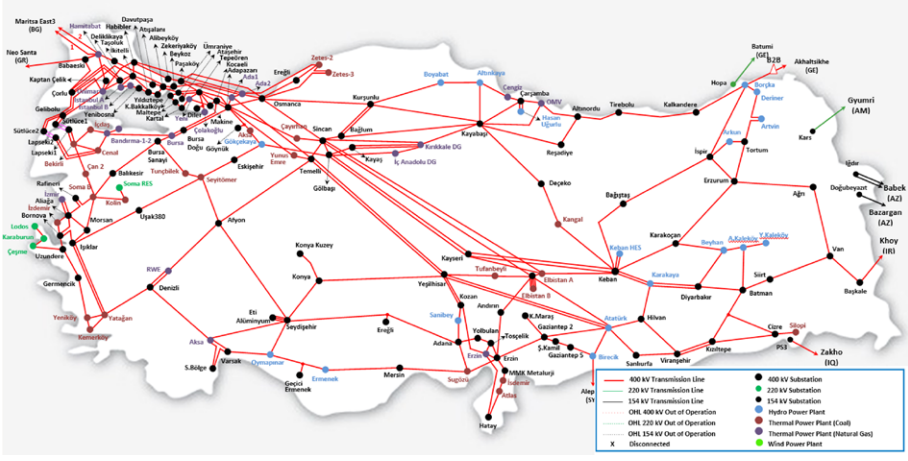


Fig. 19.6 400 kV Turkish Grid as of January, 2020

e] Transition to a Liberalized Energy Market

In 1984, the private sector was allowed to construct and operate power plants under different schemes: Build-Operate-Transfer (BOT), Build-Own-Operate (BOO) and Transfer of Operating Rights (TOOR). The auto producer model provided the private sector with the right to own & operate power plants for their industrial facilities consumption.

In 1993, TEK was restructured into two state owned entities. The distribution services were transferred to Turkish Electricity Distribution Corporation (TEDAŞ - *Türkiye Elektrik Dağıtım A.Ş.*). The generation & transmission services were transferred to Turkish Electricity Generation-Transmission Corporation (TEAŞ - *Türkiye Elektrik Üretim İletim A.Ş.*)

In 2001, in order to have a competitive electricity market, Electricity Market Law (EML) was enacted, and private sector fully gained access to market. The Energy Market Regulatory Authority (EMRA) (EPDK - *Enerji Piyasası Düzenleme Kurumu*) was established under EML. The state owned TEAŞ was restructured into three entities. Turkish Electricity Transmission Corporation (TEIAŞ - *Türkiye Elektrik İletim A.Ş.*) was established for carrying out transmission, system and market operation. The Electricity Generation Corporation (EÜAŞ - *Elektrik Üretim A.Ş.*) was established for electricity generation; and The Turkish Electricity Trading and Contracting Company (TETAŞ) was established.

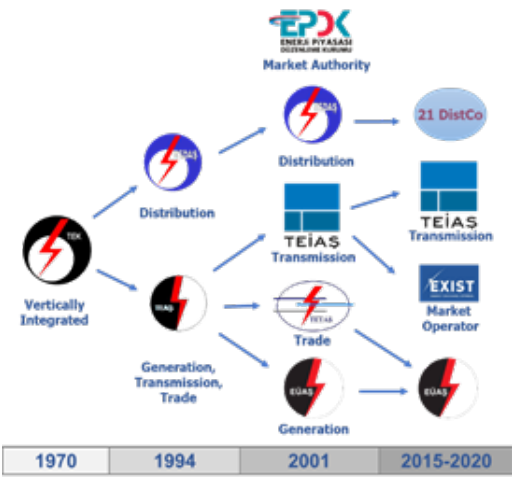


Fig. 19.7 Unbundling of Turkish Electricity Authority (TEK)

For the purpose of creating a competitive environment in the electricity distribution and retail sales services, The Electricity Distribution Corporation (TEDAŞ) was included in the privatization program by The Privatization Administration (*Başbakanlık Özelleştirme İdaresi Başkanlığı*) in 2004. The service regions of distribution were reidentified and Turkey was separated into 21 distribution regions. The regional corporations were privatized between 2008–2013, provided that the

assets would stillbe owned by TEDAŞ. The distribution and retail sale services were started to be provided by separate regional companies as of 2013.
In 2015, upon new Electricity Market Law No. 6446., the market operations of TEİAŞ was transferred to newly established Energy Exchange Istanbul (EXIST) (EPİAŞ - *Elektrik Piyasaları İşletme A.Ş.*). Currently, Day Ahead Market (DAM) and Intra-Day Market is operated by EPIAŞ while TEİAŞ is responsible for operation of Balancing Power Market, Ancillary Services Market as well as financial settlement process.

f] Interconnections and ENTSO-E

On 18 September 2010, under the Contractual Agreement between ENTSO-E & TEİAŞ for synchronous operation of Turkish and European Electricity Grids, following the project group studies and isolated operational tests, Turkish grid started synchronous operation with ENTSO-E, via two 400 kV interconnection lines with Bulgaria (commissioned in 1975 and 2002) and via one 400 kV line with Greece (commissioned in 2007). Following performance of the tests related to synchronous parallel operation and successful completion parallel operation trial period, this connection became permanent as of 15 April 2015. On January 14, 2016, TEİAŞ became the first and only observer member of ENTSO-E with the agreement signed with ENTSO-E.

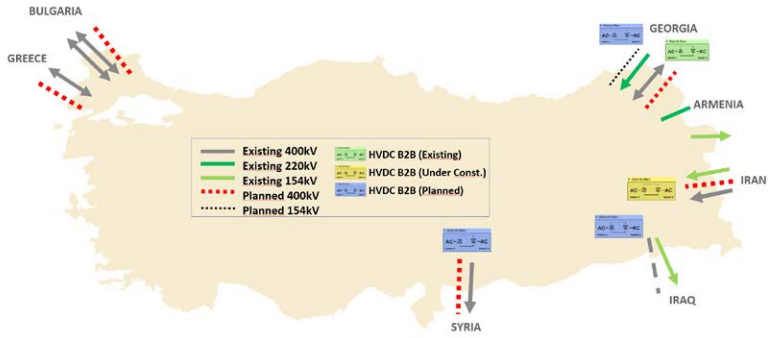


Fig. 19.8 Interconnections of Turkish Grid

Besides ENTSO-E interconnections, Turkey has interconnection lines with other neighboring countries, namely with Georgia (one 400 kV and one 220 kV lines), Armenia (one 154 kV line), Nakhichevan-Azerbaijan (154 kV line), Iran (one 400 kV and one 154 kV lines), Iraq (one 400 kV line) and Syria (400 kV line).

g) Akkuyu Nuclear Power Plant (NPP) Project

Turkey's intention to build a nuclear power plant dates back to 1960s. In 1965, the research on the establishment of the nuclear power plant was started. In 1974, the site in Akkuyu in Mersin province was considered as a suitable site for the construction of the first nuclear power plant. Until 1976, detailed geological studies were carried out and as a result, the site licensed the NPP construction. On May 12, 2010, the Governments of the Russian Federation and the Republic of Turkey signed a Cooperation Agreement for the construction of Akkuyu NPP comprised of four power units with VVER-1,200 reactors with a total capacity of 4,800 MW on the southern coast of Turkey in Mersin province. The construction commenced in 2018. The first unit of Akkuyu is planned to be in operation by the end of 2023. The other units will be put into operation at one-year intervals until the end of 2026.

19.2 CIGRE Turkish National Committee

The associations and individuals from Turkey have been following the activities of CIGRE for a long time. The most notable example is the participation of Turkey to the 2nd CIGRE Conference in 1923, it is also the year of the establishment of the Republic of Turkey.

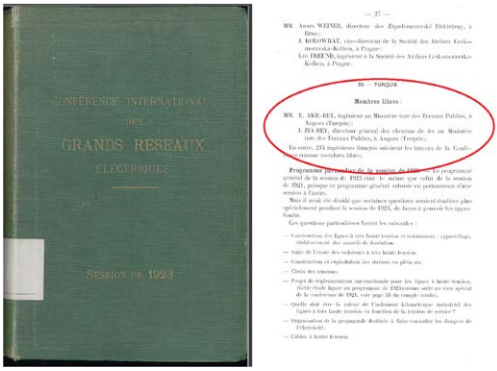


Fig. 19.9 Turkey's Participation to 2nd CIGRE Paris Session in 1923

Establishment of CIGRE Turkish National Committee has taken many years. The National Committee was first established under the leadership of Istanbul Technical University in 1955, but since continuity could not be achieved, the monitoring of CIGRE activities could not go beyond individual efforts.
With the establishment of Turkish Electricity Authority (TEK) in 1970, associations started to become effective again in CIGRE activities. TEK was a member of CIGRE in the 1970s, and the institutions that emerged after the restructuring of the Turkish electricity sector in 1993, also joined CIGRE.



Fig. 19.10 CIGRE Turkish National Committee

Although the associations and individuals have been following CIGRE activities, Turkish National Committee could not be formed for many years due to some reasons. In 2013, studies for establishment of the Turkish National Committee were initiated again. In 2014 CIGRE Turkish National Committee was established under the Turkey Electricity Industry Association (TESAB - *Türkiye Elektrik Sanayi Birliği*).

The decision-making body of the Turkish National Committee is TESAB's Board of Directors. On the other hand, considering the intensity of CIGRE activities in 2015 CIGRE Turkish Executive Committee was formed. The Executive Committee organizes activities related to CIGRE through monthly held meetings and carries out activities to increase the recognition of CIGRE.

The most remarkable of these activities is the Power Systems Conference (PSC), hold biennially. The first of this event was organized in Istanbul in 2016. The second event was organized in Ankara in 2018 with participation of around 350 representatives from electricity utilities, industry, and universities. The third conference is planned to be held in 2020 in Ankara with a wider scope and more participants.

Another activity (called as *"Meeting with Universities"*) organized by the National Committee within the scope of the promotion of CIGRE in the academic community is the gathering of academicians and sector representatives. First of this event was organized in Elazig in 2017 with participants from 4 universities in Elazig and surrounding provinces. Second of this event was organized in Kocaeli in 2018 withparticipants from 6 universities in Kocaeli and surrounding provinces.



Fig. 19.11 Power System Conferences in Istanbul, 2016 and in Ankara, 2018

Third of this event was organized in Adana in 2019 with more than 400 participants from 8 universities in Adana and surrounding provinces. This event will be continued to be organized in different regions in the coming years.

Table 19.1 List of Conferences/Events Organized by CIGRE Turkey NC (2015–2019)

Date	Location	Conference/Event
2015	İstanbul	CIGRE Turkey Conference
2016	İstanbul	Power System Conference-2016 (GSK-2016)
2017	Elazığ	Meeting with Universities (4 Universities)
2018	Kocaeli	Meeting with Universities (6 Universities)
2018	Ankara	Power System Conference-2018 (GSK-2018)
2019	Adana	Meeting with Universities (8 Universities)

The National Committee established mirror Study Committees as in CIGRE in Turkey and aimed to direct the attention of the sector to CIGRE activities. The Mirror Committees have been established for A2 Power Transformers and Reactors, B2 Overhead Lines, B5 Protection and Automation and C6 Active Distribution Systems and Dispersed Energy Resources. In addition, working groups have been formed in line with the priority working areas of Mirror Committees. The reports prepared by the working groups are shared with the members on the website of the National Committee (www.cigreturkiye.org.tr). Number of mirror committees shall be increased within time.

As National Committee maintains its domestic activities, it also undertakes the duty of representation before CIGRE and actively involved in many CIGRE processes, notably the Paris Session.

Furthermore, many representatives from Turkey join CIGRE Study Committees and Working Groups and the National Committee is pleased to host CIGRE meetings. CIGRE Technical Committee Meeting and CIGRE Turkey Conference held on 15–16 November 2015 in ITU was the first event hosted by Turkey. With this event, Turkish National Committee announced its name to the electricity sector both national and international level.

Turkish National Committee, being a member of the SEERC since 2015, follows closely the developments in Southeast Europe. Turkish National Committee has participated the SEERC Conferences organized in Slovenia in 2016– and in Ukraine in 2018–. Turkey has also applied for chairing SEERC for the period between 2020–2022. Considering the size of Turkey's electricity sector, the National Committee is expected to become more active in CIGRE.

Table 19.2 Presidents of CIGRE Turkish NC, Chairmen, Vice Chairmen and General Secretaries of Executive Board of CIGRE Turkish NC (2014–2020)

President of CIGRE Turkish National Committee	Chairman of Executive Board of CIGRE Turkish NC	Vice Chairman of Executive Board of CIGRE Turkish NC	General Secretary of CIGRE Turkish National Committee
Halil ALIŞ (2014–2016) **Nevzat ŞATIROĞLU** (2016–2018) **Mücahit ALKAN** (2018) **Dr.İzzet ALAGÖZ** (2018–....)	**Ercüment ÖZDEMİRCİ** (2015–2017) **Fatih KÖKSAL** (2017–2018) **Bahadır UÇAN** (2018–....)	**Prof. Dr. Belgin EMRE TÜRKAY** (2015–....) **Dr. Ahmet MEREV** (2015– ....) **Dr. Atalay KAYA** (2015–.....)	**Ayten SÜMER** (2014–2017 **Ahmet Cevdet GÜLTEKİN** (2017–....)

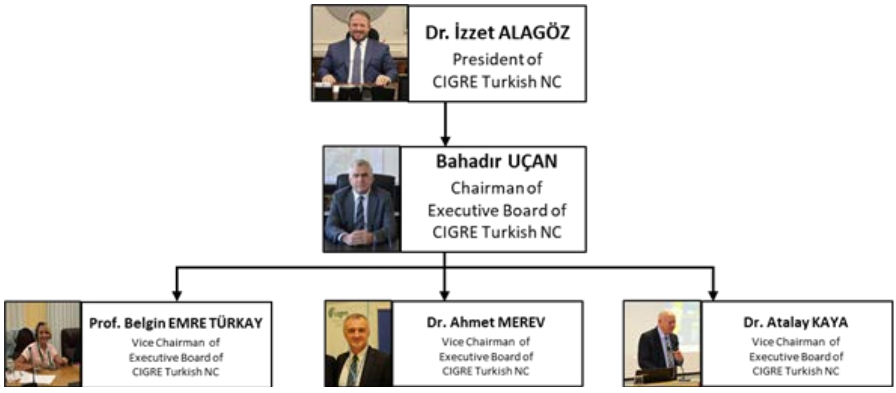


Fig. 19.12 Current President of CIGRE Turkish NC, Chairman and Vice Chairmen and Chairwoman of the Executive Board of CIGRE Turkish National Committee (2020)



Fig. 19.13 CIGRE SEERC MB Meeting, 18–19 October 2017, İstanbul

19.3 Electric Power Profile

	INSTALLED CAPACITY OF TURKEY (as of 31 Dec. 2019) (MW)												
	NATURAL GAS	LIGNITE	HARD COAL	ASPHALTITE	IMPORTED HARD COAL	FUEL OIL	WASTE HEAT	BIOMASS	GEOTHERM	HYDRO (RES/RSV/CHR)	HYDRO (RIVER)	PV	WIND
INDEPENDENT PRODUCERS	20,816	6,322	811	405	8,967	438	156	711	1,500	7,085	7,097	161	7,459
STATE OWNED by EÜAŞ	4,993	1,804	0	0	0	0	0	0	0	12,614	162	0	7
TRANSFER OF OPERATING RIGHTS (TOOR)	0	1,975	0	0	0	0	0	0	15	913	544	0	0
UNLICENSED (DISTRIBUTED GENERATION)	123	0	0	0	0	0	206	76	0	0	9	5,825	71
BUILT-OPERATE-TRANSFER	0	0	0	0	0	0	0	0	0	100	40	0	10
TOTAL	25,933	10,101	811	405	8,967	438	362	787	1,515	20,643	7,851	5,987	7,547



ANNUAL DEVELOPMENT OF INSTALLED CAPACITY (MW)	
1913	17
1923	33
1930	78
1940	217
1950	408
1960	1,272
1970	2,235
1980	5,119
1990	16,318
2000	27,264
2010	49,524
2020	91,346

ANNUAL DEVELOPMENT OF TRANSMISSION LINES					Unit : km
YEARS	380 kV	220 kV	154 kV	66 kV	TOTAL
1980	2969.6	15.7	13794.1	138.6	16918.0
1990	8514.0	84.6	22440.1	138.6	31177.3
2000	15567.0	84.6	32258.0	138.6	48048.2
2018	23248.8	84.8	44760.5	109.7	68203.8

ANNUAL DEVELOPMENT OF UNDERGROUND CABLES				Unit : km
YEARS	380 kV	154 kV	TOPLAM	
2006		147.5	147.5	
2010	28.6	179.3	211.1	
2018	89.7	464.8	554.5	

TRANSFORMERS CAPACITY								
	380 kV TRANSFORMER		154 kV TRANSFORMER		66 kV and below TRANSFORMER		TOTAL TRANSFORMER	
YEARS	NUMBER	CAPACITY MVA	NUMBER	CAPACITY MVA	NUMBER	CAPACITY MVA	NUMBER	CAPACITY MVA
1980	20	3060.0	260	7485.6	272	1251.7	552	11797.3
1990	61	9410.0	486	16396.5	129	1050.5	676	26857.0
2000	107	19270.0	755	35802.1	116	996.6	978	56068.7
2010	197	37870.0	1067	61365.0	53	617.0	1317	99852.0
2018	353	70652.2	1434	101085.4	39	538.5	1826	172276.1

ELECTRICITY GENERATION IN 2018		
SOURCE	**GENERATION (GWh)**	**SHARE (%)**
Imported coal	62,988.50	20.67
Hard Coal	5,173.10	1.70
Lignite	45,087.00	14.79
Natural Gas	92,482.80	30.34
Other Liquid Fuel	329.10	0.11
Geothermal	7,431.00	2.44
Hydro (Reservair)	40,972.10	13.44
Hydro (River)	18,966.40	6.22
Wind	19,949.20	6.54
PV	7,799.80	2.56
Other Renewables	3,622.90	1.19
TOTAL	**304,801.90**	

30% Share of Renewables in 2018

	MVA	**#**
Ditribution Transformers	183,789	487,644

	U. Cables (km)	**Overhead (km)**
Ditribution Lines	200,948	953,568

	#
Lighting Fixture	8,030,385

	MV	**LV**
Number of Distritbution Poles	4,600,891	12,172,596

ANNUAL DEVELOPMENT OF NET ELECTRICITY CONSUMPTION			
YEARS	**POPULATION (*1000)**	**NET CON. (GWh)**	**CONSUMPTION (kWh)**
1923	12,306	41	3
1930	14,448	97	7
1940	17,723	359	20
1950	20,809	679	33
1960	27,509	2,396	87
1970	35,321	7,308	207
1980	44,737	20,398	456
1990	56,473	46,820	289
2000	67,845	58,296	1,449
2010	73,723	172,051	2,334
2018	82,004	258,232	3,149

Source for Tables: TEIAS 2019 /R.17/ & TEDAS.

19.4 References

1. O. Arslan, 'Tarsus Elektrik Altyapisi Tarihine Bir Bakiş', p. 16, 2017.
2. 'Silahtarağa Power Plant'. /Online/. Available: https://www.santralistanbul.org/en/silahtaraga-power-plant/. /Accessed: 24-Mar-2020/.
3. 'Santral İstanbul - İstanbul Bilgi University'. /Online/. Available: https://www.santralistanbul.org/en/about/.
4. 'Silahtarağa PP- Turbine Hall', Wikimedia, 20-Feb-2009. /Online/. Available: https://commons.wikimedia.org/wiki/File:SantralIstanbul_turbine_hall_foto1.jpg. /Accessed: 25-Mar-2020/.
5. Re. E. KOÇU, 'Elektrik', İstanbul Ansiklopedisi, vol. 9. p. 5000.
6. 'Fabrique d'electricite de la marine, İstanbul'. /Online/. Available: https://www.loc.gov/resource/cph.3b29147/. /Accessed: 26-Mar-2020/.
7. E. Öztaner, 'Technology As A Multidirectional Construction: Electrification Of Istanbul In The Late Nineteenth And Early Twentieth Centuries', İstanbul Şehir Üniversitesi, 2017.
8. 'The Vienna International Electric Exhibition', Nature, vol. 29, no. 732, pp. 42–43, Nov. 1883, doi: 10.1038/029042a0.
9. R. FENMEN, Türkiyenin Elektrifikasyonu. 1935.
10. 'Barış Sanlı - Elektrik Tarihi Belge Arşivi'. /Online/. Available: http://www.barissanli.com/calismalar/tarih/. /Accessed: 10-Mar-2020/.
11. E. Çapangil, 'Önemli Enerji İletim Hatları Atlamaları', TEİAŞ, 2010.
12. Halûk CEYHAN - Y. Müh., Kirkor DEMİRKES - Y Müh., and Gültekin TÜRKOGLU - Y. Müh, 'Türkiye Elektrik Şebekesi', no. 35–36, Dec-1959.
13. F. Iliceto and H. Tekinel, 'Planning Criteria of the EHV system of Turkey', presented at the International Conference on Large High Tension Electric Systems, 1972.
14. F. Iliceto and G. Türkoğlu, 'Planning Features of the Extension of the 420kV Turkish System', presented at the International Conference on Large High Voltage Electric Systems, 1980.
15. '380 kV Bosphorous Crossings.jpg (2272×550)', Wikimedia. /Online/. Available: https://commons.wikimedia.org/wiki/File:380_kV_Bosphorous_crossings.jpg. /Accessed: 22-Mar-2020/.
16. 'Akkuyu NPP Construction Project AKKUYU NÜKLEER A.Ş.' /Online/. Available: http://www.akkuyu.com/index.php?lang=en. /Accessed: 29-Mar-2020/.
17. 'TÜRKİYE ELEKTRİK ÜRETİM-İLETİM İSTATİSTİKLERİ'. /Online/. Available: https://www.teias.gov.tr/tr-TR/turkiye-elektrik-uretim-iletim-istatistikleri. /Accessed: 21-Mar-2020/.

For further information contact:

CIGRE Turkish National Committee
(CIGRE Türkiye Ulusal Komitesi)
İnönü Bulvarı No:27,
KLMN Blok, Bahçelievler
Ankara/Türkiye

http://www.cigreturkiye.org.tr/
e-mail: info@cigreturkiye.org.tr
Phone: +90 312 2126915 / 3185

20. NC CIGRE UKRAINE

20.1 History of electric power sector

a) Early electrification 1880–1921

1878 - For the first time, an electromagnetic machine and 4 arc electric lamps are installed in Kyiv



Fig. 20.1 First Kyiv city electrical lamps

The first experience of the use of electricity for public needs in Ukraine took place in **Kyiv** in **1878,** when the famous Russian engineer O. P. Borodin used four electric lamps to illuminate the Kyiv railway workshops.
Alexander Borodin, who **brought Gramma electromagnetic generators** from the **Paris World's Fair** and installed experimental electric lighting using four arc lights in the turning workshop of the Main Railway Workshops. Each of them was powered by his Gramme electromagnetic machine.
In 1880 only 6 arc lamps of Yablochkov were installed in the workshops of the Dnipro Shipping Company. In 1886, electric lighting was installed in the Chateau de Fleur Garden (now the Dynamo Stadium). In 1890 the company "Savitsky and Strauss" concluded a contract with the City Duma on the electric lighting of city streets. **Lviv** at the turn of the nineteenth and twentieth centuries was one of the biggest cities in the Austro-Hungarian Empire along with Vienna, Prague, Budapest and Trieste and then experienced its peak season.

Prior to the putting into operation of the **new power plant in 1909,** the city lights were gas, instead with the advent of electricity, arc lamps consisting of two coal electrodes 25 cm long, 6 cm wide and 1.8 cm thick began to be used. An electric arc arose between these coal bars. These lamps were powerful - 2500 W. Due to the high cost, only 80 pillars were initially installed in Lviv.

1890 - Start of the first power plants in Ukraine (Kyiv, Konstantinovka, Ekaterinoslav, Lviv)



Fig. 20.2 Bratislav HPP

One of the first power plants in Ukraine was built in Nemirov in 1905, in a complex with a mill near the dam above the pond on the bank of the the Ustye River (Zamchik) along the route of the Bratslav direction, hence the name - Bratslav mill. The Bratslav mill has been operating since 1862, the type of mill being a watermill. A sugar factory (later a distillery) was opened by Count G. Stroganov in 1872. The project of a hydroelectric power plant based on a mill dam was designed by Czech architect I. Stibral. Over the 12 years of their work, "Savitsky and Strauss" managed to build three city power plants in Kyiv. The plant, opened in 1890 on Theater Square, provided electricity to the city theater, several residential buildings and 14 coal arc lamps installed on Khreshchatyk street.

The Kyiv Electric Society, having bought all three power plants in 1902, liquidated two of them, low-power in Duma and Theater Square.

From that moment, electricity consumed by Kyiv was produced at the Central City Electric Power Station, located on Andreevskaya Street.

1892 - The first electric tram in Russia and the second in Europe is put into operation in Kyiv

In September 1886, the Kyiv authorities announced the bidding process for development of the project for city railway and appointed a special commission of technical experts. The winner of the competition was Amand Struve, who organized the joint stock company of the Kyiv City Railway.

On May 2, 1892, a successful test of the first electric line of the Kyiv tram 1.5 km in length was accomplished. On July 3, 1892, the electric tram was put into experimental operation. On the route Podil - Oleksandrivska Square – Khreshchatyk several wagons were running in one-track. **Thus, for the first time in the Russian Empire, a tram appeared in Kyiv.**

1894 - An electric tram was launched in Lviv

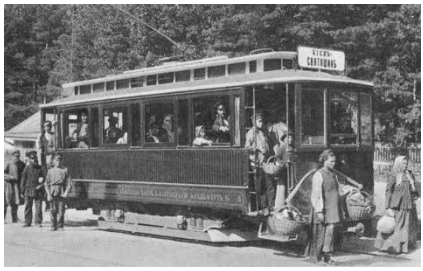


Fig. 20.3 Electric tram in Kyiv

At the time of the invention of electricity, Lviv was the capital of the Kingdom of Galicia and Vladimir, an important province of Austro-Hungarian Empire, so it could not stand aside from the progress that Europe was making. The reason for the introduction of electrification was the case: in 1894 Lviv planned to hold the Regional Exhibition, the transport connection between the railway station and Stryi Park was absent, and the administration of the horse tram, which operated here since 1880, refused to lay a strategically important route. Well-known engineer, the first head of the department of electrical engineering, opened in Lviv Polytechnic in 1892, Professor Roman Dzeslevsky initiated the launch of the electric tram.
Two years later, the city bought a tram and a power plant from **Siemens-Galske.** From 1897 to 1925, Mr. Joseph Tomitsky was entrusted with the post of Director of the City Electrical Institutions. Mr. Joseph Tomitsky one of the most respected power engineers in Austro-Hungarian Empire. Tomitsky, a well-educated and dedicated person, dynamically developed the city's energy industry, including at his initiative, a new power plant at Persenkovka and an AC network were built.

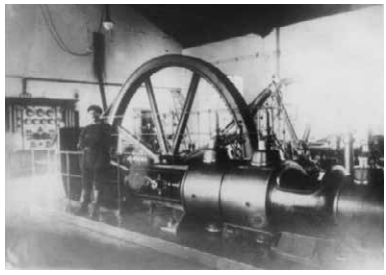


Fig. 20.4 Electric tram was launched in Lviv

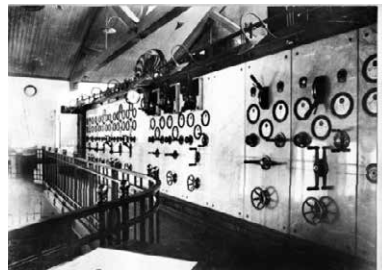


Fig. 20.5 Lviv. Internal halls of the first power plant

In 1900, the city administration took another important step towards the massive electrification of Lviv - deciding that the new opera house should have electric lighting. The work was delegated to Joseph Tomitsky. At first, they planned to build a small local station in the basements of the theater. There were seventeen such small stations in the city at that time. Joseph Tomitsky denied the feasibility of such actions, proposing to extend the cables from the power plant to Sakharov, and to locate a switchgear and a battery substation in the opera to compensate for the voltage drop. This method allowed to provide light not only the main building, but also the surrounding premises. 1909–72 transformer substations were installed in Lviv. More than forty were housed in special transformer booths, the rest were in cellars or basements of city buildings. Finally, half a year later, the magistrate decided to erect a power plant at Persenkivka, which was put into operation on February 18, 1909. The magistrate allocated funds for construction in the amount of 14 million crowns to the MEE as a loan. Finally, half a year later, the magistrate decided to erect a power plant at Persenkivka, which was put into operation on February 18, 1909. The magistrate allocated funds for construction in the amount of 14 million crowns to the MEE as a loan.

1913 - Power of Ukraine's power plants amounted to 304.3 thousand kW

Small power plants are put into operation in the cities of Ekaterinoslav (now Dnipro), Konstantinovka (Donbass), Lviv and Odessa. Transmission of electricity from such power plants was carried out at low generator voltage by air and cable lines of simple structures. However, in 1910 power boosting transformers were installed for the first time in the territory of Ukraine (in Donbass) and operation of the first air lines of three-phase alternating current of 22 kV was started.

In 1913, the installed capacity of the power plants of Ukraine was only 304.3 thousand kW, the annual production of electricity was 543 million kWh, which corresponded to the consumption of electricity per inhabitant of Ukraine only 15 kWh per year. The distribution of power plants by industries of Ukraine in 1913 is shown in the table below. The vast majority of power plants operated in the metallurgical and coal industries (more than 63%), while public power plants were concentrated only in major cities of Ukraine. **In 1916, the largest power plant was the Alexander Plant in Katerynoslav, which had a capacity of 14,500 kW.** In general, despite the presence of large reserves of fuel and energy resources, in 1917 Ukraine had underdeveloped electricity.

Table 20.1 Distribution (by industry branches) of power plants in Ukraine with a capacity of over 1000 kW in 1913

Branches	Total number of power plants	Total capacity, ths. KW	Specific weight, %
Coal mines	26	68.2	29.8
Metallurgical plants	19	95.4	41.6
Other industrial enterprises	6	11.7	5.2
Public power plants (in cities)	20	53.7	23.4
Total	71	229.0	100.0

1926 - Start of the first unit of the Shterov SRPP (State Regional Power Plant)
The intensive construction of power stations, power grids and high-power transformer substations on the territory of Ukraine began only during the period of implementation of the GOELRO plan *(the first-ever Soviet plan for national economic recovery and development)* adopted in 1920, in which the development of energy of Ukraine, especially the Donbass region, was given priority.
Almost **30% of the new energy capacity** foreseen by the GOELRO plan was planned to be located and put into operation **in Ukraine.** The GOELRO plan also envisaged a priority merger in the Donbass for the transition to the parallel operation of 24 coal and power plants with a total installed capacity of 67.4 MW, as well as number of power plants at the Dnieper metallurgical plants with a total capacity of 22.5 MW. GOELRO's firstborn in the Donetsk region - the Shterov SRPP (State Regional Power Plant) - has become a catalyst for growth of electrification in the region and in the country.

The Shterov State Regional Power Plant named after F. Dzerzhinsky is the first thermal power plant built on the territory of the Ukrainian SSR according to the GOELRO plan.

The power plant is located in the city of Miusinsk, Luhansk region. The construction site was determined by the choice of the anthracite mine in nearby dumps and a source of water supply from the Mius River. Construction began in **1922,** the first generator was launched in **1926.** In February 1927 with the start of the second power generator power from the plant was supplied via **OHL-115 (!) kV.** During the construction of the first stage of the **20 MW power plant,** two 10 MW turbines were installed, each of Metrovikers firm and six boilers of the Babkoks-Vilkoks company. In 1928 the construction of the **second stage with**



a capacity of 49 MW began, and in 1929 - the **third stage with the capacity of 88 MW.** By 1953, the station was rebuilt and modernized, the installed capacity increased to **200 MW.**

Fig. 20.6 Shterov State Regional Power

b) Time of creation of systems 1921-1951, restoration of the energy complex after the Second World War, construction of new facilities 1945–1960

The rapid expansion of energy capacities

Simultaneously with construction of the regional power plants in Donbass region, large-scale works were carried out to unite local capacities for parallel operation within the network. 22 power plants of mines and metallurgical plants (a total of 71.6 MW) were incorporated in the network. Similar activities were carried out for the Dnieper region (total 22.5 MW).

The energy supply to the Krivbas' industry was facilitated by the launch of a 44 MW power plant.

In 1925 was decided to build a new power station for Kharkiv and the Kharkiv' region. For this purpose, the unitary partnership ESKhAR (Electric Station of the Kharkiv region) was created. The planned capacity of the power plant was 45.5 MW - two turbine-generators of 22 MW each were ordered in Germany. The first unit was launched in 1930. The power was supplied at 110 kV, and the main step-down substation was built in Kharkiv, which was the capital of Ukraine. A new power plant was built in Kyiv. Work began in 1926. The ceremonial opening of the first stage of Kyiv regional power plant with a capacity of 21.3 MW took place on May 1, 1930. Similar objects appeared in other big cities.

How Dnipro HPP was built



Fig. 20.7 1934. Dnipro HPP construction

According to the GOELRO plan a powerful hydroelectric power plant on the Dnieper (Slavutych) river, near the city of Zaporizhzhya and the legendary island of Khortitsa was to become a key facility. The designing of the hydropower plant began in 1921, but the conditions for practical implementation of the project became due in 1927.

It was expected that hydropower turbines with a capacity of 37 MW would be used at the hydroelectric power plant, but 9 turbines with a capacity of 62 MW were selected. The total capacity of 558 MW was supposed to exceed any available power plant' capacity at that time on the globe. All 9 turbines are Francis-type vertical shaft turbines, five out of nine generators were ordered from the United States, transformers were brought from Germany. The ceremonial launching of the Dnieper hydroelectric plant took place on October 10, 1932. On the date of the plant' opening five generators worked. Few years later (in 1932–1939) four generators were put into operation.

The energy base of the Soviet "five-year plans" and the creation of regional energy associations

In 1930–1940 were built:

- Zuevska State District Power Plant with a full design capacity of 350 MW (for the third stage the turbine of domestic production with the highest for that time capacity of 100 MW was installed)
- the second stage of the Kyiv District Power Plant with a capacity of 25 MW
- the first stage of Dneproderzhinska State District Power Plant
- Sevastopol State District Power Plant (12 MW)

- Kamysh - Burun State District Power Plant in the city of Kerch
- for agricultural regions, the construction of small hydroelectric power plants was widely used (for example, Korsun-Shevchenkovska hydroelectric power station 1,650 kW)
- Kyiv TPP (12 MW)

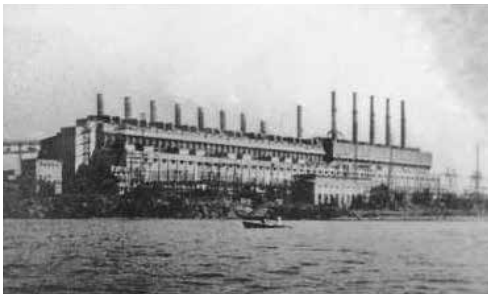


Fig. 20.8 Zuevska State District Power Plant

Simultaneously with the construction of new power plants, power lines were built, which allowed the creation of branched networks. In 1932 in Ukraine the total length of 220 V lines was 427 km, 35 kV - 633 km, 110 kV - 568 km, 154 kV - 233 km. In 1937, 22 kV lines were no longer used, but the length of 35 kV lines increased to 1463 km, 110 kV - 836 km, 50 kV - 440 km.

Table 20.2 Dynamics of changes in the number and capacity of substations as of 01.01.1941

Rated voltage, kV	Transformer substations	
	Quantity	Power, MW
35	156	1650
110	12	680
154	10	776
220	3	360

In the process of energy system' forming in the 30s of the 20th century, JSC In the process of energy system' forming in the 30s of the 20th century, JSC "Kharkiv Association of State Power Plants", State Joint-Stock Company "Kyivtok", the association of Donetsk coal-coal basin' state power stations "Donbastok", subordinate to Moscow, worked. Later in the 30s years, the Kyiv association "Kyivtok" was transformed into the management of power stations and networks of the Western region of Ukraine "Zukrenergo", which later began to act as "Kyivenergo". JSC "Kharkiv Association of State Power Plants" and "Donbastok" were merged into "Severdonenergo", and after were formed into "Kharkivenergo" (Kharkiv) and "Donbassenergo" (Gorlovka). In 1934, the "Dneprenergo" department was established (Zaporozhye). In 1931, "Krymenergo" was founded

(Simferopol). In 1940, the construction of the country's first intersystem power transmission line Dnepr-Donbass with a voltage of 220 kV was completed. Further development of lines and networks allowed the formation of the United System of the South with a total power plants' capacity of 1800 MW.

Electricity of the western regions of Ukraine

After the First World War Galicia and western Volhynia belonged to Poland, Bukovina - to the Kingdom of Romania, and Transcarpathia to the Czechoslovak Republic.

Thus, the economy of the western Ukrainian territories functioned in accordance with this division. Electrification of Transcarpathia was carried out by transmitting electricity from base power plants located near Uzhgorod. In 1930, the construction of a new power plant (2 x 2.5 MW) was completed in Uzhgorod based on the "Mundus" plant. At the same time, a network of 0.38 kV, 6 kV and 35 kV power lines was created, which connected Uzhhorod with Mukachevo and Chop. Construction of two hydroelectric power plants began - Onokievskaya and Uzhgorodskaya. Their construction was completed in 1942, when Transcarpathia belonged to Hungary.

The first 30 kV overhead power line 14 km long from the Lviv power plant (32 kW) was built in Galicia in 1928.

In 1930, a decision was made to significantly expand the borders of Lviv, which led to the modernization of the city's electrical networks.

As of 1939, the total electric power capacity of Podkorpattia (Borislav) was 12 MW. The power plant was connected to the cities of Drohobych, Sambor, Stryi, and Truskavets by means of 15 kV overhead power lines.

During 1928–1930. A city power plant was built and put into operation in Stanislavov. Three diesel generators of alternating current with a total capacity of 1080 kW were installed here. 6 kV cable lines were connected to 14 substations. In 1937, 2 MW steam turbine generators were additionally installed at the power plant.

The station in Kolomyia began operating in 1925 with a capacity of 150 kW (later it was expanded by another 500 kW). In addition, power plants have also been built in Kalush and Sniatyn, Bytkiv.

As of 1934, 30 kV power lines were laid from Lviv to Zhovkva and Yavoriv.

Second World War period (1939–1945) and restoration works



Fig. 20.9 1943. DniproHPP exploded

During World War II Ukraine experienced the tragedy of the worst war in human history

At the beginning of World War II in 1939, in accordance with the Molotov-Ribbetrop Pact, the territories of Galicia and Volhynia became part of the Soviet Union from Poland, and in 1940 the Chernivtsi region of the USSR was established on the lands of Northern Bukovina, which belonged to Romania. The war caused the loss of large areas. During the retreat of Soviet troops, most of the energy equipment was dismantled and moved to the rear. In case of impossibility to take out the construction, equipment and power lines were blown up. The DniproHPP dam was first blown up by Soviet troops in August 1941. The occupiers partially rebuilt the power plant, but in 1943 they blew up the dam again.

In 1944. the Soviet government passed a resolution to restore the DniproHPP. In 1947, the first three units were launched, and in 1950 - the station was fully operational. Its new capacity was 640 MW. i.e. 13% more than before the war. After the liberation of Ukraine, the energy industry was in a terrible state. During 1943–1945 the first turbogenerators at Shterovska, Zuevska, Dneprodzerzhinska and other State District Power Plants, 220 kV power lines from Zuevskaya State District Power Plant to Zaporozhye were put into operation. After restoration work during 1946–1950. the total installed capacity of all power plants in Ukraine was 3341 MW (24% higher than before the war). Annual electricity production reached 14,711 million kWh (18% more than before the war).

Energy resources of Ukrainian rivers

In the postwar years it was decided to form the Dnipro cascade of hydroelectric power plants on the Slavutych (Dnipro) River. In 1945–1948 the Ukrainian branch of the All-Union Design Institute "Hydroenergoprojekt" has developed a term of reference for the construction of the Kremenchug HPP. The government has decided to prioritize the construction of the Kakhovka HPP (downstream). Six vertical units with blade propeller type turbines were installed in Kakhovka HPP building. The capacity of Kakhovka HPP was 351 MW. In 1954, the con-



Fig. 20.10 Dniester HPSPP 7 units x 320/423 MW

struction of the Kremenchug HPP began. 12 vertical units with a total capacity of 625 MW were installed here. The first unit was launched in 1959, the rest - in 1960. In 1949–1960 there was an intensive construction of small hydropower plants on the rivers of Ukraine - Vorskla, Zbruch, Murafa, Oskol, Southern Bug, Prut, Psel. Ros, Teterev. Among the small hydropower plants, the Tereblya-Rikskaya HPP in Transcarpathia with an installed capacity of 37 MW deserves special attention. For many years, small hydropower plants successfully provided electrification of regions, but later, with the development of high-power power plants and power grids, the operation of such hydropower plants lost its economic viability.

During 1960–1970 the construction of new energy facilities on the Dnipro river continued.

- At the end of 1961, the operation of Dniprodzerzhynska (now Serednyodniprovska) HPP began. Its total capacity was 352 MW (eight hydraulic units of 44 MW each)
- In 1964, Kyiv HPP with a total capacity of 361 MW (20 hydraulic units of 18.5 MW each) was built.
- The next part of the Dnipro cascade of hydroelectric power plants and reservoirs was Kaniv HPP, which was put into operation during 1972–1975. The station had a total capacity of 444 MW (24 hydro units of 18.5 MW each).
- The regulated flow of the Dnipro river allowed to place the structures of Dnipro HPP-2 with a total capacity of 847.2 MW. The first launch of Dnipro HPP-2 took place in 1974.



Fig. 20.11 DniproHPP-1 and Dnipro HPP-2 today

- One of the first hydro-pump storage plant in the USSR, Kyiv PSP, began operating in 1970 with six 37.5 MW units. Three of them operate in reverse mode (turbine pump). After the completion of all works of the Dnipro cascade, the total installed capacity of HPPs in this system amounted to 4 000 MW.
- In 1973, the construction of Dniester HPP on the Dniester River began. Completed in 1983. The station reached a design capacity of 702 MW (six hydraulic units of 117 MW each)
- In 1983, construction work began on the Dniester HPP-2 and the Dniester PSP.
- In 1980–2020 units of Dniester HPSPP, Kyiv HPSPP, Tashlyk HPSPP were put into operation. Dniester HPSPP is designed as one of the biggest in Europe with 7 projected units 320/423 MW each. HPSPPs were constructed for power regulation in electric power system in complex with NPPs.

Improvement of TPPs' parameters and construction of new TPPs

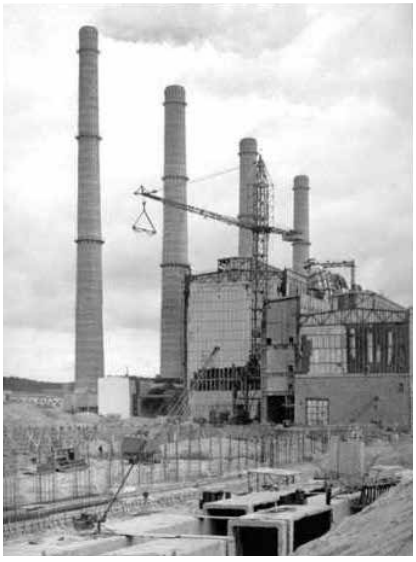


Fig. 20.12 Voroshvlovgrad (Lugansk) TPP

In the post-war years, restoration, modernization of thermal power plants and the construction of new ones took place actively. For example, in 1949–1957 the Mironovskaya TPP (Donetsk Region) was built with an installed capacity of 500 MW. In 1951–1966 - Pridneprovskaya state district power station (Dnipro region). The capacity of the power plant is 2,400 MW. In 1951–1957 - The first stage of the Slovyansk State District Power Station (Donetsk region). The power of the first stage is 500 MW. In 1952–1958 - Voroshylovgrad (Lugansk) state district power station (Donetsk region). Installed capacity of 2,300 MW.

- 1954–1960 - Starobeshevskaya DRES (Donetsk region). Installed capacity of 2,300 MW.
- 1954–1960 - Damitskaya TPP (Kyiv) with a capacity of 250 MW.

- During 1965–1973, Kryvyi Rih SDPP was put into operation.
- In 1968, construction of Ladyzhyn SDPP in Vinnytsia region began. The power plant with a total capacity of 1 800 MW was launched within one calendar year - the first unit with a capacity of 300 MW was launched in December 1970, the last sixth - in December 1971.
- Trypillya SDPP was built in Kyiv power system (six power units of 300 MW each)
- In the territory of Lviv region in 1956–1964 three stages of Dobrotvirska SDPP were put into operation.
- In the territory of Ivano-Frankivsk region in 1965–1969 Burshtyn SDPP was built with a total capacity of 2 400 MW. The construction of thermal power plants continued. Kyiv CHP-5 became the largest in Ukraine with a design electric capacity of 700 MW. Overall, the increase in energy resources over a short period of time has been impressive.
- 1960–1990 - turbine generating units (300 MW, 800 MW) were put into operation on the Vuhlehirska TPP, Zaporizhzhia TPP and other TPPs were constructed.

c) Interconnections time 1961–2000

Development of the integrated power system (IPS) of Ukraine. Energy interaction with Europe

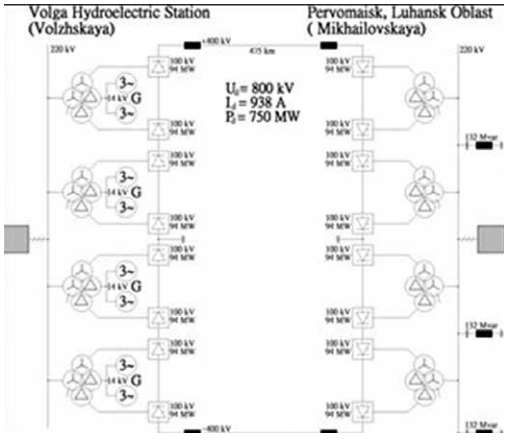


Fig. 20.13 400 kV Direct current transmission line

Along with the construction of new power plants on the territory of Ukraine, the construction of high-voltage power lines began. In 1960, a voltage of 330 kV was used for the first time.

During 1958–1967 the Kharkiv, Odesa, Kyiv, Vinnytsia, Crimea, Lviv and Moldavian power systems were connected to parallel operation by the new 220–330 kV transmission lines. Integrated power system of Ukraine and Moldova was formed.

At the same time, strong interconnections were formed by building high-voltage transmission lines. In 1962–1965 a unique overhead direct current transmission line between Donbass (Ukrainian SSP) and Volga HPP (Russia SFSR) was put into operation. Two combined unipolar lines (+ 400 kV and - 400 kV) had a total length of 470 km.
Establishment of interconnections between Ukraine and countries of Central and Eastern Europe - members of the Council for Mutual Economic Assistance, founded in 1949 had become an important stage of European power industry.

- In 1962, Dobrotvirska GRES - Lviv - Mukachevo - Shayoseged (Hungary) double-circuit 220 kV transmission line was laid.
- In 1963, 220/400 kV interconnection node substation was built in Mukachevo, which enabled the parallel operation of the power systems of Hungary, Romania, Czechoslovakia and the Lviv power system of the Ukrainian SSR.
- Export of Ukrainian electricity to Eastern Europe was facilitated by construction of new 400 kV line Burshtyn SDPP – Mukachevo.
- During 1971–1975, a 750 kV overhead line Donbass-Dnipro-Vinnytsia-Western Ukraine with a length of over 1,100 km was put into operation.

As of 1976, the total length of power lines in Ukraine reached 768.65 thousand km. In particular, the length of lines with a voltage of 750–800 kV amounted to 1.35 thousand km.

Improvement of NPPs

Nuclear power of Ukraine dates back to 1977, when the first Chornobyl NPP unit was put into operation. According to the plans of nuclear power development 9 nuclear power plants had to be built in the former USSR at the territory of Ukraine. In the period from 1977 till 1989 it was planned to put into operation 16 units with total capacity of 14800MW at 5 nuclear power plants, which were Zaporizhzhya NPP, Khmelnytsky NPP, Chornobyl NPP and South-Ukraine NPP. Increasing demand for electricity encouraged the fast construction of nuclear power units: 10 units, 8 of which with capacity of 1000 MW (four VVER-1000 reactors and four RBMK-1000 reactors) were in the operation at the time of technogenic accident at the fourth unit of Chornobyl NPP in April 1986 in Ukraine. From 1986 and till 1990 6 nuclear power units with the capacity of 1000MW each were put into operation: three units at Zaporizhzhya NPP and one unit for each nuclear power plant, which are South-Ukraine, Rivne and Khmelnytsky NPP.

However after Chortnobyl NPP accident, In August, 1990 Verkhovna Rada of Ukraine declared a moratorium on the construction and commissioning of new nuclear power units , which resulted in suspension of the construction of new units at Khmelnytsky, Zaporizhzhya and Rivne NPP. After Verkhovna Rada called off the moratorium, the questions concerning the renewing and restructuring of uncompleted units arose. Construction and putting into operation were important first of all to compensate for the capacity of the units, which had exhausted their lifetime, replacement of units, which did not meet current safety requirements. In 1993 operation at 6th unit of Zaporizhzhya NPP, 4th unit of Rivne NPP and 2nd unit of Khmelnytsky NPP were resumed. In October, 1995 it was energy startup of the 6th unit of Zaporizhzhya NPP. Zaporizhzhya nuclear power plant with installed capacity of 6 million kW became the biggest one in Europe.

Chornobyl NPP is the first Ukrainian nuclear power plant, the operation of which was suspended till the end of the design lifetime. Nowadays three units of the plant with RBMK-1000 reactors are at the stage of decommissioning; particularly 2nd unit from 1991 after the fire in turbine hall, 1st unit from 1996 according to the decision of Ukrainian Government, 3rd unit was stopped in the end of 2000. After the shutdown of Chornobyl NPP, in Ukraine there are 4 nuclear power plants with VVER reactors in operation: Zaporizhzhya NPP, Rivne NPP, Khmelnytsky NPP and South-Ukraine NPP, here 15 nuclear energy units with installed capacity of 13835 MW operate.



Fig. 20.14 Chornobyl NPP

Construction of transboundary transmission lines
To the existing high-voltage lines were added those coming directly from the new NPPs.

- In 1979 - 750 kV transmission line Chernobyl NPP – Western Ukrainian substation.
- In 1982 - 750 kV transmission line Chernobyl NPP – Vinnytsia .
- In 1983 - 750 kV transmission line Zaporizhzhya NPP – Dnipropetrovsk.
- In 1979 - 330 kV transmission line Rivne NPP – Rivne.
- In 1982 - 330 kV transmission line South Ukrainian NPP – Trykhaty

The 479 km long 750 kV Vinnytsia – Albertirsha (Hungary) transmission line, built in 1979 to strengthen connections with the energy systems of the CMEA member countries, has become of paramount importance.

In 1984–1986, the 750 kV Khmelnitsky NPP - Rzeszow (Poland) and the South Ukrainian NPP - Isaccea (Romania) - Varna (Bulgaria) were laid.
Exports of electricity from the IPS of Ukraine to CMEA member countries increased to 28–30 billion kWh per year.

As of 1990 integrated power system of Ukraine operated more than 55 million kW of generating capacity, which produced more than 290 billion kWh of electricity (10% was intended for export), about 1 million km of system-forming and distribution electricity networks of different voltage classes. Ukraine's IPS' energy facilities were state-owned and subordinated to the Ministry of Energy. The first Minister of Energy of independent Ukraine was Vitaliy Sklyarov.
In 1995, the energy systems of Poland, Hungary, Czech Republic Slovakia were integrated into the European energy system UCTE, where strict requirements were set for the parameters of electrical systems. This deprived the IPS of Ukraine of the opportunity to work synchronously with UCTE. But the presence of interstate lines allowed to export electricity from Ukraine to certain regions of Central Europe outside the UCNE - in particular from Burshnyn TPP to Hungary, from the Dobrotvorska CHP - to Poland. Later, based on Burshtyn TPP and existing interstate power lines, the so-called "Island of Burshtyn TPP" was created, which since 2002 has worked in parallel with the UCTE power system (now ENTSO-E).
Functions of the Transmission system operator (TSO) of the Integrated Power System (IPS) of Ukraine is performed by Power Company "Ukrenergo". The company consists of eight regional power systems.

The IPSS of Ukraine joins more than 100 high voltage substations 220–750 kV with a total installed capacity of over 78.8 thousand MVA and more than 21.3 thousand km of main trunk and interstate transmission lines.
The governmental "Energy Strategy of Ukraine" provides for the elimination of "bottlenecks" in the power grid. These include Crimea, the south of Odessa region, the east of Donbass and the Volyn region. After the closure of the Chernobyl NPP, the Kyiv load node joined the deficit regions.
Objects that were built to solve the problems of energy supply of the regions:

A. to improve the reliability of energy supply in Luhansk region
   - in 2002 - construction of 750 kV transmission line South Donbass-Donbass;
   - in 2004 - construction of Substation 550 kV "Novodonbaska" with 500 kV transmission line Donbasska Novodonbaska;

B. to improve the reliability of energy supply in Odessa region
   - in 2013 - construction of 330 kV transmission line Adzhalyk – Usatove;

C. to improve the reliability of energy supply in the Volyn region
   - in 2003 - construction of 330 kV transmission line Rivne NPP - Lutsk North;
   - in 2002 - construction of transmission line 330 kV Khmelnitsky NPP – Khmelnitsky;

D. to improve the reliability of energy supply of the Crimean peninsula
   - in 2005 - construction of 330 kV transmission lines Melitopol – Simferopol;
   - in 2011 – transfer to the voltage class of 330 kV 220 kV transmission line Simferopol - Sevastopol and reconstruction of 5 substations.

In order to supply the capacity of Rivne and Khmelnitsky NPPs to the deficit central region and increase the stability of consumers of the Kyiv load node, the project for construction of 750 kV transmission line Rivne NPP - Kyiv with construction of 750 kV Kyivska Substation was started.

- In December 2018 - construction of 750 kV Kyivska Substation was completed.
- In December 2017 - construction of 750 kV transmission line Rivne NPP - Kyiv was completed
- In September 2016 - feeders of 750 kV Khmelnytsky NPP - Chornobyl NPP to 750 kV SS Kyivska Substation were build.

The project of construction of 750 kV transmission line Zaporizhzhya NPP - Kakhovska Substation has been implemented



Fig. 20.15 550 kV SS Kreminska

On July 9, 2020 TSO NPC Ukrenergo presented the substation Kreminska lately constructed and put into operation. The substation links the North of Lugansk region with the Integrated Power System of Ukraine, thus it provides one more source of electricity supply in addition to existing Lugansk TPP.
There are input power lines with voltage of 500 kV from the substations Donbaska and Donska and the output line 220 kV to the substation Yuvileyna. The transformer capacity of the substation Kreminska is 501 MWA, there are four transformers with voltage range 500/220/35 kV SS is completely automatic; its activity can be managed by the dispatch center in Kharkiv or one in Kyiv. The new substation lets release additional 50 MW reserves of Lugansk TPP's units.

Electrification of transport

It was a time of extraordinary construction activity. A corresponding increase in energy capacity and expansion of power supply network was the necessary condition for a rapid construction process.
Intensive electrification of railway transport was carried out. As of 1968, the total length of Ukrainian electrified railways was 4,750 km. At the same time, a single-phase alternating current system with a voltage of 27.5 kV became widespread.
In Ukrainian cities, the development of electric vehicles - trams and trolleybuses - continued. The Crimean trolleybus became a unique example of long-distance communication. Traffic 84 km long between Simferopol and Yalta, part of which

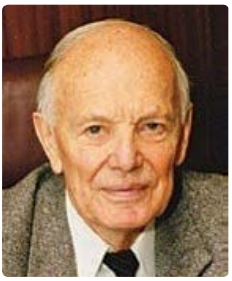


Fig. 20.16 1960. Kyiv metro station Dnipro

ran along the slopes of the Crimean Mountains, was opened in 1961.
Subway lines were built in the largest cities. The opening of the first metro in Ukraine (Ukrainian SSR) and the third in the USSR took place in Kyiv in November 1960. The movement of subway trains was carried out by supplying a direct current voltage of 825 V.

d) Scientific activities

During the period of development of electric power sector in Ukraine electrotechnical faculties in Kyiv, Lviv, Kharkiv, Vinnitsa Polytechnic Institutes were established. Electrotechnical Institutes were created for the development of power system: Ukrenergomerezhproekt, UkrSelEnergoProekt, NASU Institute of Electrodynamics, E.O. Paton Institute of Electric Welding.



Borys Paton (November 27, 1918 – August 19, 2020) Recipient of the Hobart Memorial Medal from the American Welding Society (1983), president and academician of the National Academy of Science of Ukraine and director of E.O. Paton Institute of Electric Welding, Kyiv, Ukraine.

Fig. 20.17 Borys Paton

Ivan Puluy (February 2, 1845 – January 31, 1918) was a Ukrainian physicist and inventor, who has been championed as an early developer of the use of X-rays. Puluj made many other discoveries as well. He is particularly noted for inventing a device for determining the mechanical equivalent of heat that was exhibited at the Exposition Universelle, Paris, 1878. Puluj also participated in opening of several power plants in Austria-Hungary. Puluj did heavy research into cathode rays, publishing several papers about those rays between 1880 and 1882.



Fig. 20.18 Ivan Puluy

In 1881 as a result of experiments into what he called cold light Prof. Puluj developed the Puluj lamp; it was awarded the Silver Medal at the International Electrotechnical Exhibition in Paris, 1881. Throughout the world, it has become known as the "lamp of Puluj" and even it was mass-produced for some time. He served as the rector of the Higher Technical School in Prague (German part) in 1888–1889. Puluj also worked as a state adviser on electrical engineering for Bohemian and Moravian local governments.

Fedir Pirotsky (February 17, 1845 – February 28, 1898) engineer of Ukrainian origin and inventor of the world's first railway electrification system and electric tram. While the commercialization of his inventions in Russia was relatively slow, Pirotsky is known to have met with Carl Heinrich von Siemens and influenced Siemens' eventual introduction of the first regular electric tram line (for the Berlin Straßenbahn). In 1880, he modified a city two-decker horse tramway to be powered by electricity instead of horses, and on 3 September [O.S. August 22] 1880 the unusual form of public transport started to serve residents of Saint Petersburg amid the vocal protests of the owners of the horse-cars. The experiments continued until the end of September 1880. Some historians claim that this was the first electric tram in the world. Pirotsky did not have the money to continue his experiments, but his works stirred interest in electric trams around the world. Among people who met Pirotsky was Carl Heinrich von Siemens who was very interested and asked many questions. In 1881 the brothers Siemens started producing their own design of electric trams commercially. The first permanent electric tram line using Siemens tram cars was opened in Berlin in 1881 and the first permanent tram line in the Russian Empire was opened in Kyiv in 1892.

Julius Lilienfeld (April 18, 1882 – August 28, 1963) was born in Lviv and is known as first who invented transistor principle (patented in Canada, 1925, almost 20 years before three Americans Shockley, Bardeen, Brattain, who received Novel prise for invention of transistor. In the United States Lilienfeld did research on anodic aluminum oxide films, patenting the electrolytic capacitor in 1931, the method continuing to be used throughout the century. He also invented an "FET-like" transistor, filing several patents describing the construction and operation of transistors, as well as many features of modern transistors.

Stanisław Fryze (Fryze power theory) – (December 1, 1885 – March 3, 1964). He developed the theory of the transfiguration of an electrical circuit, as well

as active, passive and imaginary power in circuits of currents and voltages, introduced the concept of variable electromotive force, as well as calculation methods using loop currents and nodal potentials, simplified the theory and methods of analyzing multiphase systems by introducing symbolic methods. Author of 32 scientific works, including a 3-volume (in 6 parts) course "General Electrical Engineering". Member of the International Congress of Electricians in Paris (1932)



Fig. 20.19 Lubomyr Romankiw

Lubomyr Romankiw (born 17 April 1931 in Zhovkva, Ukraine) is an IBM Fellow and researcher at IBM's Thomas J. Watson Research Center in Yorktown Heights, New York. He is listed as an (co)inventor on over 65 U.S. patents, 150 papers and has edited 10 volumes of various technical symposia. Much of his work involves magnetic materials, reflective displays and copper plating. While working for the IBM, the inventor developed magnetic thin-film storage heads (co-invented with David Thompson in the 1970s), a revolutionary technology for recording and reading information on hard drives. He is an IBM Fellow, a member of the IBM Academy of Technology, an IEEE Fellow, and an Electrochemical Society Fellow. He received the 1993 Society of Chemical Industry Perkin Medal, the 1994 IEEE Morris N. Liebmann Technical Field Award, and the 1994 Electrochemical Society Vittorio de Nora Award.

21.2 History of NC CIGRE

The history of Ukrainians' participation in CIGRE activities may be divided in three periods:

- 1957–1991 - Ukrainians participation in former USSR (Union of the Soviet Socialist Republics) CIGRE Committee activities,
- 1992–2004 - Ukrainian participation as individual members in CIGRE activities
- 2004 – up to now - history of the Ukrainian National Committee of CIGRE.

USSR joined CIGRE two years after the creation of the organization, when delegates of the USSR took part in the second session of CIGRE in 1923. In 1957 the National Committee of the USSR was approved by the Administrative Council of the CIGRE. Traditionally, the functions of the Soviet National Committee for

the formation of a unified policy and the representation of interests in CIGRE were performed by state structures (ministries). During the period of **1994–2004** the following companies (collective members) and engineers (individual members) have become CIGRE members and took part in CIGRE activities not being jointed by the country' national committee: National Power Company "Ukrenergo", OJSC "Zaporozhtransformator", Closed JSC "Enpaselectro", OJSC "Ukrhydroenergo", State Factory "Electrotyazhmash", OJSC "Ukrhydroproject", OSC "VIT", **Mr. Batalov Anatoliy, Mr. Bondarenko Yuriy, Mr. Livshyts Oleksandr, Mr. Sklyarov Vitaliy.**

In the period **1992–2004,** Ukrainian engineers took part in the presentation of Ukrainian energy and technology at CIGRE Sessions and technical exhibitions jointly with Russian and other foreign power engineers.



CONSEIL INTERNATIONAL DES GRANDS RÉSEAUX ÉLECTRIQUES
INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

21 RUE D'ARTOIS, F-75008 PARIS
Tel : + 33 (0)1 53 89 12 90
Fax : + 33 (0)1 53 89 12 99
http://www.cigre.org

CERTIFICATE OF RECOGNITION

CIGRE UKRAINIAN NATIONAL COMMITTEE

It is certified that the CIGRE UKRAINIAN NATIONAL COMMITTEE was officially recognized by the CIGRE Administrative Council on 1st March 2004.

Paris, 15th March 2004

Jean KOWAL
Secretary General

CIGRE
21 rue d'Artois
F-75008 Paris

Fig. 20.20 Letter of recognition

In early 2004, being based on the CIGRE "Rules of Procedure", with the support of Jean Kowal, the "old cigreans" decided to create the CIGRE National Committee in Ukraine, and later received the approval of the Administrative Committee.

For the period of March 2004 – March 2006 the functions of the National Committee were entrusted to the Public Organization "Association "Ukrhydroenergo".

In 2006 Public Organization "Association "CIGRE-Ukraine" with the functions of the Ukrainian National Committee CIGRE was established.

In September 2017, the non-profit Public Union "International Council on Large Electric Power Systems CIGRE in Ukraine" was registered in accordance with the new Law of Ukraine for Public Organizations.

As an example, the following reports were prepared for participation in the CIGRE Session:

38 CIGRE Session (2000)	Technical and economic efficiency of reducing the insulation level of power transformers and service experience concerned - A. K. LOKHANIN*, T. I. MOROZOVA, L. N. SHIFRIN (Russia), **A. I. SAVCHENKO (Ukraine)**
	Catching up the challenge of the synchronous interconnection between the two largest European systems i.e. TESIS and UPS - Jean-Marie COULONDRE, Jean-Yves BUSSON, Jean KOWAL (France), Jacques DEUSE (Belgium), Eckhart GREBE (Germany), Sarkiz ARISTAKISEAN (Moldova), Alexander BONDARENKO, Valentin GUERIKH (Russia), Alexander KOZLOVSKI (Belarus), **Alexander VOEVODA (Ukraine)**
39 CIGRE Session (2002)	Internal insulation failure mechanisms of equipment under service conditions. A. K LOKHANIN - G. Y. SHNEIDER (Russia) **V. V. SOKOLOV - V. M. CHORNOGOTSKY (Ukraine)**



Fig. 20.21 Viktor Sokolov

Our colleague - technical director of Scientific and Engineering Center "ZTZ-Service" (SIC "ZTZ-Service", Zaporizhzhya, Ukraine) **Dr. Viktor Sokolov** (1940–2008) was an eminent world-renowned transformer expert from Ukraine. He lent his many years of experience in the design, build and defect analysis of large transformer to the transformer community. He used this experience to chair transformer committees in CIGRE and IEC. His experience was in great demand around the world and he presented many technical papers at CIGRE IEC and IEEE. A methodology developed by Dr. Viktor Sokolov is how to carry out field testing, this provides 'online' condition assessment of critical transformers.
Since 1991 he has been working for CIGRE, in particular, in Study Committees A2 "Power transformers" and D1 "Materials and technologies".
He was the leader of the **WG A2.18 "Guide for life management techniques for power transformers",** as well as an independent expert on "Operation of transformers (problem solving on site)". Dr. Viktor Sokolov was the head of the group **WG A2.30 "Moisture Equilibrium and Moisture Migration within Transformer Insulation Systems".** The work on the results of the group's work was published after his death.
In addition, Dr. Viktor Sokolov was the liaison between the CIGRE SC A2 and SC D1 committees and was a member of the SC A2 Strategy Advisory Board. In Working Group **WG D1.01 "Gas Monitors for Oil-Filled Electrical Equipment"** liaised between academics and practicing engineers.

Table 20.7 Leading people in Ukrainian NC CIGRE

Year	President	Vice-president Technical Council Chair	General Secretary
2004–2015	Mr. SKLYAROV Oleksandr	Mr. BONDARENKO Yuriy	Mrs. PRYSTUPCHUK Olena
2015 – ...	Mr. SVETELIK Oleksandr		Mr. BONDARENKO Yuriy



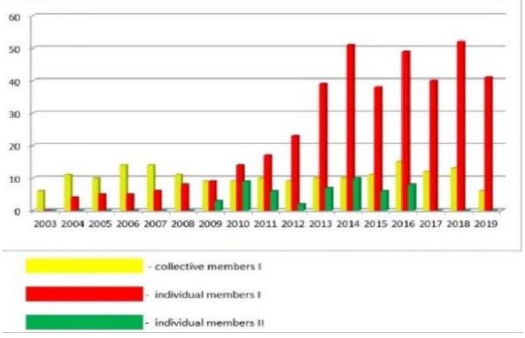
Fig. 20.22 First President (2004–2015) of Ukraine NC CIGRE Mr. Sklyarov Vitaliy



Fig. 20.23 Acting President (2015 – ...) of Ukraine NC CIGRE Mr. Svetelik Oleksandr and Vice-President (2004 – ...) Mr. Bondarenko Yuriy. Signing of the Memorandum of understanding with Ukrainian NC of IEC

20.3 Activities and achievements of NC CIGRE

a] Membership



Over the past eight years, the number of members of the CIGRE National Committee has remained steady, with **equivalent membership** of approximately **100 members.** Since 2007, the Ukrainian National Committee of CIGRE has been represented on the Governing Body of CIGRE. An irreplaceable member of the Administrative Council is Mr. Bondarenko Yuriy, who participates in the discussion and decision-making on organizing the work of the International Council, developing strategic and practical work plans.

b) Participation of the Ukrainian members to international activities of CIGRE

Our colleagues take part in the activity of the CIGRE Working Groups. The most experience in such activity for the moment has Doctor of Science Agamalov Oleg, head of the electrical department of the Tashlykskaya PSPP, which is part of Energoatom South-Ukrainian NPP complex. Only as of 2020, Mr. Agamalov is a member of such working groups.

- WG A1.44 "Guideline on Testing of Turbo and Hydrogenerators".
- WG B5.56 "Optimization of Protection Automation and Control Systems".
- JWG C2/C4.37 "A proposed framework for coordinated power system stability control".
- JWG C4/B4.52 "Guidelines for Sub-synchronous Oscillation Studies in Power Electronics Dominated Power Systems".

In addition, he is the author of reports at the CIGRE Paris Sessions.

Mr. Andryienko Bogdan, Mr. Tarchutkin Alexander, Mr. Ostrenko Maxim (Company "SoftTeamGroup", Zaporizhzhya) - active members of the working group

- JWD A2/C4.52 "High-frequency transformer models for nonstandard waveforms".

SoftTeam is a group of experienced professionals in the field of electrical, mechanical and heating engineering, high tech software developing, computer modeling, 3D design and visualization, etc. methods and techniques developed by "SoftTeamGroup" are validated and accepted by the companies from such countries as Australia and Mexico, India and China, Malaysia and Taiwan, USA and South Korea, Russia and many others.

Mr. Perevertayev Andrey, Ukrainian and international expert in the field of electricity markets, conducts his activity and researches in the working group

- WG C5.24 "Exploring the Market Value of Smart Grids and Interactions with Wholesale (TSO) and Distribution (DSO) Markets" together with colleagues from many countries.

Mr. Mudryk Anatoliy (GE Energy, Kyiv) was the member of

- WG A2.49 "Condition assessment of power transformers"

Mr. Semenko Oleg (PROMiK. Ltd., Dnipro)

- WG B2.61 Transmission Line Structures with Fiber Reinforced Polymer (FRP) Composites

Mrs. Dubina Anna (PROMiK. Ltd., Dnipro)

- WG B2.23 Geotechnical Aspects of Overhead Transmission Line Routing ~ An Overview

- For the period 2014–2016 Ukrainian National Committee was represented by Mr. Denysenko Oleksandr in capacity of observer member in SC C4 Power system technical performance.

Ukrainian National Committee of CIGRE hosted the following international SEERC events:

- On June 2015 the 3rd official MB Meeting of SEERC.
- On June 2018 the 2nd SEERC Conference "Energy Transition and Innovations in Energy Sector".



Fig. 20.24 Second SEERC Conference 2018 in Kyiv

c) National Working (Discussion) Groups

National CIGRE Conferences, Panels, Workshops organized during the last three years

Table 20.7 National Working (Discussion) Groups

Year of establishment	Title	Convener
2014	Liberalization of the electricity market	Mr. Yevdokimov Volodymyr
2014	RAB regulation	Mr. Czech Serhiy
2015	Technical and economical features of Hydroelectric energy storages' (HPSPPs) implementation and operation in electric power systems for load balancing	Mr. Bondarenko Yuriy
2019	Smart-Grid Implementation	Mr. Bondarenko Yuriy

d) Awards



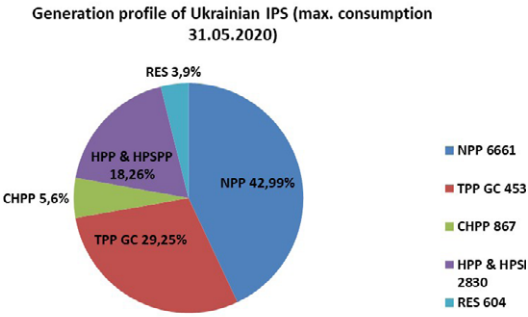
Technical Council Award

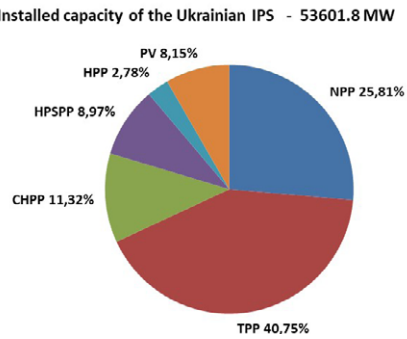
Year	SC	Name, title
2000	A2 - Transformers	Sokolov Viktor, Technical Director of Scientific and Engineering Center "ZTZ-Service"

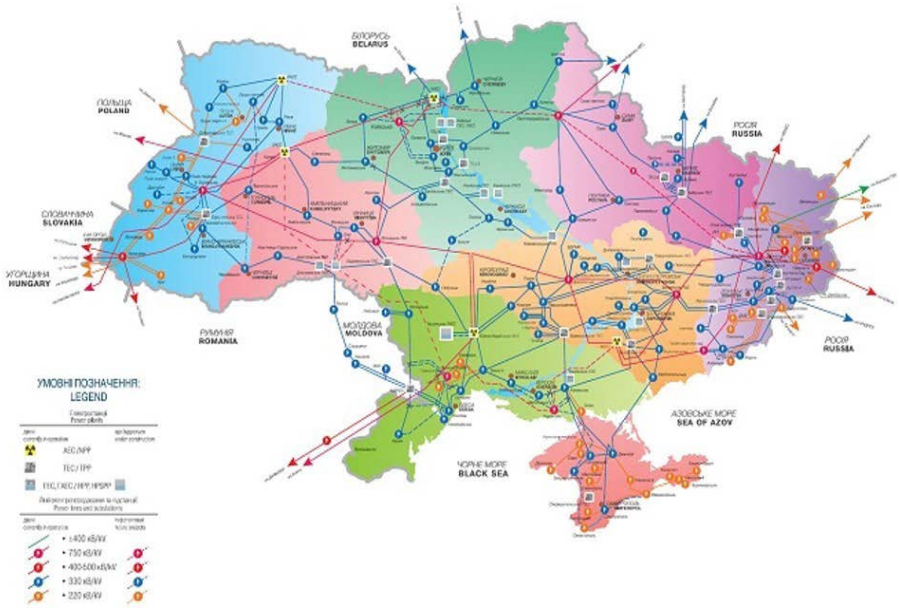
Distinguished members

Year	SC
2014	**Bondarenko Yuriy,** Vice-President of Ukrainian NC of CIGRE (2004 – ...)
2016	**Sklyarov Vitaliy,** First President of Ukrainian NC of CIGRE (2004–2015)
	Agamalov Oleg, Head of Electrical Department, Tashlyk Pump Storage Power Plant
2018	**Kontorovych Leonid,** Technical Director of PJSC Zaporizhtransformator
2020	**Denysenko Oleksandr,** expert, "Science and Technology Company ENPASELECTRO" Ltd.

20.4 Country electric power profile / RES vision





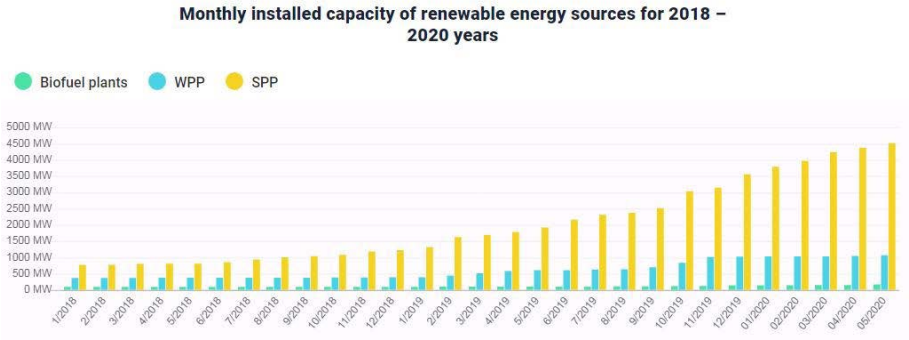


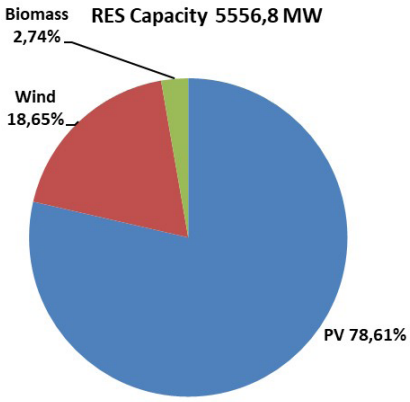
Geographical location and the existence of high-capacity interstate power transmission lines in the Power System of Ukraine allows to facilitate significant exchange of electricity with power systems of European Union member states (Hungary, Slovakia, Poland and Romania) and power systems of CIS states (Russia, Belarus, Moldova).

Connection with power systems of other countries is maintained via Ukrenergo's interstate power transmission lines. It helps ensure mutually beneficial electricity exchange and improve reliability of electricity supply to consumers and integration of electricity markets of various countries.
The Power System of Ukraine is divided into two parts. The main part of the Power System of Ukraine operates simultaneously with power systems of CIS and Baltic states, and the other part - Burshtynska TPP Island - as part of ENTSO-E. Simultaneous operation of the Power System of Ukraine as part of high-capacity power systems allows to boost its reliability and reduce the aggregate amount of emergency reserve required for its functioning.
Ukrenergo transmits electricity via interstate power lines in the following directions:

- *from Burshtynska TPP Island to Hungary, Slovakia, and Romania.*
  Maximum export capacity: 650 MW.

- *"Directional transmission" via 220 kV Dobrotvirska TPP — Zamosc (Poland) power line*
  Maximum export capacity: 235 MW.
- *Moldova 's power system*
  Maximum flow capacity between the IPS of Ukraine and the IPS of Moldova: 700 MW but may be limited to zero.
- *Republic of Belarus*
  Maximum flow capacity between the Power System of Ukraine and the IPS of Belarus: 900 MW.
- *Russian Federation*
  Maximum flow capacity between the Power System of Ukraine and the IPS of Russia: 3000 MW.





20.5 References

1. Енергетика. Історія, сучасність і майбутнє. – У 5 томах / С.Г.Плачкова, І.В.Плачков, Н.І. Дунаєвська,В.С.Подгуренко та ін./Ред. Ю.О. Ландау, І.Я.Сігал. – К.. 2013
2. М.К. Бно-Айріян, М.Б.Кальницький, З.Ю.Буцьо, А.М.Бажан, В.К.Осадчук, С.С. Шадрін, Я.К.Батог . – Електроенергетика України - К.: Видавничий дім "Артек", 2020.- 163 с.
3. Ишкин В.Х. СИГРЭ в России: 50 лет (1957-2007). – М.: ФИЗМАТЛИТ, 2007. – 224 с.- ISBN 978-5-92221- 0912-3.
4. Укргідроенерго. Дніпровська ГЕС. Історія будівництва /Online/. Available: https://uhe.gov.ua/filiyi/dniprovska_hes /Accessed 31-May-2020/.
5. История Донбассэнерго /Online/. Available: https://de.com.ua/history /Accessed 05-June-2020/.
6. "ДОНБАССЭНЕРГО": НАСТОЯЩЕЕ ПРОШЛОЕ / Бондаренко Э.Н., Добров П.В., Стяжкина Е.В. -"Эпика Люкс", 2015 (https://de.com.ua/uploads/0/2419-Book%20Present%20Past.pdf)
7. Соколов Віктор Володимирович /Online/. Available: http://www.ztz-service.com.ua/uk/sokolov /Accessed 12-June-2020/.
8. Диспетчерська інформація. Робота ОЕС. /Online/. Available: https://ua.energy/diyalnist/dyspetcherska-informatsiya/robota-oes-ukrayiny-za-tyzhden/ /Accessed 31-May-2020/.
9. Диспетчерська інформація. Транскордонні перетоки. /Online/. Available: https://ua.energy/diyalnist/dyspetcherska-informatsiya/peretoky/ /Accessed 31-May-2020/.
10. Встановлена потужність енергосистеми України на 04/2020 /Online/. Available: https://ua.energy/vstanovlena-potuzhnist-energosystemy-ukrayiny//Accessed 31-May-2020/.
11. Electric Power Industry of Ukraine – Kyiv (2020)
12. Electric Power industry. Expertise and experience – the way to modern Electric Power industry. ISBN 966-8163-11-7
13. Electric Power industry. Development of nuclear energy and interconnected power system. ISBN 978-617-635-005-7
14. The History of CIGRE (International Council on Large Electric Systems), A key player in the development of electric power systems since 1921, ISBN.978-2-85873-166-4, Paris, 2011.
15. The History of CIGRE National Committees, A major contribution to the International history of CIGRE: Creation and Development of National Committees since the 1920s. Paris, 2013.
16. V. Kh. Ishkin, International Council on Large Electric Systems: Cigre History activity 1921–2006, UDK 621.311, Moscow, 2006.

For further information contact:
NC CIGRE Ukraine 04112, Kyiv, Ukraine
Igor Sikorsky st., 8

www.cigre.org.ua
tel. +38 044 456 24 69
email: cigre.ukraine@ukr.net

All photos used in chapters are published by credit of the National Committees members of SEERC.

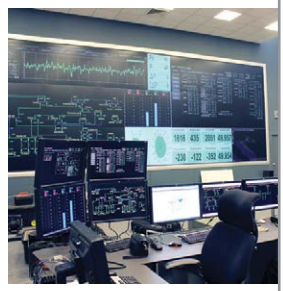
ACKNOWLEDGEMENT

The Publishers and Authors are grateful to the following for sponsoring this book and make it accessible to a large range of experts: KONČAR, Croatia, CESI, Italy, TERNA, Italy, ELES, Slovenia, KOLEKTOR ETRA, Slovenia, MITAS, Turkey, and Scientific & Technology Company ENPASELECTRO, Ukraine.

www.koncar.com











tradition.
knowledge.
responsibility.

KONČAR



KOLEKTOR

ETRA





With the energy of tradition firmly into the future.

Since 1933.

www.kolektor-etra.si
info.kolektor.etra@kolektor.com


ELES
TRANSMITTING ENERGY.
MAINTAINING BALANCE.
Energy flows with us. As the system operator of the Slovenian electric power transmission network we provide safe, reliable and continued transmission of energy 24/7. We are professionals with knowledge and experience and co-create the energy future of Slovenia on diligently set foundations: responsibility, engagement, knowledge, reliability, cooperation and determination. We endeavour to strategically and sustainably plan, construct and maintain Slovenia's transmission network. Electricity always at hand.
Over 2550 km of transmission network
Over 550 employees
We distribute more than 20,000 gigawatt hours of electricity in the transmission network. This energy would light up a bulb for more than a million years.
www.eles.si



CESI is a world-leading technical consulting and engineering company operating in 40 countries around the world.
We have more than 60 years' experience of testing and partnering with international cable manufacturers and utilities to introduce innovative solutions.
CESI use the best industry-standard methodologies and technologies to test the latest innovative solutions and provide the highest quality certification services.

Shaping a Better Energy Future
www.cesi.it

CESI

Testing • Consulting • Engineering • Environment

THE RESPONSIBILITY OF ENERGY
THE ENERGY OF RESPONSIBILITY



Terna is the largest independent electricity transmission grid operator in Europe. It is responsible for the transmission and dispatching of electricity flows throughout the country and actively contributes to the transition to a future powered by renewable energy through the development of innovative solutions for the energy market and participation in international projects.

terna.it

Terna

74.669 km lines • **888** electrical substations • **26** interconnections • **4** control centers



MPowering the World

As Mitaş Group, we operate in the business of engineering, procurement, manufacturing and construction of towers, poles and high masts for power transmission and distribution, switchyards, solar power plants, telecommunication, lighting and transportation infrastructure on a global scale.

With more than 60 years experience, we have expanded our product range to:

- Design and manufacture of composite utility poles and parts
- Design and manufacture of smart poles for smart-city applications

Would you like to know more about us?
Turn on your phone's camera and scan the QR code

info@mitasindustry.com
sales@mitasindustry.com

MİTAŞ ENERGY MİTAŞ INDUSTRY MİCHA MİTAŞ BOLT
MİTAŞ COMPOSITES TECNOLINES ITALIA CHARIGNON



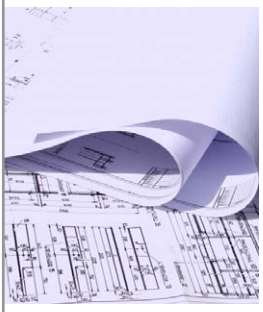




ENPAS ELECTRO

Scientific and Technology Company ENPASELECTRO

ENPASELECTRO is a multifunctional engineering company which has been operating in the energy market of Ukraine and abroad for more than 25 years



04112, Kyiv, Ukraine
8, I. Sikorsky str., block A, 2 floor
enpas@enpaselectro.com
www.enpaselectro.com



cigre Ukraine

Active member of Ukrainian NC

Famous scientists, inventors, innovators from SEERC Region related to electricity, electrification, power technologies: *Thales of Miletus, Luigi Galvani, Alessandro Volta, Antonio Pacinotti, Galileo Ferraris, Nikola Tesla, Guglielmo Marconi, Abraham Ganz, Josef Stefan, Franz Pichler, Josef Stern, Franz Hafferl, Julius Lilienfeld, Károly Zipernowsky, Ottó Bláthy, Miksa Déri, Oton Kučera, Milan Vidmar, Niko Nikoladze, Franz Heinrich Ollendorff, Fedir Pirotsky, Ivan Puluy, Lubomyr Romankiw, Nikolai Benardos, Paul Dimo ...*


Austria


Bosnia and Herzegovina


Czech Republic


Slovakia


Croatia


Georgia


Greece


Hungary


Italy


Israel


Kosovo


North Macedonia


Montenegro


Romania


Serbia


Slovenia


Turkey


Ukraine

SPONSORS:

KONČAR
Croatia

ELES
Slovenia

KOLEKTOR ETRA ŽIRM
Slovenia

CESI
Italy

Terna
Italy

ENPAS ELEKTRO
Ukraine

MİTAŞ
Turkey

PRICE: 30 eur

9 789616 265362