

Mrežni incidenti – postaju li češći i s većim posljedicama?

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HOPS

Sadržaj prezentacije

- Ljestvica za klasifikaciju incidenata (ICS)
- Pojedinačni incidenti
- Kritički osvrt:
 - Učestalost incidenata prema klasifikaciji iz ICS
 - Učestalost incidenata kroz godine
 - Učestalost incidenata prema uzroku
- Incident 28.4.2025. – preliminarne informacije

Ljestvica za klasifikaciju incidenata

- Klasifikacija prema posljedicama incidenta
- Konačna ocjena prema najvišem kriteriju

Scale 0 Noteworthy incident		Scale 1 Significant incident		Scale 2 Extensive incident		Scale 3 Major incident / 1TSO	
Priority/Short definition (Criterion short code)		Priority-Short definition (Criterion short code)		Priority-Short definition (Criterion short code)		Priority-Short definition (Criterion short code)	
#20	Incidents on load (L0)	#11	Incidents on load (L1)	#2	Incidents on load (L2)	#1	Blackout (OB3)
#21	Incidents leading to frequency degradation (F0)	#12	Incidents leading to frequency degradation (F1)	#3	Incidents leading to frequency degradation (F2)		
#22	Incidents on transmission network elements (T0)	#13	Incidents on transmission network elements (T1)	#4	Incidents on transmission network elements (T2)		
#23	Incidents on power generating facilities (G0)	#14	Incidents on power generating facilities (G1)	#5	Incidents on power generating facilities (G2)		
		#15	N-1 violation (ON1)	#6	N violation (ON2)		
#24	Separation from the grid (RS0)	#16	Separation from the grid (RS1)	#7	Separation from the grid (RS2)		
#25	Violation of standards on voltage (OV0)	#17	Violation of standards on voltage (OV1)	#8	Violation of standards on voltage (OV2)		
#26	Reduction of reserve capacity (RRC0)	#18	Reduction of reserve capacity (RRC1)	#9	Reduction of reserve capacity (RRC2)		
#27	Loss of tools and facilities (LT0)	#19	Loss of tools and facilities (LT1)	#10	Loss of tools and facilities (LT2)		

Pojedinačni mrežni incidenti

(nepotpuni popis)

- Portugal 9.5.2000. - ICS 2/3, ptica, zaštita
- Hrvatska 20.9.2002. - ICS 1, nevrijeme, zaštita
- Hrvatska 27.8.2003.- ICS 2, čovjek, zaštita
- Danska/Švedska 23.9.2003. – ICS 2, elektrana, TS
- Italija 28.9.2003. – ICS 3, vegetacija, N-1
- CE SA 4.11.2006. – ICS 2, brod, N-0
- Poljska 8.4.2008. – ICS 2, snijeg, N-2
- Francuska/Španjolska 23.1.2009. – ICS 2, oluja

Pojedinačni mrežni incidenti

(nepotpuni popis)

- Hrvatska 14.5.2014. – ICS 2, N-x, zaštita sabirnica
- Turska 31.3.2015. – ICS 2, N-1
- Velika Britanija 9.8.2019. – ICS 2, grom, elektrane
- Hrvatska 29.12.2020. – ICS 1, potres
- CE SA 8.1.2021. – ICS 2, N-1
- Poljska 17.5.2021. – ICS 2, čovjek
- CE SA 24.7.2021. – ICS 2, požar
- Crna Gora 28.5.2023. – ICS 1, grom

Pojedinačni mrežni incidenti

(nepotpuni popis)

- Ukrajina 30.5.2023. – ICS 2, rat, N-x
- Mađarska 9.5.2024. – ICS 1, kvar DV-a, N-1
- Balkan 21.6.2024. – ICS 2/3, N-2, vegetacija
- Španjolska/Portugal 28.4.2025. – ICS 3
- Sjeverna Makedonija 18.5.2025. – ICS 3, naponi
- Češka 4.7.2025. – ICS 2, kvar DV-a i TE

Učestalost incidenata prema klasifikaciji iz ICS za 2024.

Table 3.2: Number of incidents per scale and synchronous area in 2024.

	Scale 0	Scale 1	Scale 2	Scale 3	Grand total
Baltic	48	3	-	-	51
Continental Europe	2731	1116	-	1	3848
Great Britain	-	-	-	-	-
Ireland	43	-	-	-	43
Isolated systems	14	2	-	-	16
Nordic	5662	2133	-	-	7795
Grand total	8498	3254	-	1	11753

Table 3.4: Percentage distribution of incidents per scale and synchronous area in 2024.

	Scale 0	Scale 1	Scale 2	Scale 3
Baltic	94.1%	5.9%	-	-
Continental Europe	71.0%	29.0%	-	0.0%
Great Britain	-	-	-	-
Ireland	100.0%	-	-	-
Isolated systems	87.5%	12.5%	-	-
Nordic	72.6%	27.4%	-	-
Grand total	72.3%	27.7%	-	0.0%

Table 3.3: Number of events per scale and synchronous area in 2024.

	Scale 0	Scale 1	Scale 2	Scale 3	Grand total
Baltic	48	3	-	-	51
Continental Europe	2824	1121	27	3	3975
Great Britain	-	-	-	-	-
Ireland	45	-	-	-	45
Isolated systems	14	2	-	-	16
Nordic	5671	2134	-	-	7805
Grand total	8602	3260	27	3	11892

Table 3.5: Percentage distribution of events per scale and synchronous area in 2024.

	Scale 0	Scale 1	Scale 2	Scale 3
Baltic	94.1%	5.9%	-	-
Continental Europe	71.0%	28.2%	0.7%	0.1%
Great Britain	-	-	-	-
Ireland	100.0%	-	-	-
Isolated systems	87.5%	12.5%	-	-
Nordic	72.7%	27.3%	-	-
Grand total	72.3%	27.4%	0.2%	0.0%

Učestalost incidenata kroz godine prema klasifikaciji iz ICS

Scale	ICS criterion	2020	2021	2022	2023	2024
Scale0	Incidents on load (L0)	4	4	11	14	7
	Incidents leading to frequency degradation (F0)	360	819	280	302	388
	Incidents on network elements (T0)	1362	1664	1596	2064	1786
	Incidents on power generating facilities (G0)	146	197	179	145	158
	Separation from the grid (RS0)	2	2	3	3	8
	Violation of standards on voltage (OV0)	454	495	480	437	5949
	Reduction of reserve capacity (RRC0)	-	26	185	91	99
	Loss of tools, means and facilities (LT0)	189	107	105	145	207
	Total	2517	3314	2839	3201	8602
Scale1	Incidents on load (L1)	9	2	5	27	157
	Incidents leading to frequency degradation (F1)	7	95	7	13	16
	Incidents on network elements (T1)	35	35	29	24	25
	Incidents on power generating facilities (G1)	1	6	-	3	5
	N-1 violation (ON1)	62	68	69	59	164
	Separation from the grid (RS1)	1	1	1	-	1
	Violation of standards on voltage (OV1)	117	513	392	359	2694
	Reduction of reserve capacity (RRC1)	66	63	74	60	110
	Loss of tools, means and facilities (LT1)	30	32	22	19	88
	Total	328	815	599	564	3260
Scale2	Incidents on load (L2)	1	2	2	2	1
	Incidents leading to frequency degradation (F2)	-	1	-	-	-
	Incidents on network elements (T2)	-	4	1	1	20
	Incidents on power generating facilities (G2)	-	1	-	-	-
	N violation (ON2)	-	1	-	-	4
	Separation from the grid (RS2)	-	6	-	-	-
	Violation of standards on voltage (OV2)	-	-	-	-	2
	Reduction of reserve capacity (RRC2)	-	1	-	-	-
	Loss of tools, means and facilities (LT2)	-	1	-	-	-
	Total	1	17	3	3	27
Scale3	Blackout (OB3)	-	-	-	-	3
	Total	-	-	-	-	3
Grand Total		2846	4146	3441	3768	11892

17. savjetovanje, Neum, 12 - 15.10.2025.

Učestalost incidenata prema uzroku

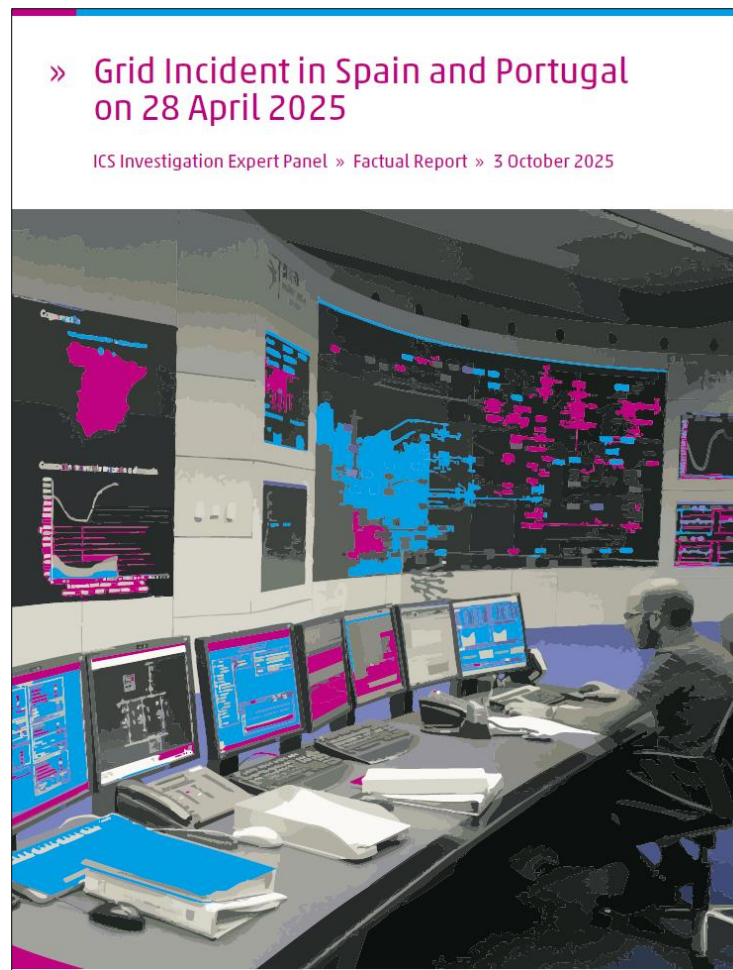
- ICS prati posljedice, uzroke nije jednostavno (ako je uopće moguće) jednoznačno odrediti:
 - vremenske neprilike i drugi prirodni uzroci, te s njima povezane (n-x) situacije
 - više neovisnih tehničkih kvarova koji su se dogodili u kratkom vremenu uzrokujući (n-x) situacije
 - kvar na relejnoj zaštiti ili loše podešenje relejne zaštite
 - ljudska greška
 - prekomjerno dodijeljeni kapaciteti
 - nedovoljna primarna oprema za učinkovito vođenje pogona
 - slabe točke u mreži, npr. koridor Jadran-Crno more ili granica Francuska-Španjolska
 - ...

Zaključak

- Raspadi i „raspadi”
- Objektivna analiza incidenata
- Preporuke za poboljšanja kao ključni ishod analize svakog incidenta
- Nema pravila kad, kako, s kojim uzrocima i s kojim posljedicama će se incident dogoditi

Španjolska/Portugal 28.4.2025.(1)

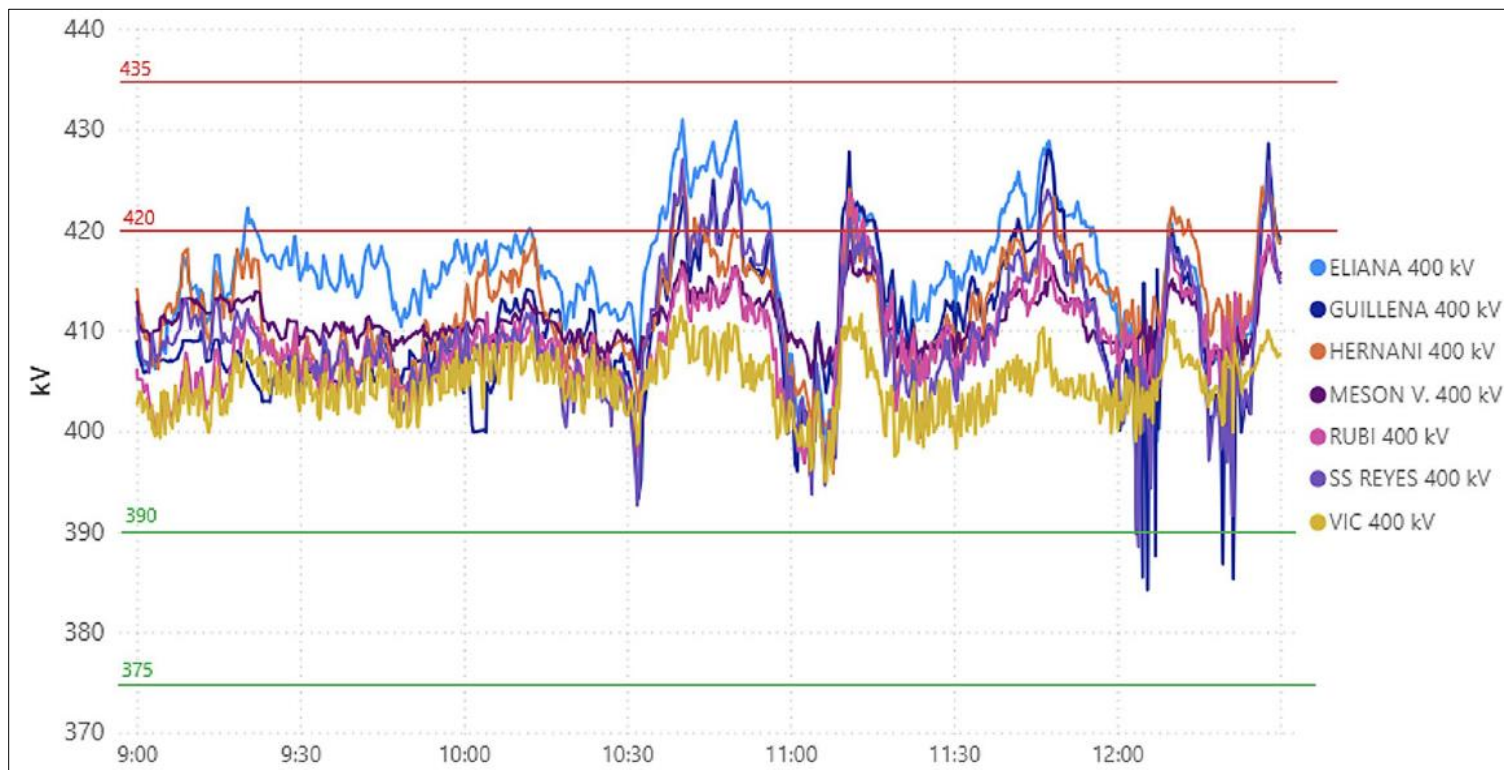
- Objavljeno izvješće o činjenicama vezanim za incident
- Završno izvješće će sadržavati i:
 - Utvrđene uzroke incidenta
 - Regulacija napona
 - Ponašanje/odziv raznih dionika
 - Preporuke
 - ...



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(2)

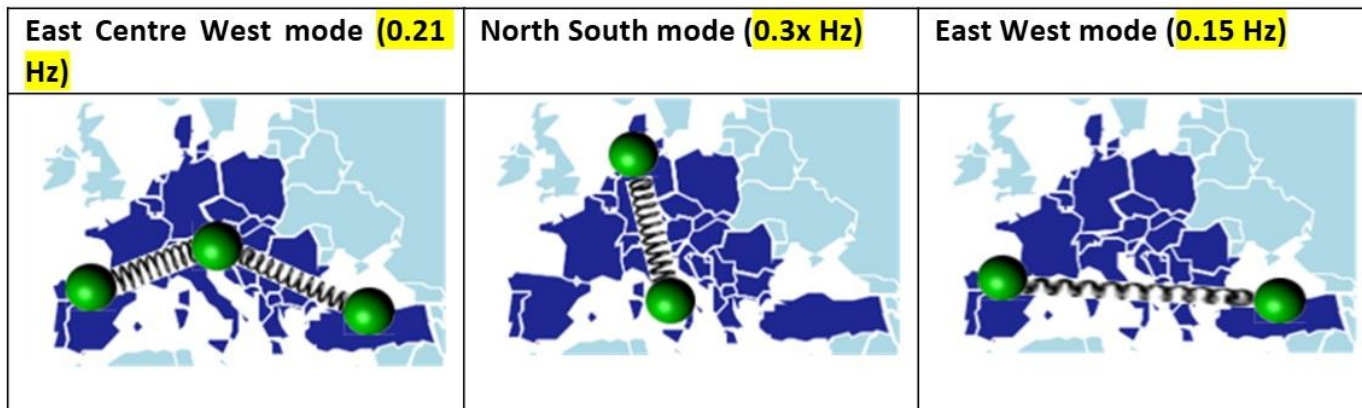
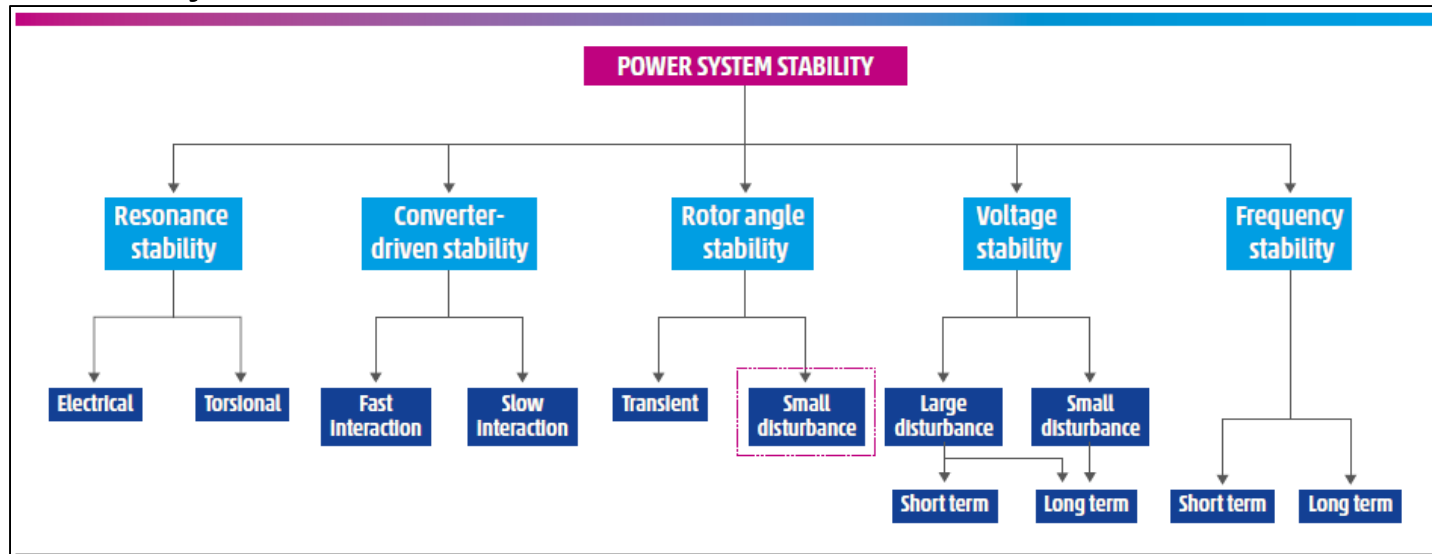
- Potpuni raspad u Španjolskoj i Portugalu, pogođen i mali dio Francuske
- 28.4.2025. 12:32h – 29.4.2025. 04:00h
- Oscilacije napona, tokova, opterećenja: 12:03-12:08 i 12:19-12:22



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(3)

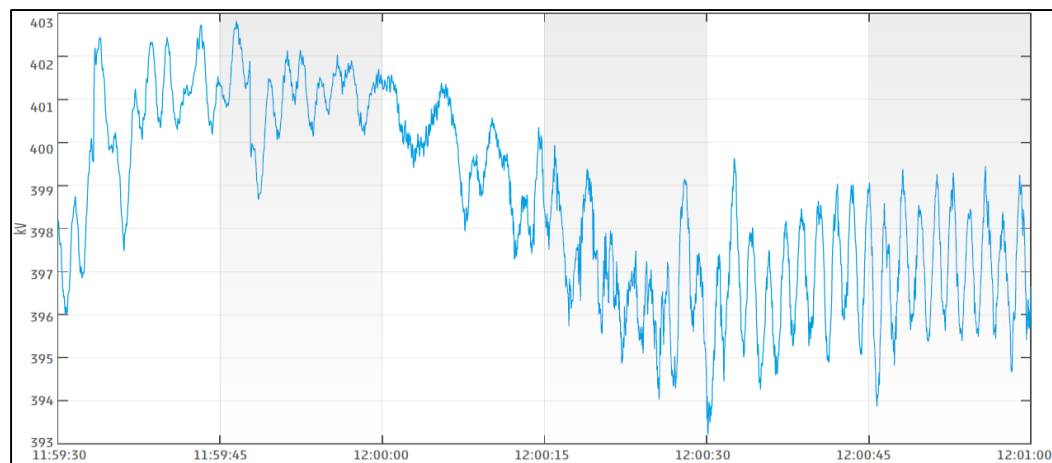
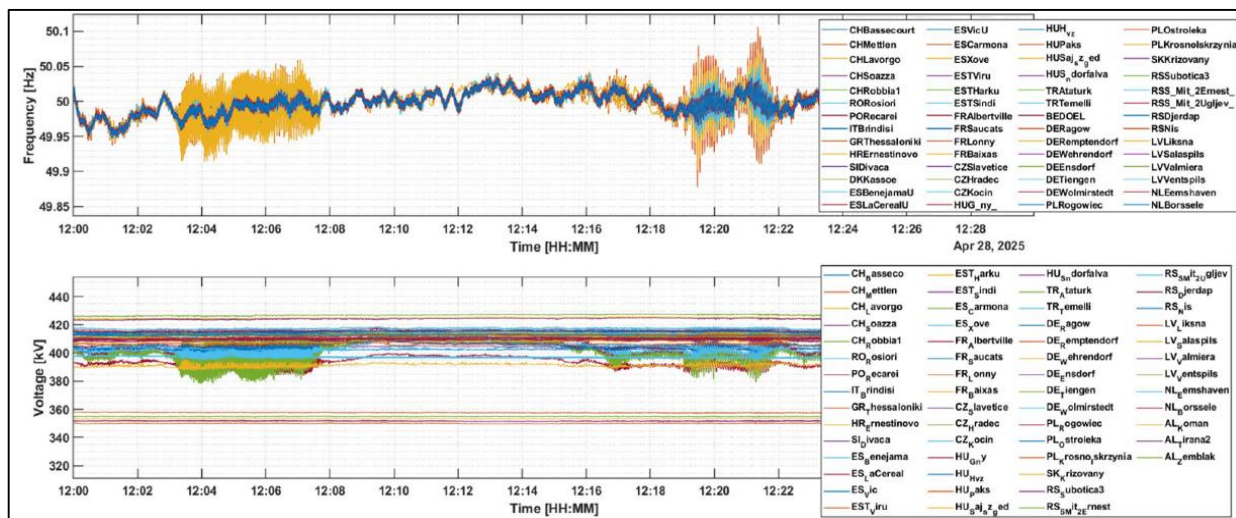
- Oscilacije



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(4)

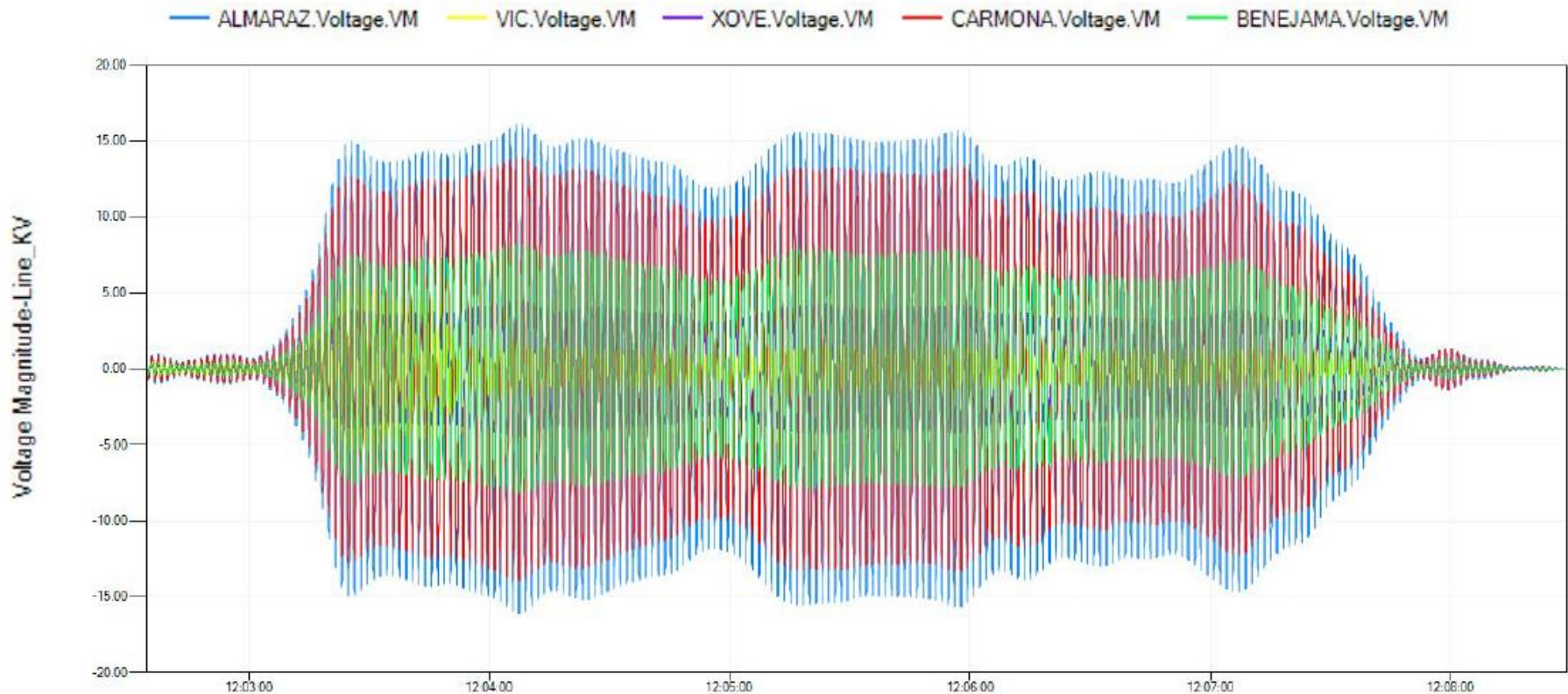
- Oscilacije frekvencije i napona



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(5)

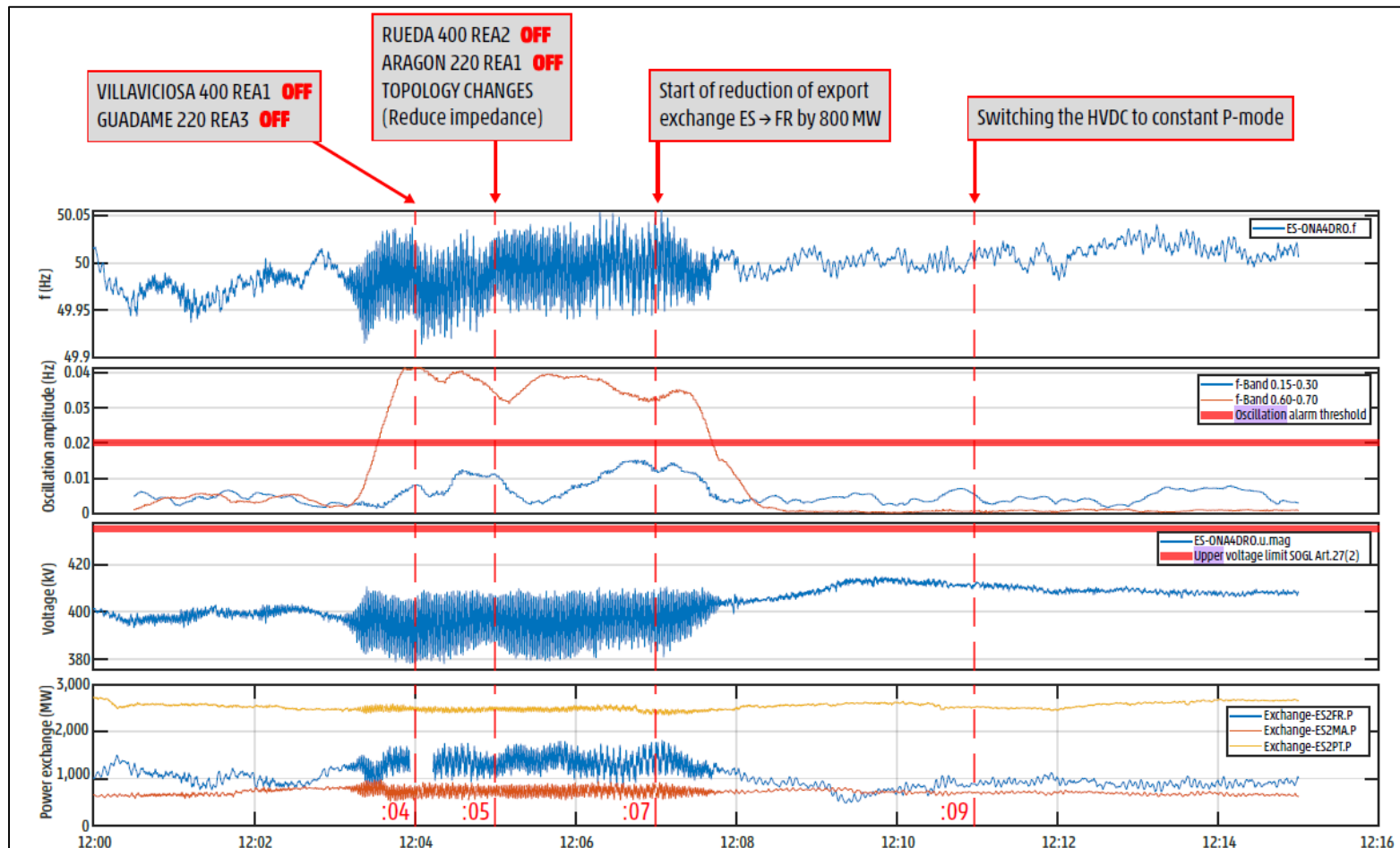
- Stari/novi fenomeni
- Oscilacije



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(6)

- Oscilacije – mjere prigušenja

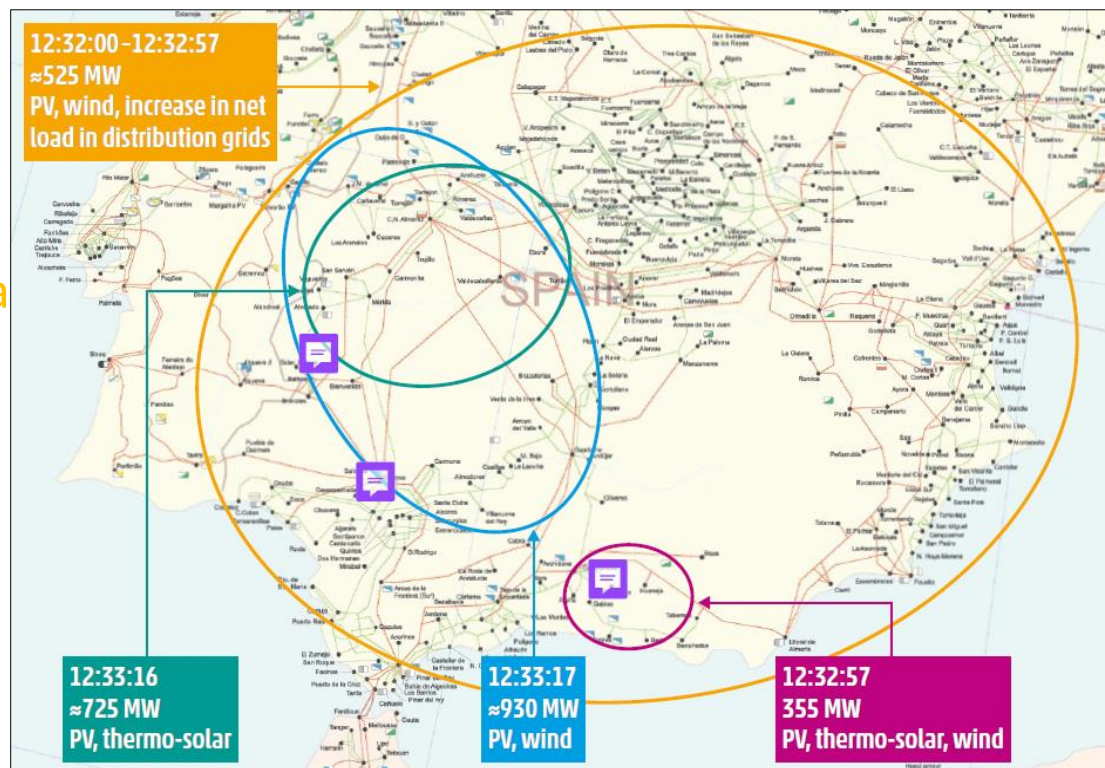


17. savjetovanje, Neum, 12 - 15.10.2025.

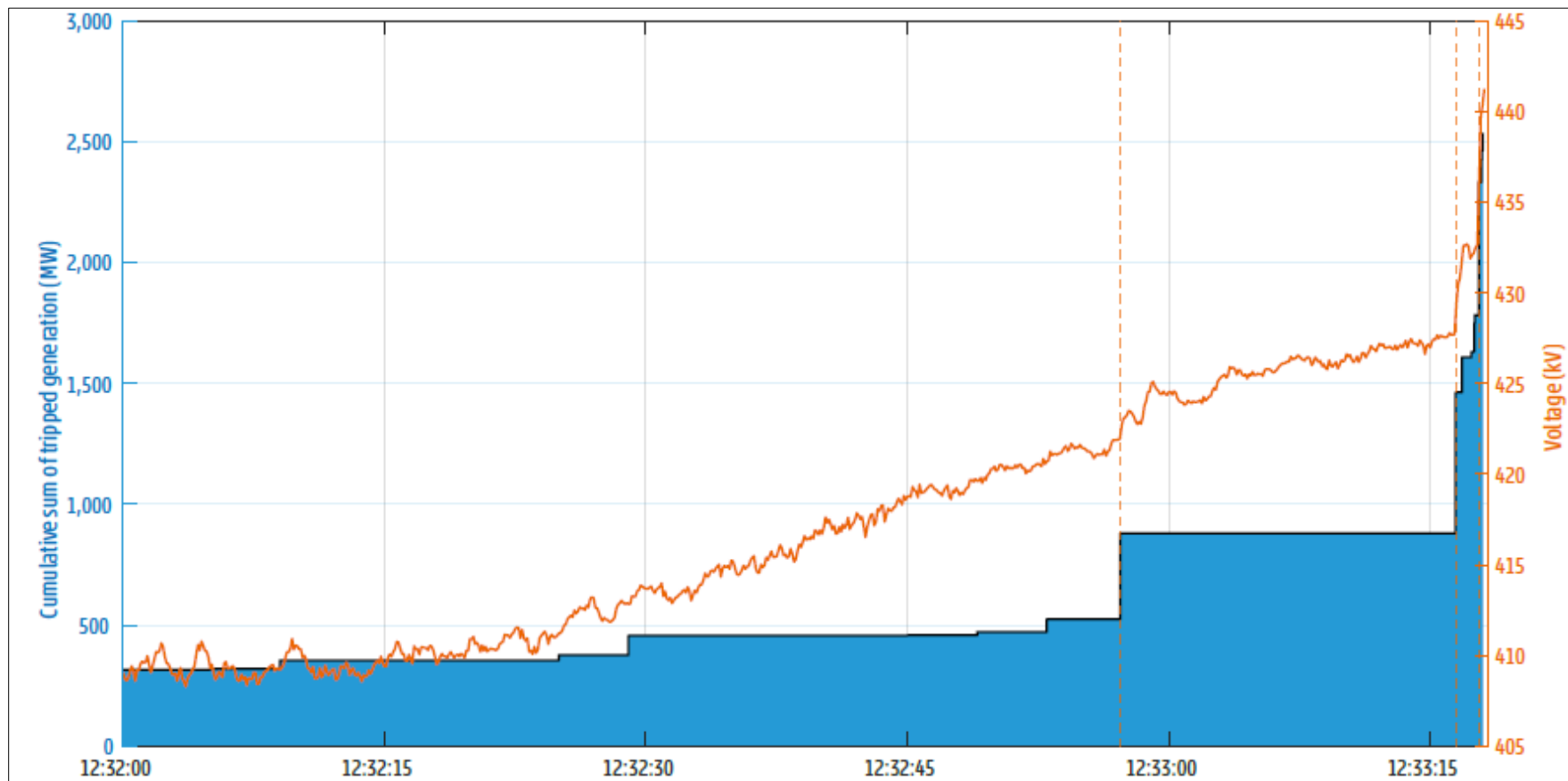
Španjolska/Portugal 28.4.2025.(7)

- Protumjere za smanjenje oscilacija djeluju na povišenje napona:
 - Smanjenje razmjene Španjolska -> Francuska
 - Uključenje dalekovoda koji su bili isključeni kao korektivna protumjera snižavanja napona
- U 12:32:00 bez oscilacija i naponi ispod 420kV

1. Povećanje neto opterećenja
2. Ispad transformatora
3. Nepoznat uzrok
4. Generation trip



Španjolska/Portugal 28.4.2025.(8)

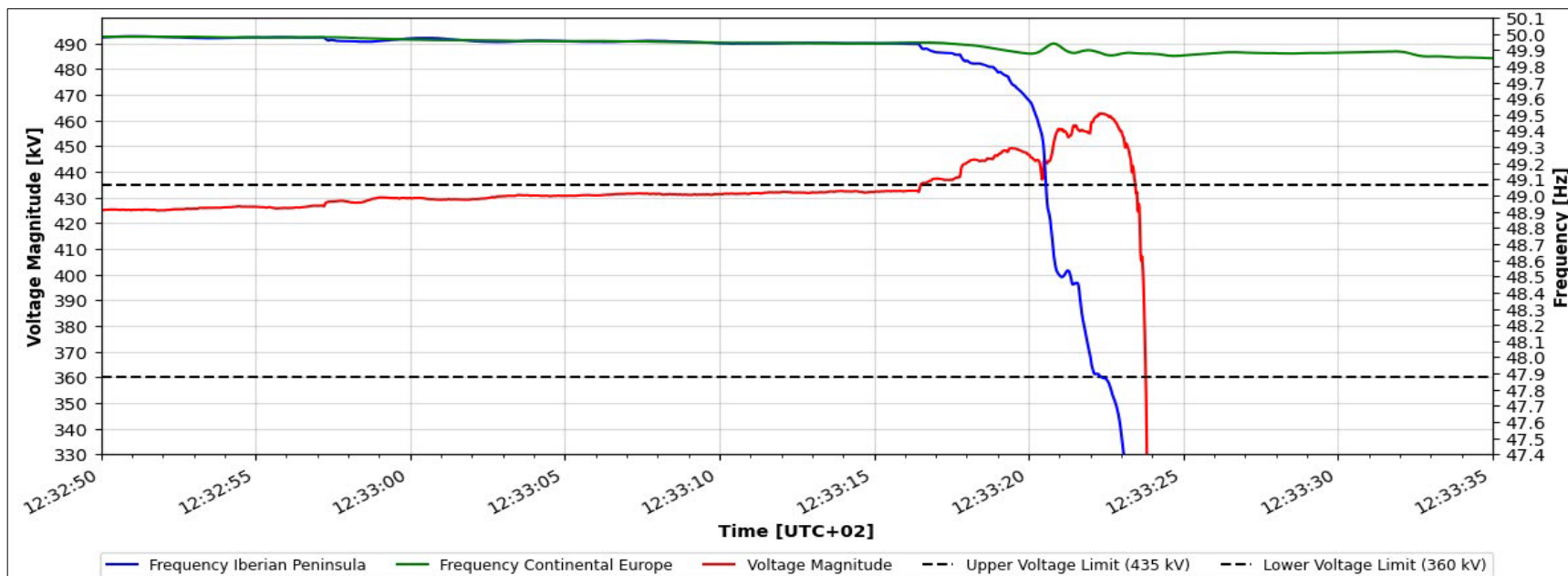


- Kumulativni gubitak opterećenja u Španjolskoj i rast napona u TS Carmona
- Manjak proizvodnje uzrokuje gubitak sinkronizma s ostatkom Europe

17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(9)

- 12:33:18 - Kaskadni ispadi proizvodnje
- 12:33:19 – 12:33:22 - podfrekvencijsko rasterećenje (svih 6 stupnjeva)
- 12:33:20.473 – ispad interkonekcije s Marokom zbog podfrekvencije
- 12:33:21.535 – ispad AC interkonekcije s Francuskom zbog gubitka sinkronizma
- 12:33:23.960 – ispad DC interkonekcije s Francuskom

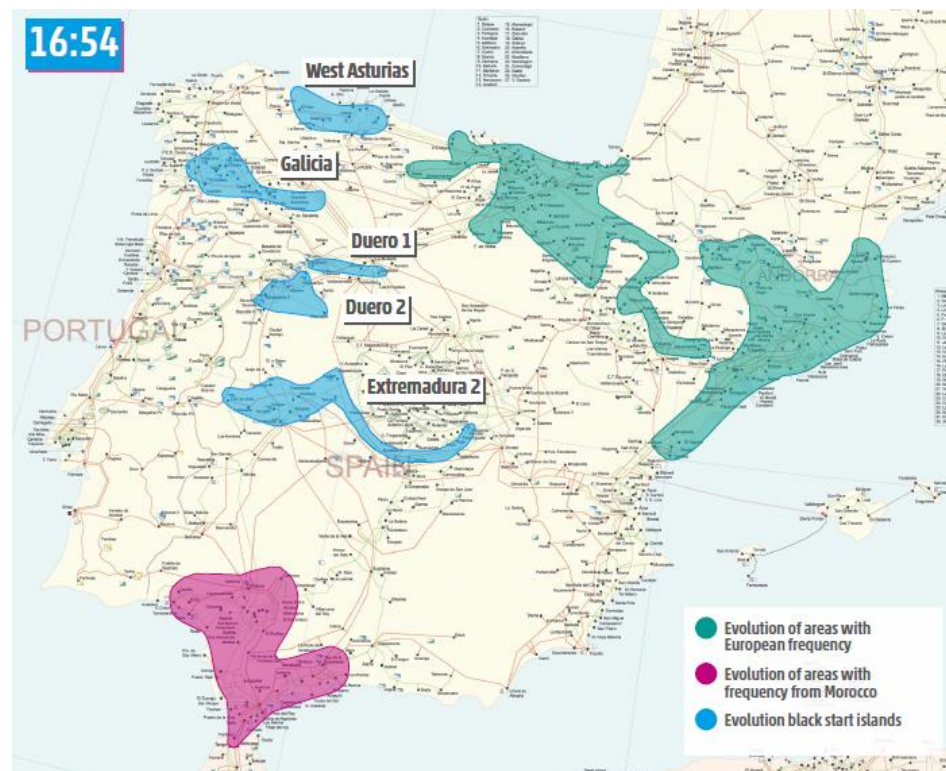
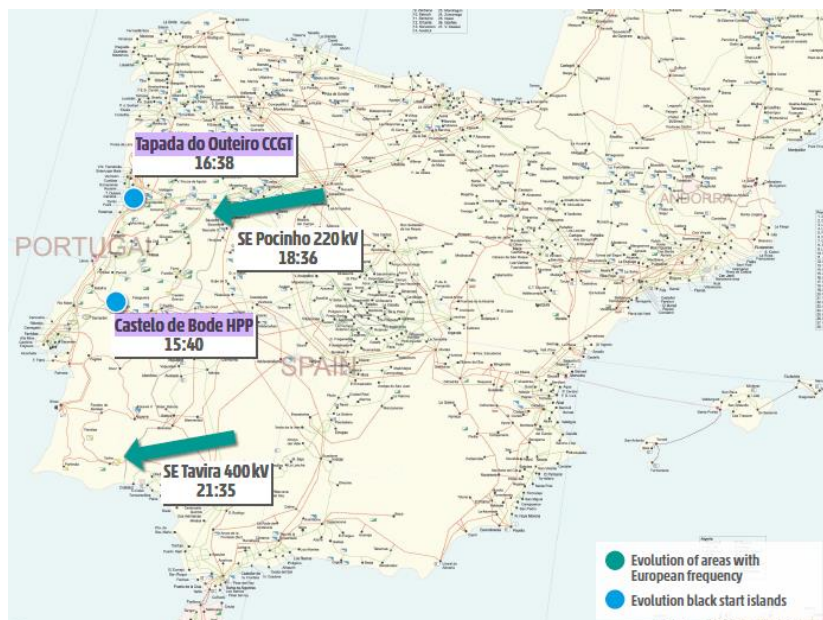


17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(10)

Ponovna uspostava sustava

- Metoda odozgo prema dolje – putem tri pravca
- Odozdo prema gore:
 - 7x2 HE (Španjolska)
 - HE + TE (Portugal)



17. savjetovanje, Neum, 12 - 15.10.2025.

Španjolska/Portugal 28.4.2025.(11)

- Jedna od preporuka nakon incidentaće vjerojatno biti aktivnije praćenje inercije
 - Sustav u kojem su samo sinkrono spojeni generatori

$$H_{eq} = \frac{\sum_i^N H_{gen,i} S_{gen,i}}{\sum_i^N S_{gen,i}}$$

- Sustav u kojem imamo module elektroenergetskih parkova (spojeni preko invertera)

$$H_{eq} = \frac{\sum_i^N H_{gen,i} \times S_{gen,i} + \sum_j^N 0 \times S_{inverters,j}}{\sum_i^N S_{gen,i} + \sum_j^M S_{inverters,j}} = \frac{\sum_i^N H_{gen,i} \times S_{gen,i}}{\sum_i^N S_{gen,i} + \sum_j^M S_{inverters,j}}$$

Hvala na pažnji

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17. savjetovanje, Neum, 12 - 15.10.2025.