Partial Blackout of the Balkans 21st of June 2024

entsoe

Reliable Sustainable Connected

Overview

June 21, 2024 at approximately 12:20 CET

Blackout in Albania, Montenegro, Bosnia and Herzegovina and parts of Croatia

Power restored within approximately 3 hours

General cause, voltage collapse following multiple trips

Involvement of Swissgrid

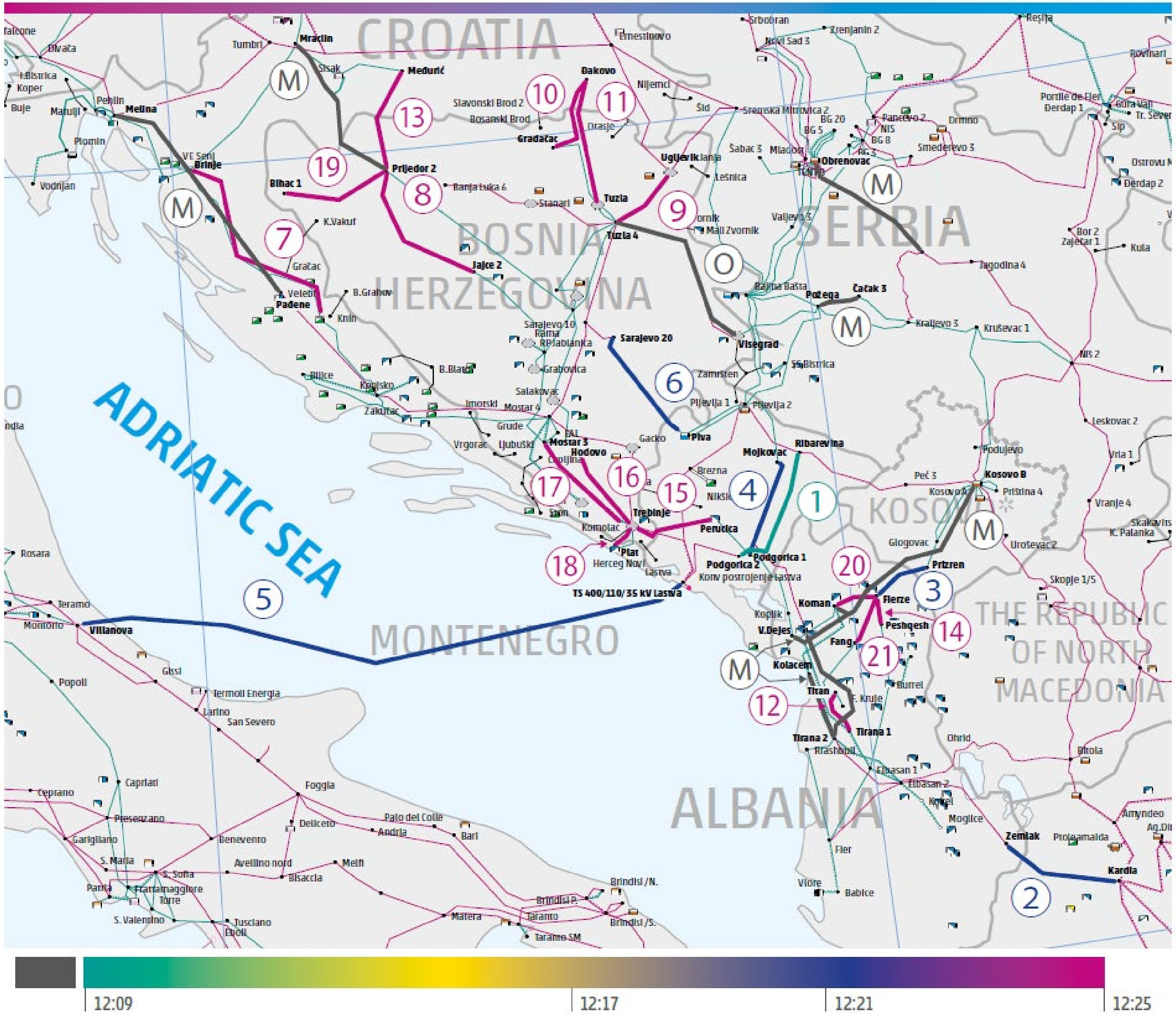
The black out of the Balkans was categorized as ICS Scale 3

- Events of an ICS Scale 2 or 3 require an official investigation of ENTSO-E
- The investigation was led by Bastien Grand (Swissgrid) and Bernard Malfliet (Elia)
- The Technical Analysis was led by Agnes Linnet (Swissgrid)

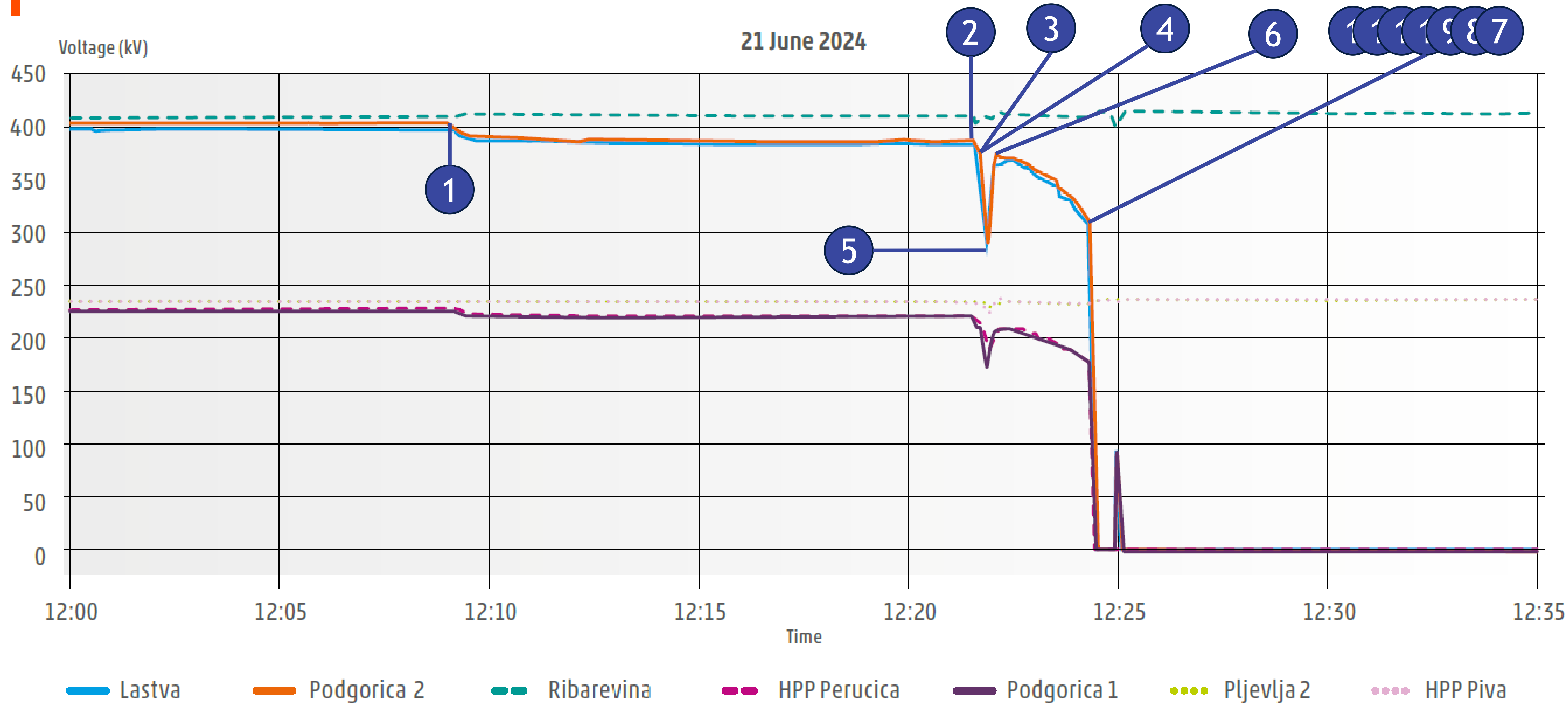
Scale 0 Noteworthy incident		Scale 1 Significant incident		Scale 2 Extensive incident		Scale 3 Major incident / 1TSO	
Priority / Short definition (Criterion short code)		Priority / Short definition (Criterion short code)		Priority / Short definition (Criterion short code)		Priority / Short definition (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)		

ICS methodology can be accessed here.

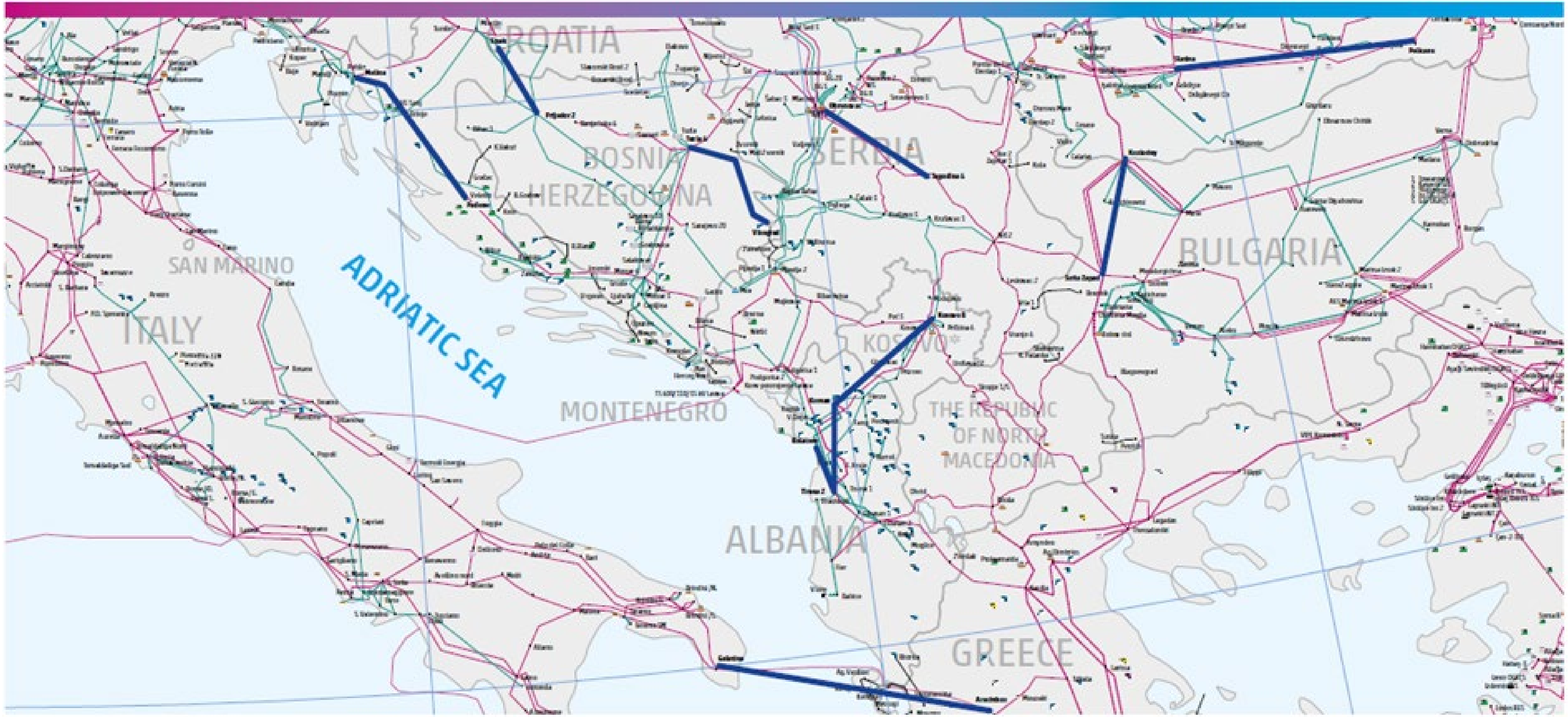
Factual Sequence of Events



Voltage evolution in CGES network on the 400 kV and 220 kV levels



System and Market conditions before the incident



entsoe

System and Market conditions before the incident

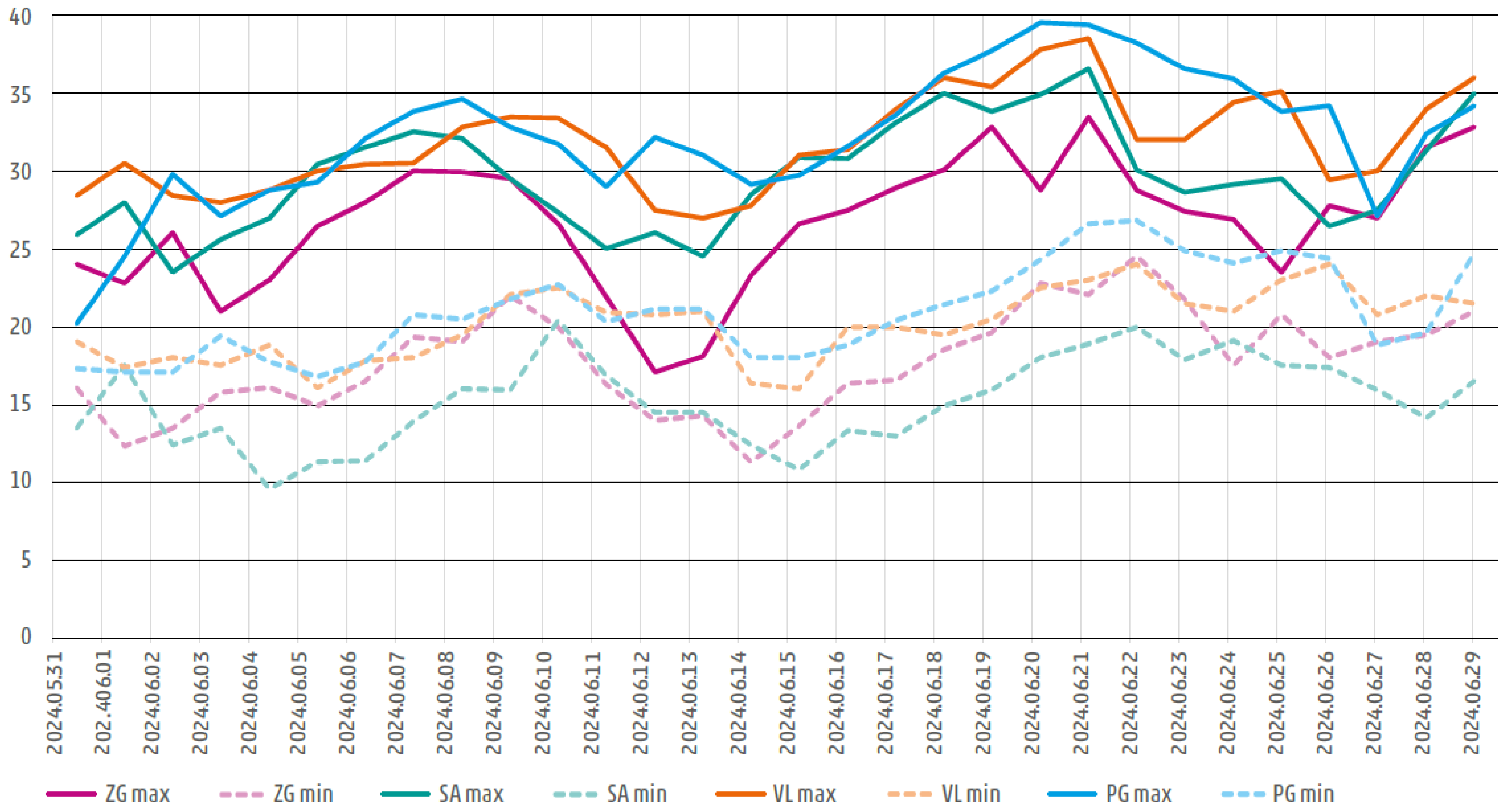


Figure 3: Maximal and minimal daily temperatures during June 2024 in Zagreb (HR), Sarajevo (BA), Podgorica (ME) and Vlore (AL)

System and Market conditions before the incident

Figure 16: Cross-Border physical flows for 12th hour, 21 June 2024 (bold) and corresponding unscheduled loop-flows (underlined) in MW

System and Market conditions before the incident

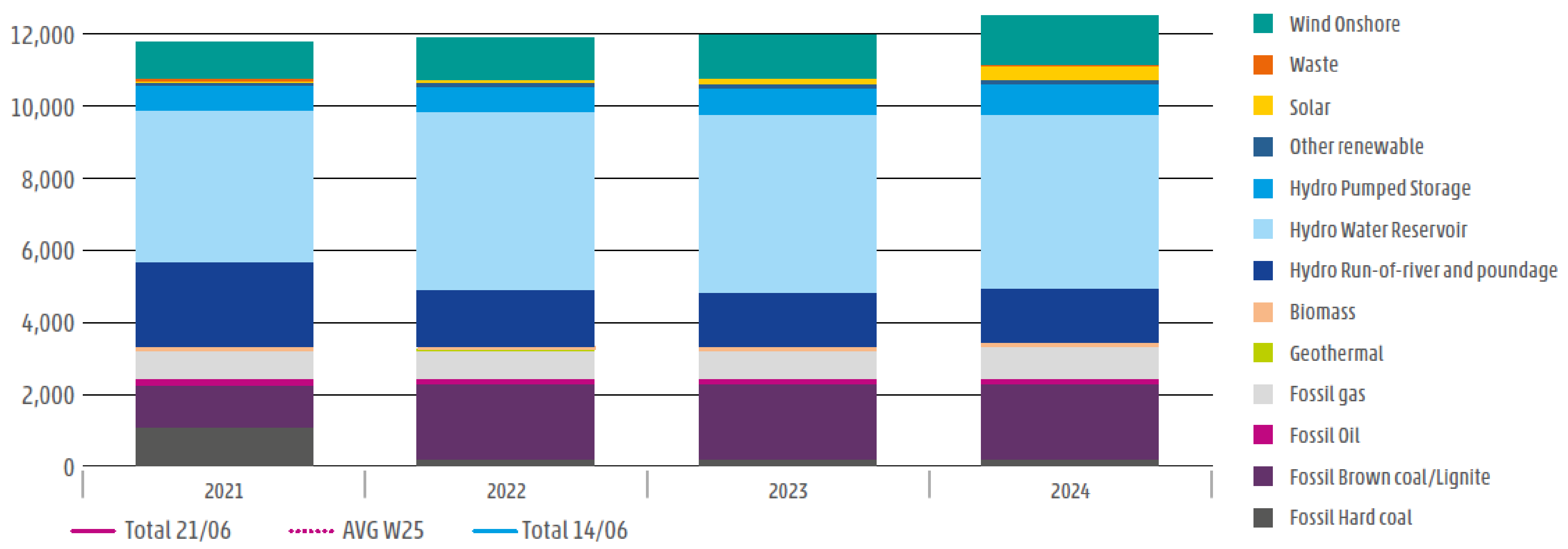


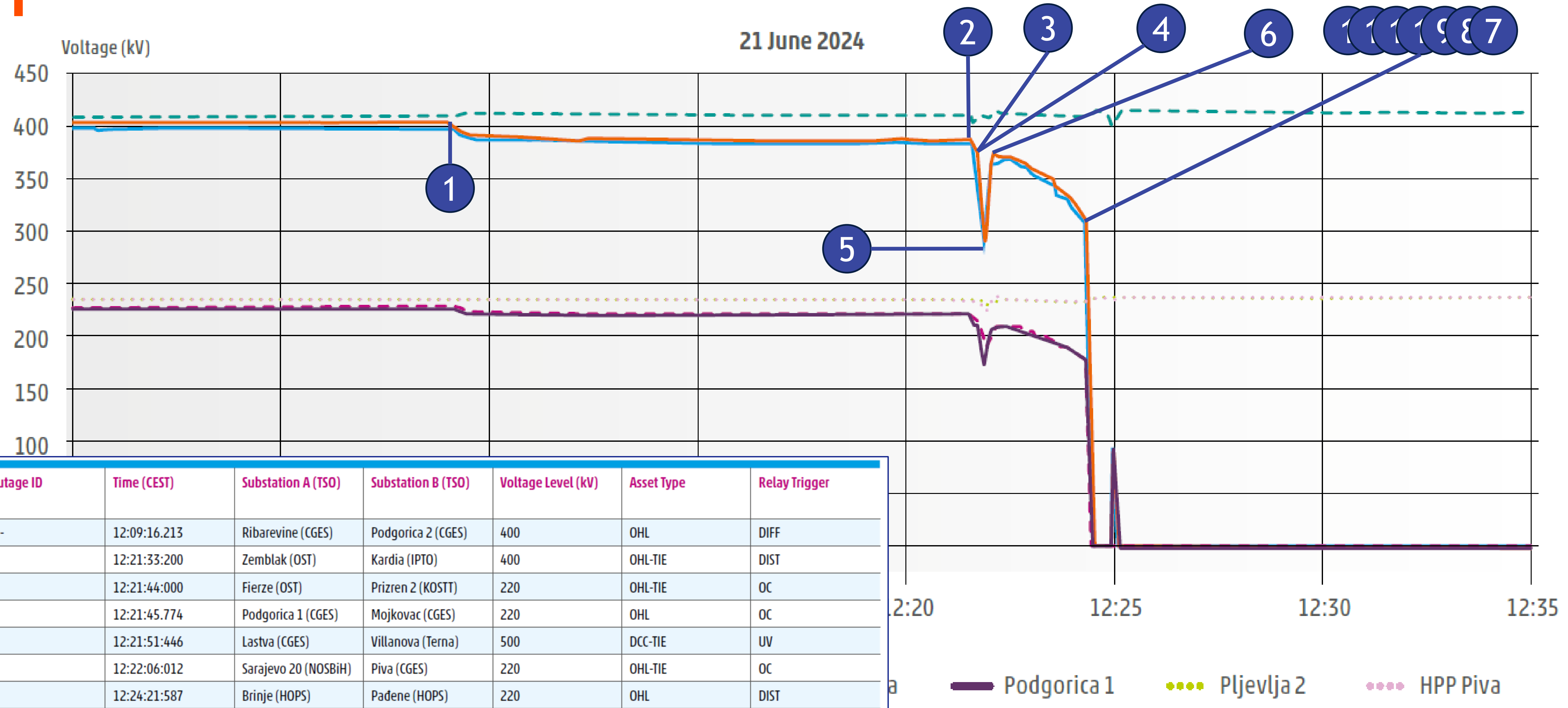
Figure 11: Generation structure of the affected systems during the past years.

Factual Sequence of Events

Outage ID	Time (CEST)	Substation A (TSO)	Substation B (TSO)	Voltage Level (kV)	Asset Type	Relay Trigger
1--	12:09:16.213	Ribarevine (CGES)	Podgorica 2 (CGES)	400	OHL	DIFF
2	12:21:33:200	Zemblak (OST)	Kardia (IPTO)	400	OHL-TIE	DIST
3	12:21:44:000	Fierze (OST)	Prizren 2 (KOSTT)	220	OHL-TIE	OC
4	12:21:45.774	Podgorica 1 (CGES)	Mojkovac (CGES)	220	OHL	OC
5	12:21:51:446	Lastva (CGES)	Villanova (Terna)	500	DCC-TIE	UV
6	12:22:06:012	Sarajevo 20 (NOSBiH)	Piva (CGES)	220	OHL-TIE	OC
7	12:24:21:587	Brinje (HOPS)	Pađene (HOPS)	220	OHL	DIST
8	12:24:22:341	Prijedor 2 (NOSBiH)	Jajce 2 (NOSBiH)	220	OHL	OC
9	12:24:22:350	Ugljevik (NOSBiH)	Tuzla 4 (NOSBiH)	400	OHL	OC
10*	12:24:22:959	Đakovo (HOPS)	Gradačac (NOSBiH)	220	OHL-TIE	UV
11*	12:24:22:959	Đakovo (HOPS)	TPP Tuzla (NOSBiH)	220	OHL-TIE	UV
12	12:24:23:000	Titan (OST)	Tirana 1 (OST)	220	OHL	DIST
13	12:24:23:089	Međurić (HOPS)	Prijedor 2 (NOSBiH)	220	OHL-TIE	DIST
14	12:24:24:000	Fierze (OST)	Peshqesh (OST)	220	OHL	MAN
15	12:24:26:558	Trebinje (NOSBiH)	Perucica (CGES)	220	OHL-TIE	UV
16	12:24:26:579	Trebinje (NOSBiH)	Hodovo (NOSBiH)	220	OHL	UV
17	12:24:26:583	Trebinje (NOSBiH)	Mostar 3 (NOSBiH)	220	OHL	UV
18	12:24:26:593	Trebinje (NOSBiH)	Plat (HOPS)	220	OHL-TIE	UV
19	12:24:27:694	Prijedor 2 (NOSBiH)	Bihac 1 (NOSBiH)	220	OHL	DIST
20	12:24:28:000	Fierze (OST)	Koman (OST)	220	OHL	MAN
21	12:24:28:000	Fierze (OST)	Fang (OST)	220	OHL	OC

Definition of Abbreviations	
CGES	TSO of Montenegro
OST	TSO of Albania
NOSBiH	TSO of Bosnia and Herzegovina
HOPS	TSO of Croatia
IPSO	TSO of Greece
Terna	TSO of Italy
KOSTT	TSO of Kosovo
OHL	Overhead line
OHL-TIE	Inter-TSO overhead line
DCC	Direct Current Connection
DIFF	Differential protection
DIST	Distance protection
OC	Overcurrent protection
UV	Undervoltage protection

Voltage evolution in CGES network on the 400 kV and 220 kV levels



Outage ID	Time (CEST)	Substation A (TSO)	Substation B (TSO)	Voltage Level (kV)	Asset Type	Relay Trigger
1--	12:09:16.213	Ribarevine (CGES)	Podgorica 2 (CGES)	400	OHL	DIFF
2	12:21:33:200	Zemblak (OST)	Kardia (IPTO)	400	OHL-TIE	DIST
3	12:21:44:000	Fierze (OST)	Prizren 2 (KOSTT)	220	OHL-TIE	OC
4	12:21:45.774	Podgorica 1 (CGES)	Mojkovac (CGES)	220	OHL	OC
5	12:21:51:446	Lastva (CGES)	Villanova (Terna)	500	DCC-TIE	UV
6	12:22:06:012	Sarajevo 20 (NOSBiH)	Piva (CGES)	220	OHL-TIE	OC
7	12:24:21:587	Brinje (HOPS)	Pađene (HOPS)	220	OHL	DIST
8	12:24:22:341	Prijedor 2 (NOSBiH)	Jajce 2 (NOSBiH)	220	OHL	OC
9	12:24:22:350	Ugljevik (NOSBiH)	Tuzla 4 (NOSBiH)	400	OHL	OC
10*	12:24:22:959	Đakovo (HOPS)	Gradačac (NOSBiH)	220	OHL-TIE	UV

Loss of Load

- 1102 MW for Albania (97%*)
- 1500 MW for Bosnia and Herzegovina (100%*)
- 709 MW for Croatia (26%*)
- 338 MW for Montenegro (72%*)

Total of approximately 3650 MW - restoration around 15:15

*of the demand before the incident

ENTSO-E Awareness System (EAS)

HOPS:

- » 12:28:06 – Alert State – “07 Critical Event”
- » 12:39:47 – Emergency State
- » 12:57:56 – Restoration State
- » 14:50:03 – Alert State
- » 15:03:10 – Normal state

NOSBiH:

- » 12:36:15 – Black Out State – “07 Critical Event”
- » 12:53:07 – Restoration State
- » 14:29:38 – Alert State – “01 N-1 Violation”
- » 15:09:49 – Normal state

OST:

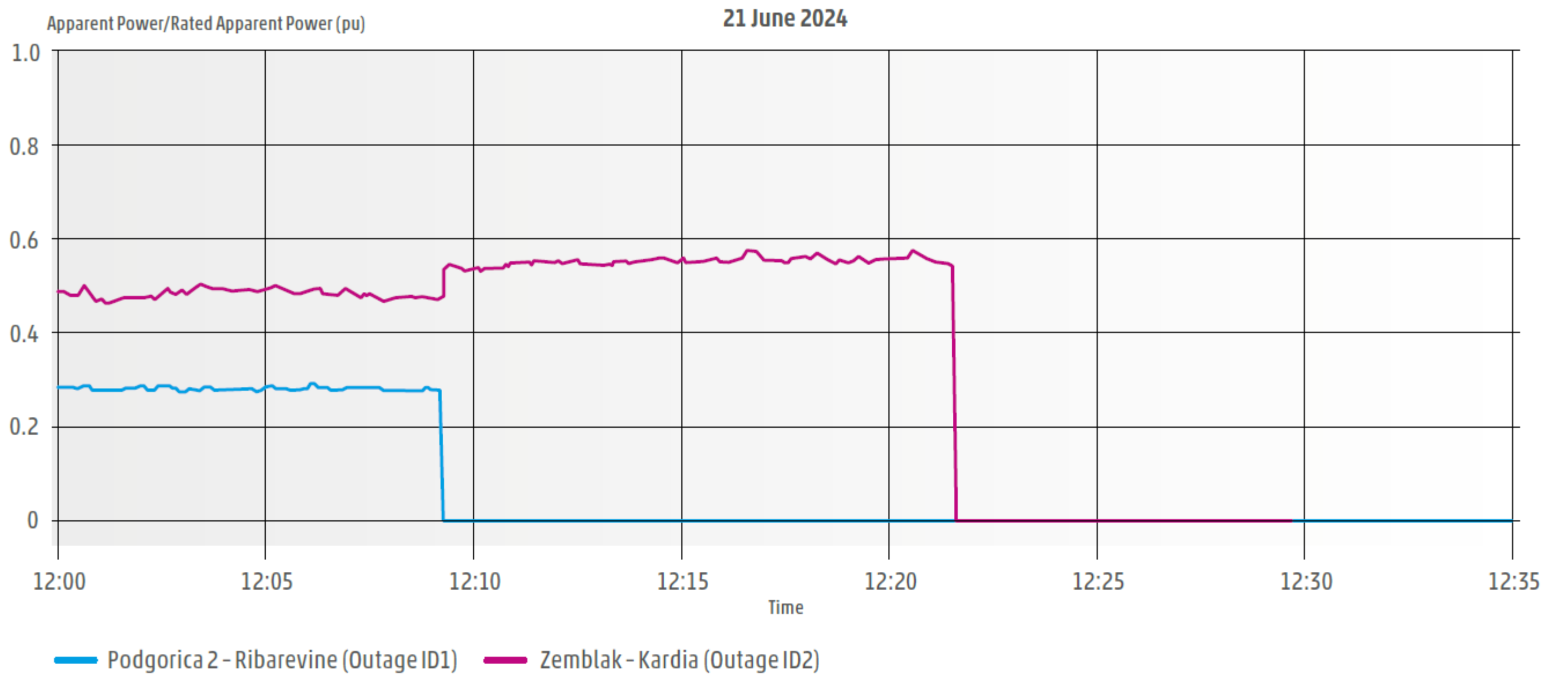
- » 12:38:07 – Black Out State – “07 Critical Event”
- » 12:48:05 – Restoration State
- » 13:08:48 – Alert State – Frequency Degradation
- » 13:11:48 – Alert State – “01 N-1 Violation”
- » 15:03:29 – Normal state

CGES:

- » 13:08:51 – Restoration state – “07 Critical Event”
- » 15:37:53 – Normal state

Root Cause 1: Vegetation higher than expected

Picture of the area of the short circuit -TIE 400 kV Zemlak - Kardia



Root Cause 2: Overloads not detected/Calculated

- The real-time calculations performed between the first and second outage did not reveal any N-1 violations in the area, although subsequent analysis and the facts show that there were N-1 violations in the grid.

- Due to the status of the real-time observability area and despite the recurrency of the automatic real time N-1 calculation (every 15 minutes) it was not possible to see that the grid wasn’t secure after the trip of the OHL 400 kV Podgorica – Ribarevina.

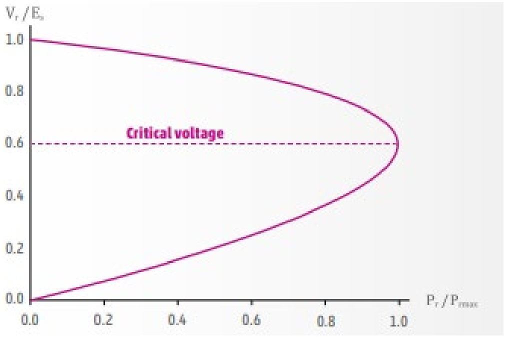
- Furthermore, the contingency list of some TSOs didn't include the external contingency, that didn't allow them to assess the consequences of the second trip on the grid.

Root Cause 3: Potential instability not detected/calculated

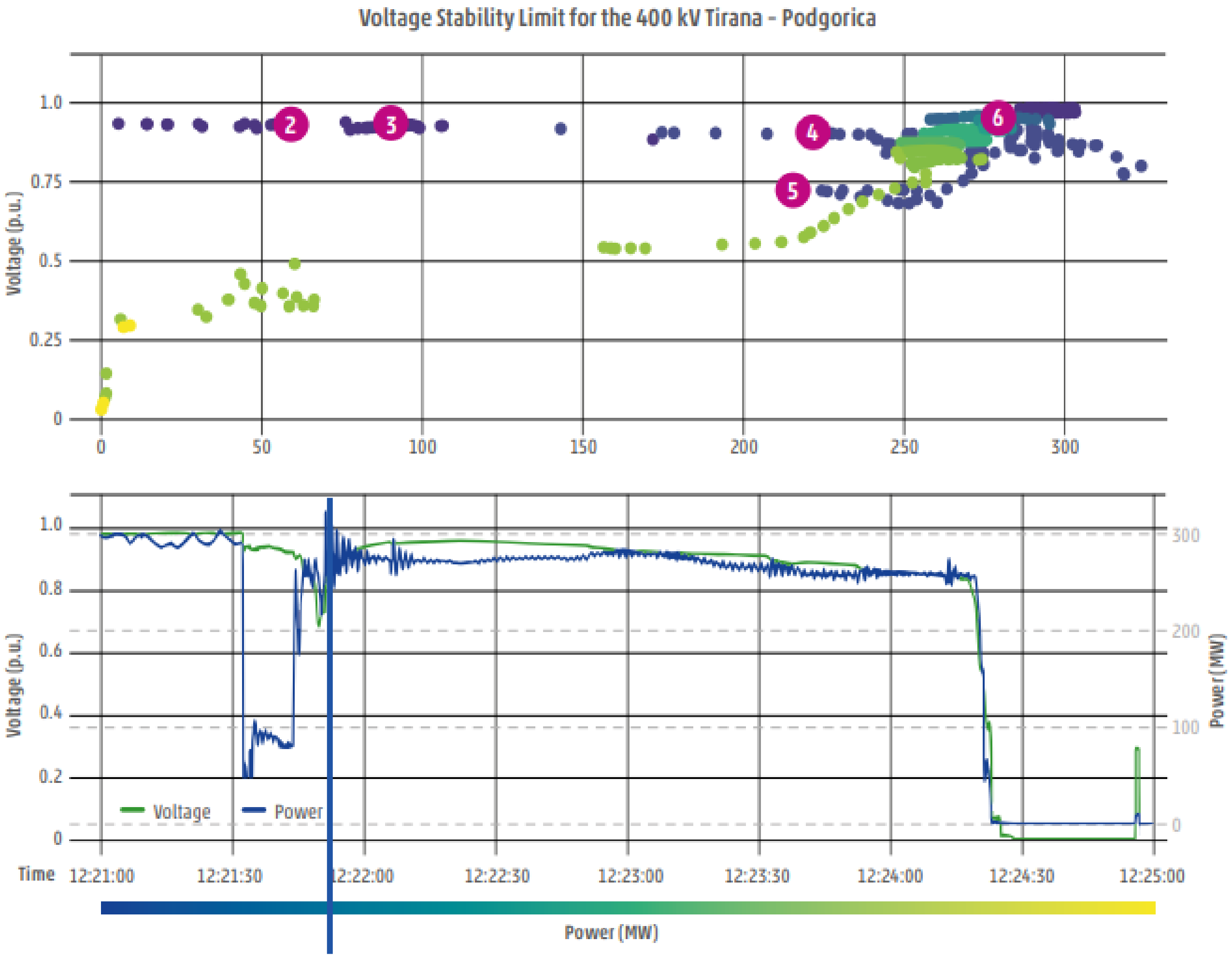
- The available and existing tools, were by design not able to detect any risk of voltage instability
- The situation was not considered abnormal nor requiring any urgent action. Voltages were regarded as normal and even better than usual as they were below 420 kV, as this region is typically struggling with very high voltages
- Post analysis, however, showed that the system encountered voltage instability after Event 4 or approximately two minutes before the voltage collapse

Root Cause 3: Potential instability not detected/calculated

- Each power can be transmitted at a two different voltage levels, one is stable and the other one is unstable.
  - This can be depicted by the so-called PV curve

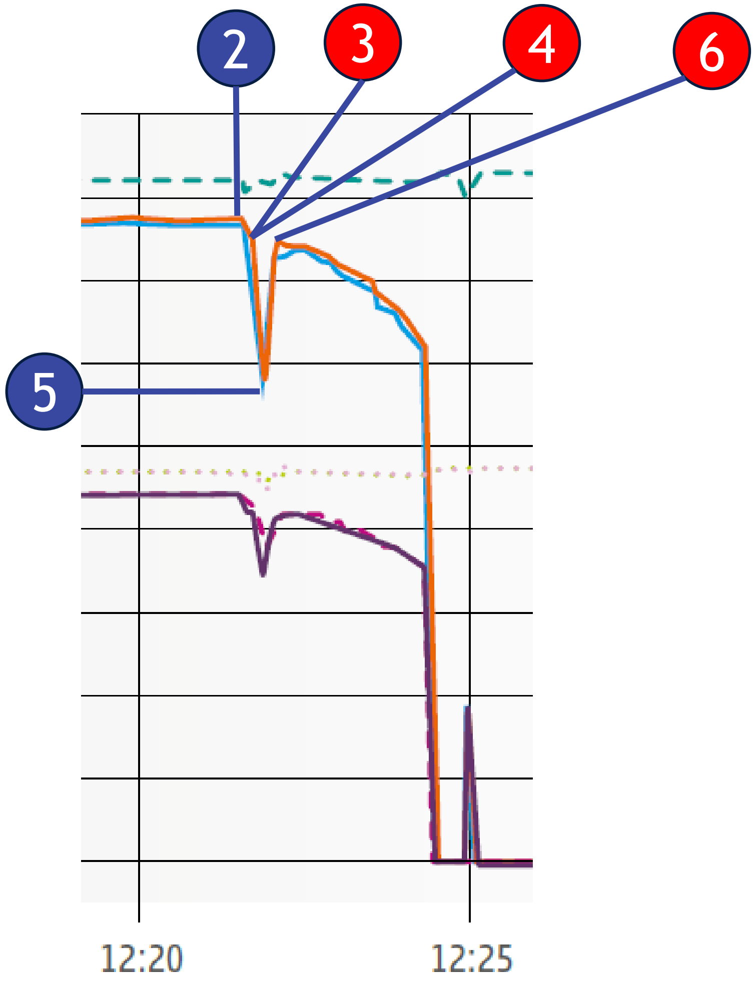


  - By plotting the active power over the voltage for the line 400 kV Tirana – Podgorica we can see that we were below the critical voltage after event 4 and before event 5



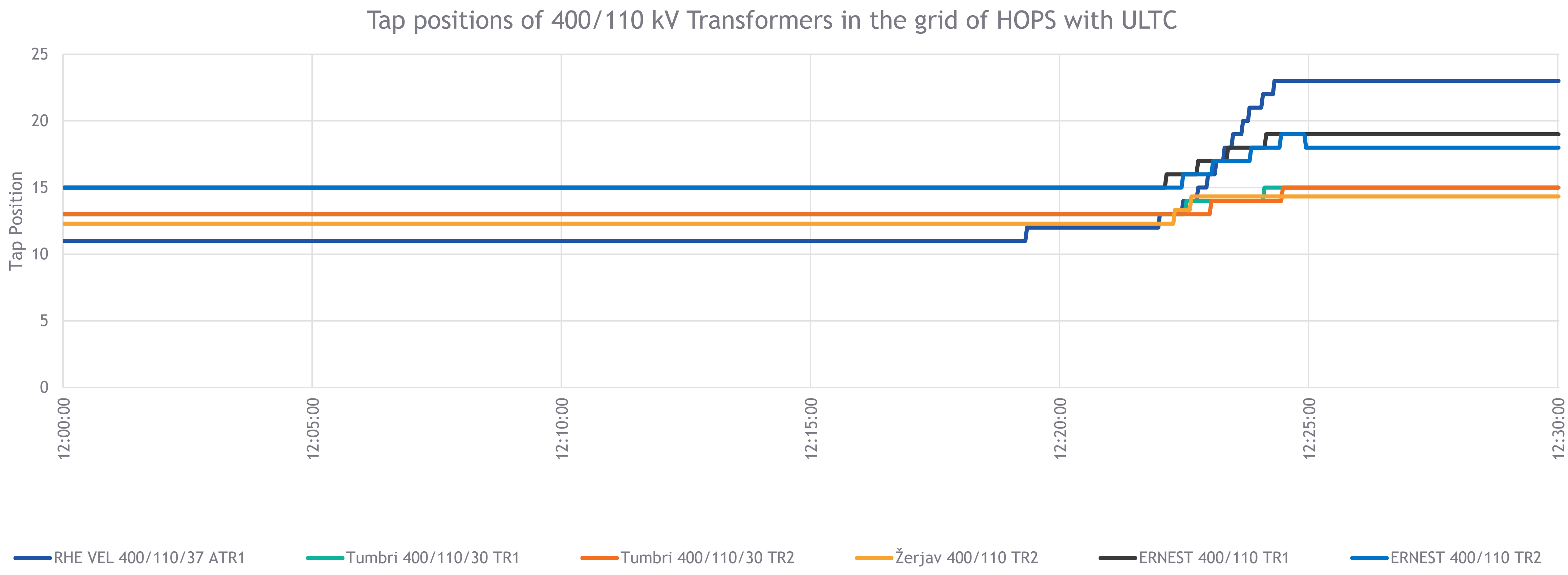
System not stable anymore

Root Cause 4: Overload protections activated

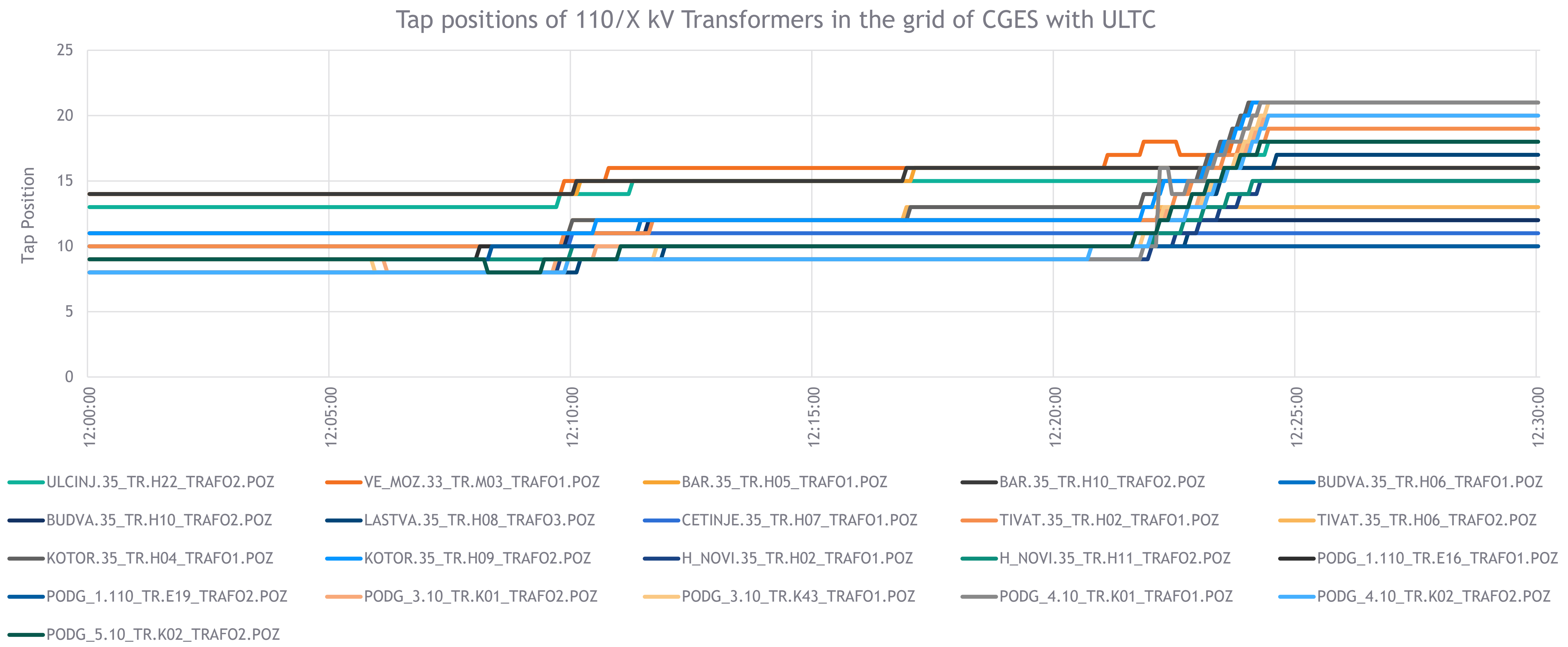


- Subsequent to the second outage several overloads occurred in the grid and 3 lines were disconnected by an overload protection.
- These protections acted within seconds and did not allow for any action to be taken by the dispatchers to reduce the flows in the grid.
- The analysis revealed a very quick (within 31.5 seconds) cascading trip of three lines caused by overcurrents (around 120-130 %) and due to a short time delay setting of the protection.

Root Cause 5: Tap changing transformers reaction (1)

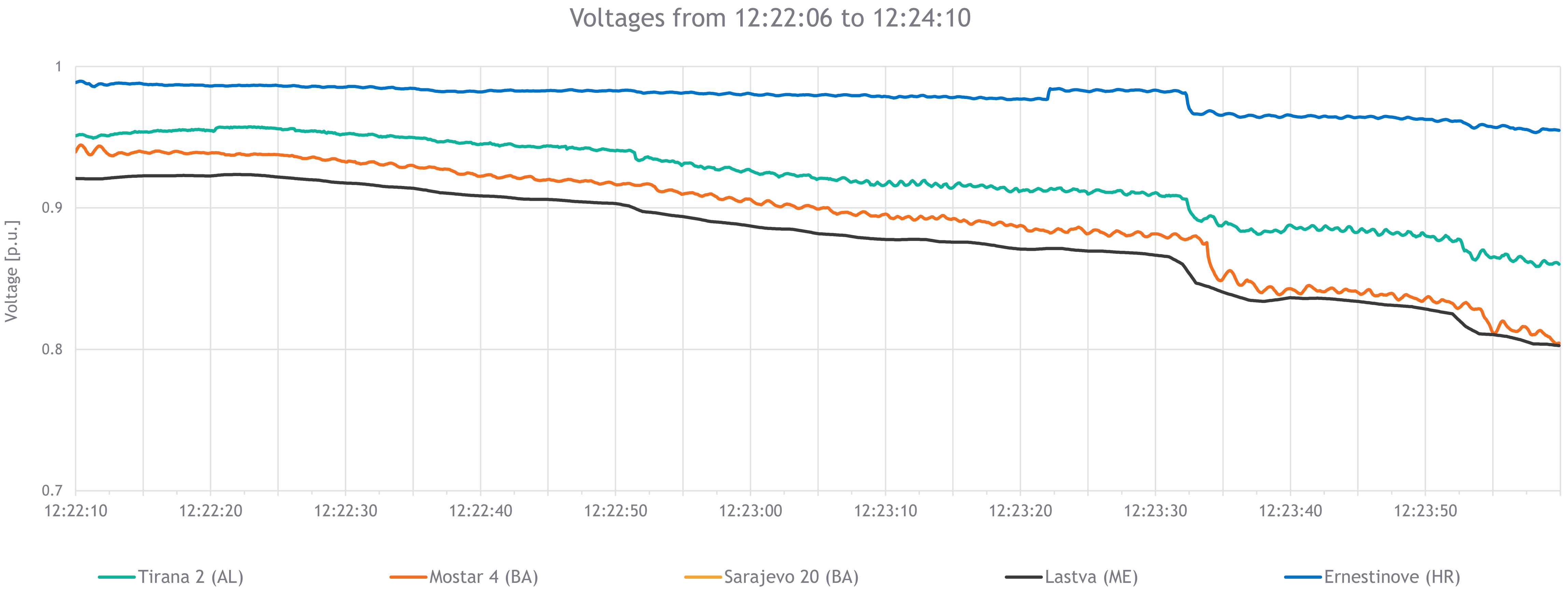


Root Cause 5: Tap changing transformers reaction (1)



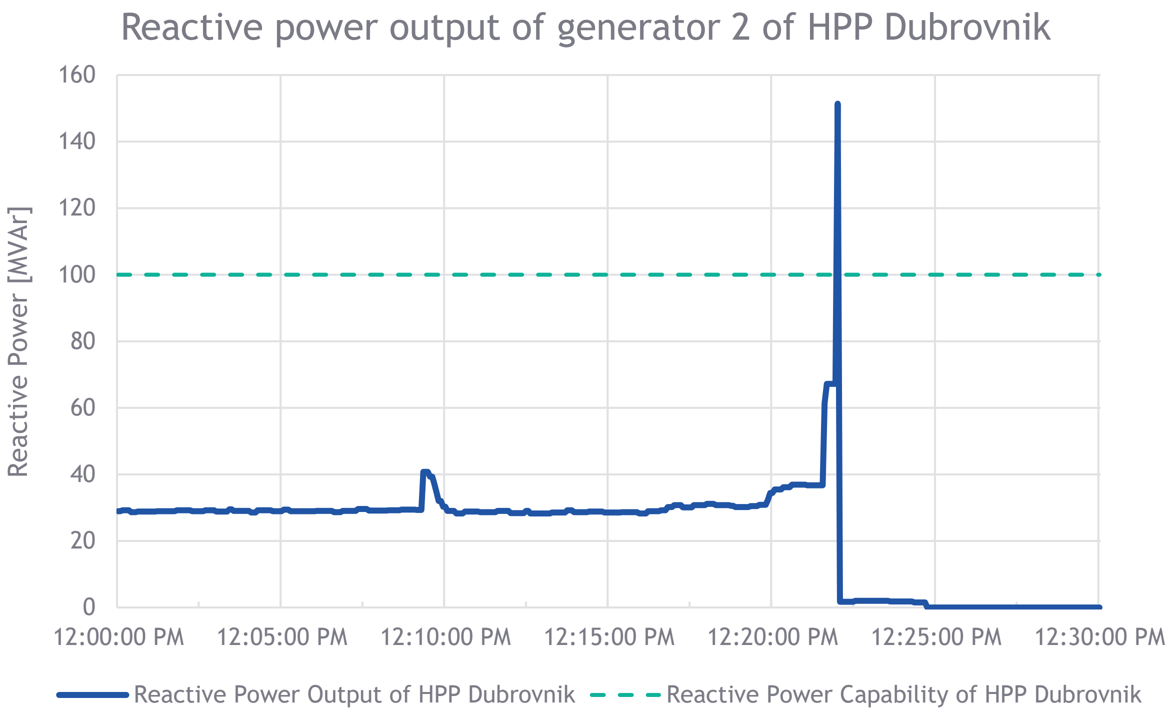
entsoe

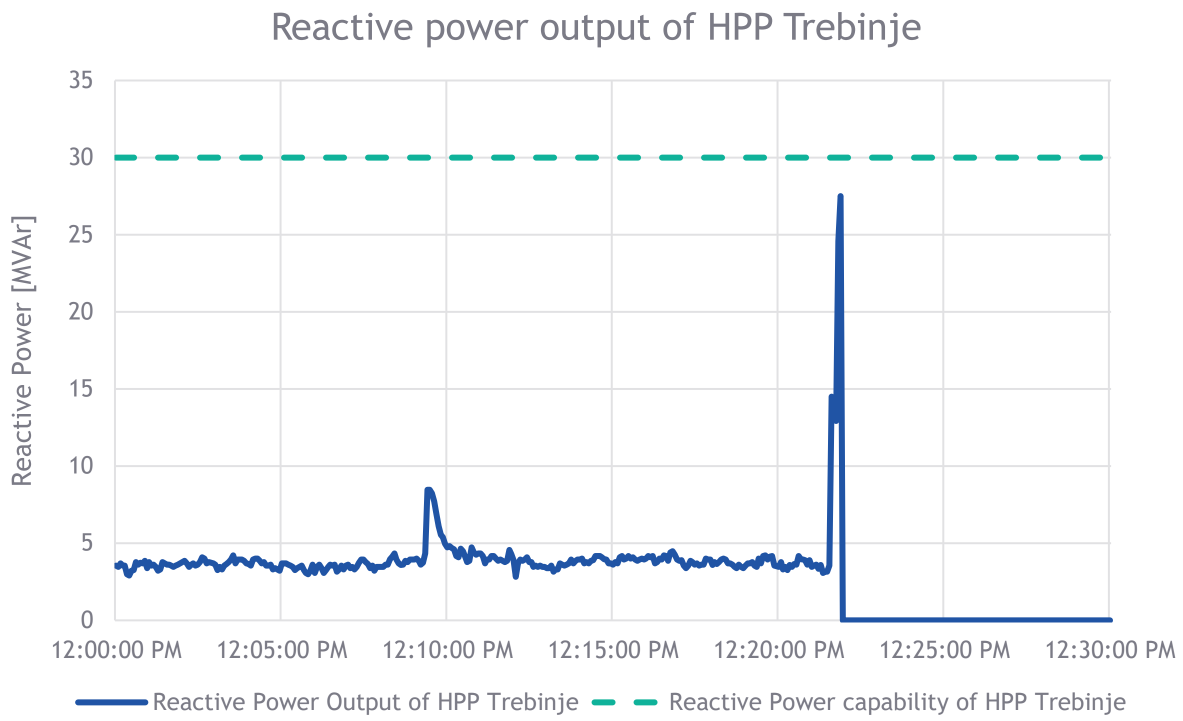
Root Cause 5: Tap changing transformers reaction (2)



Root Cause 6: Insufficient other sources of MVAr

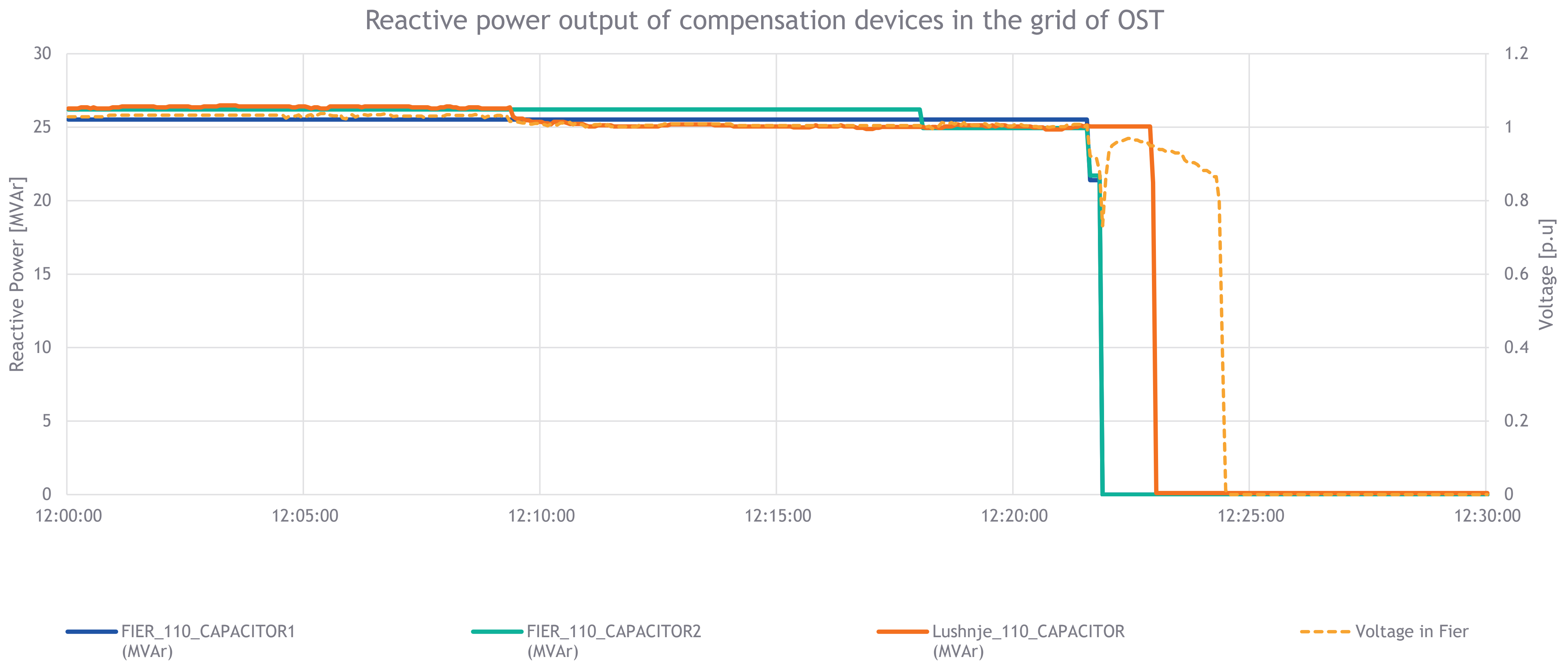
Reactive power support of generators during the incident



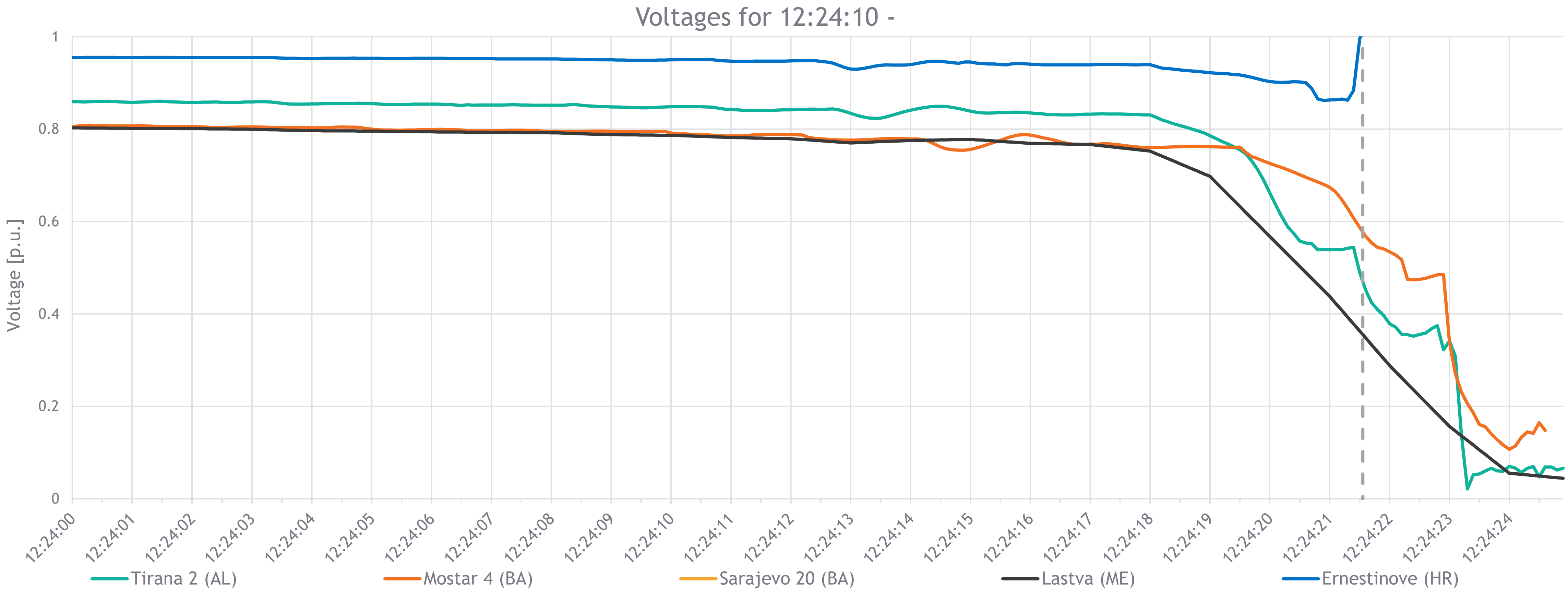


Root Cause 6: Insufficient other sources of MVAr

Reactive Power Compensation devices during the incident

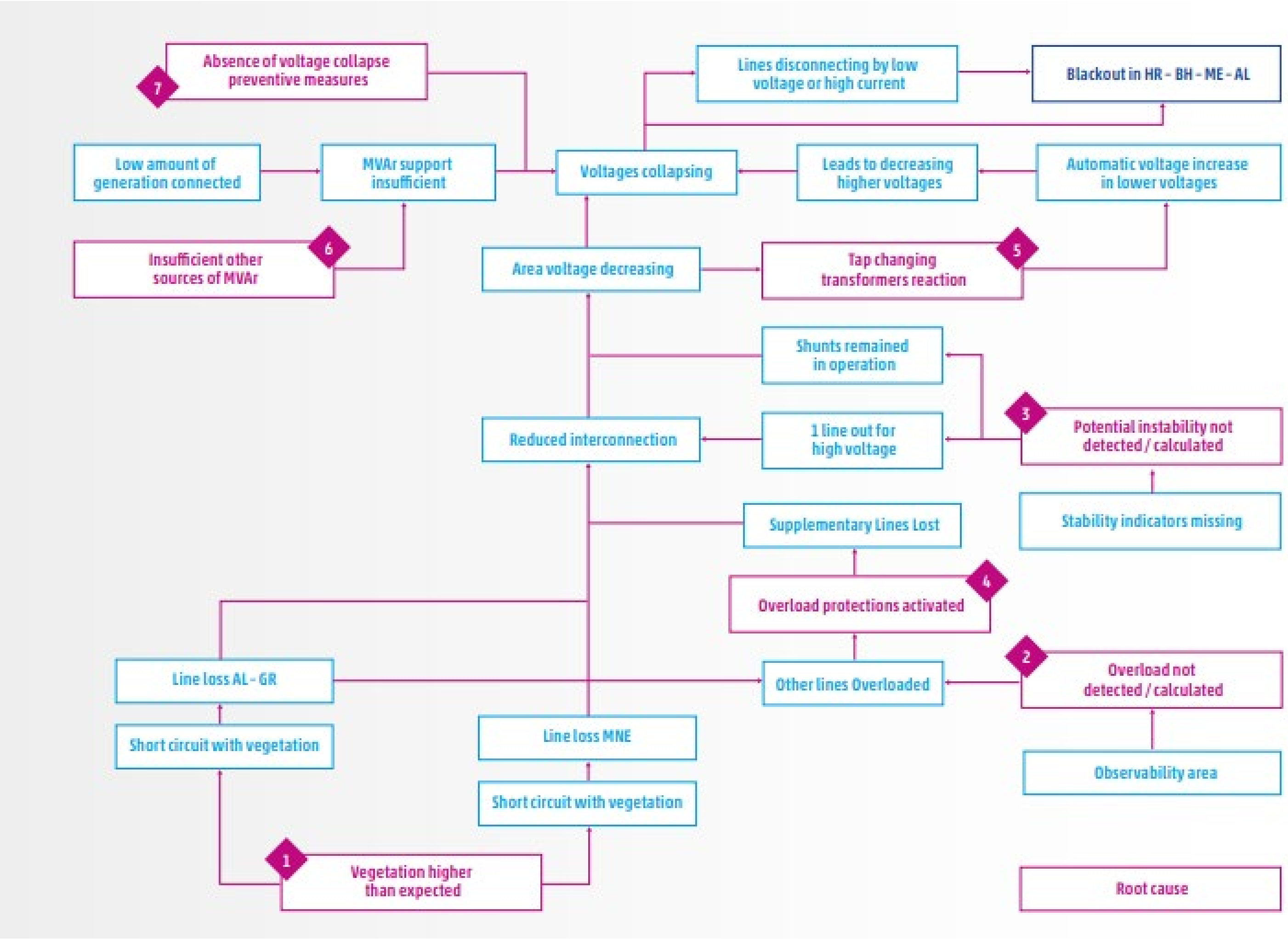


Root Cause 7: Absence of voltage collapse preventive measures



entsoe

Conclusions on the incident



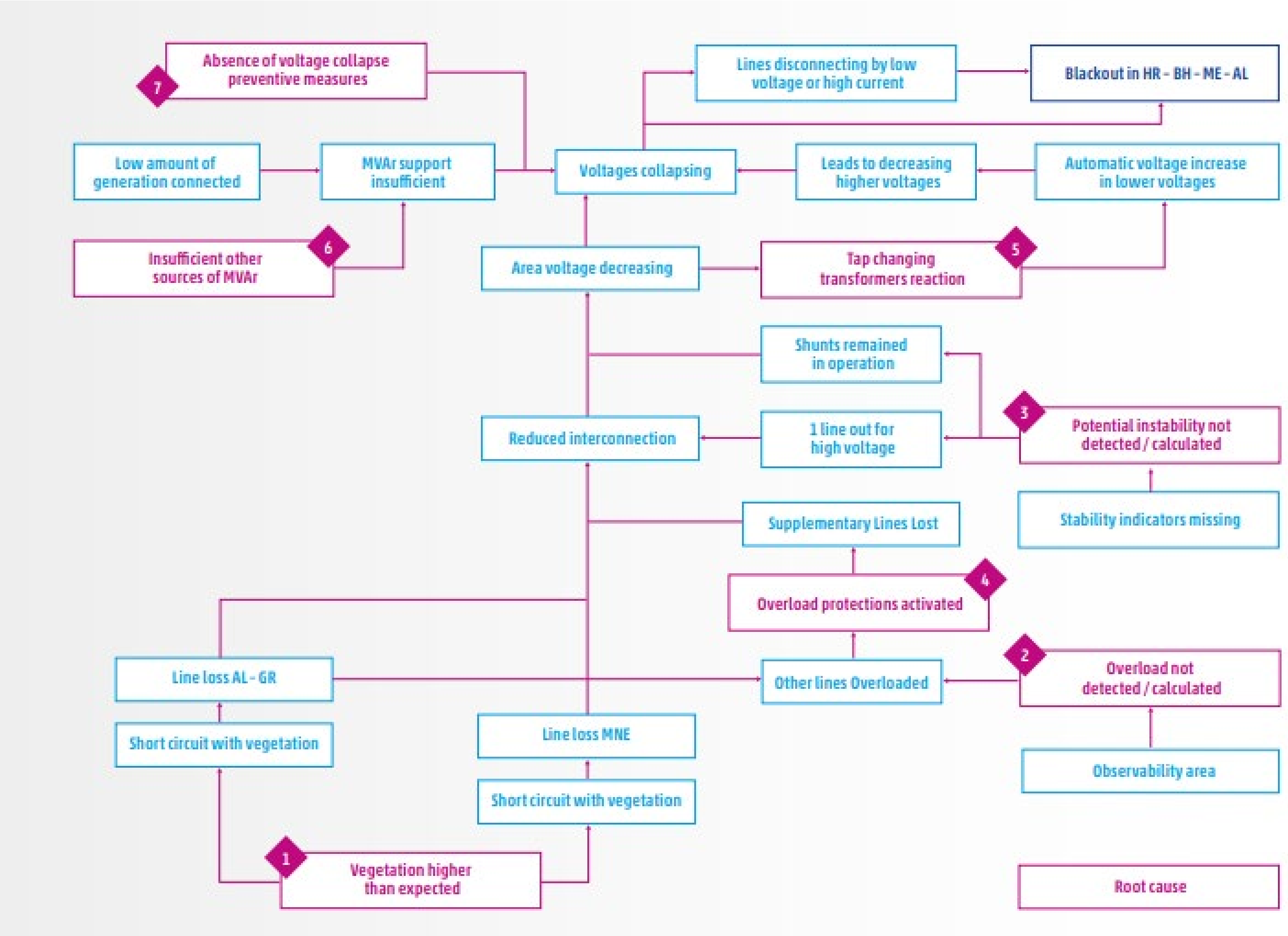
Means of a technical analysis of this scale

- Information was gathered from multiple system
  - We used recording from multiple different systems, such as SCADA, protection relays, WAMs etc.
  - Communication and co-operation is a key factor

- To be able to capture dynamic phenomena, recordings from Wide Area Monitoring (WAM) systems are essential
  - PMU data coming from WAM systems allow us to have a time synchronized measurements with a higher resolution than a traditional RTU

- For this event, WAM was mainly used for a post-mortem analysis
- In the future, WAM systems might represent the backbone of our situational awareness systems providing early warnings of potential stability issues

Recommendations on the incident



Recommendations

1. Check the national policy and operational process of vegetation growth control near the OHL and review them if needed.
2. Evaluate the N-1 calculations of incidents in the neighbouring grid in the real-time SCADA-EMS systems, and if needed adjust the Observability Area.
3. Regular assessment of voltage stability aspects in operational planning.
4. Analyse the possibility to identify easy to use KPI to detect reduced voltage stability and risk of voltage collapse
5. Review the already existing guidelines of ENTSO-E with respect to overcurrent protections in OHL to analyse a potential update if said guidelines with the findings of this incident.
6. Blocking of ULTC (under-load tap changers) of Transformers (V)HV-MV and VHV-HV, where appropriate (depending on renewable infeed and load characteristic).
7. Perform a voltage and reactive power assessment for potential low-voltage situations to be considered during the system design. Review the installation of support measures in areas where there is a risk of voltage collapse.
8. Study the possibility of implementing of an automatic emergency control concept for reactive power compensation devices on Mvar sources (capacitors IN, inductors OUT) at preset extreme voltage levels.
9. Assessment and installation of under-voltage load shedding (UVLS) at loads with a positive contribution on voltage in cases where insufficient other means of voltage support are available.

Priorities

High Medium Low

Thank you

entsoe

Reliable Sustainable Connected