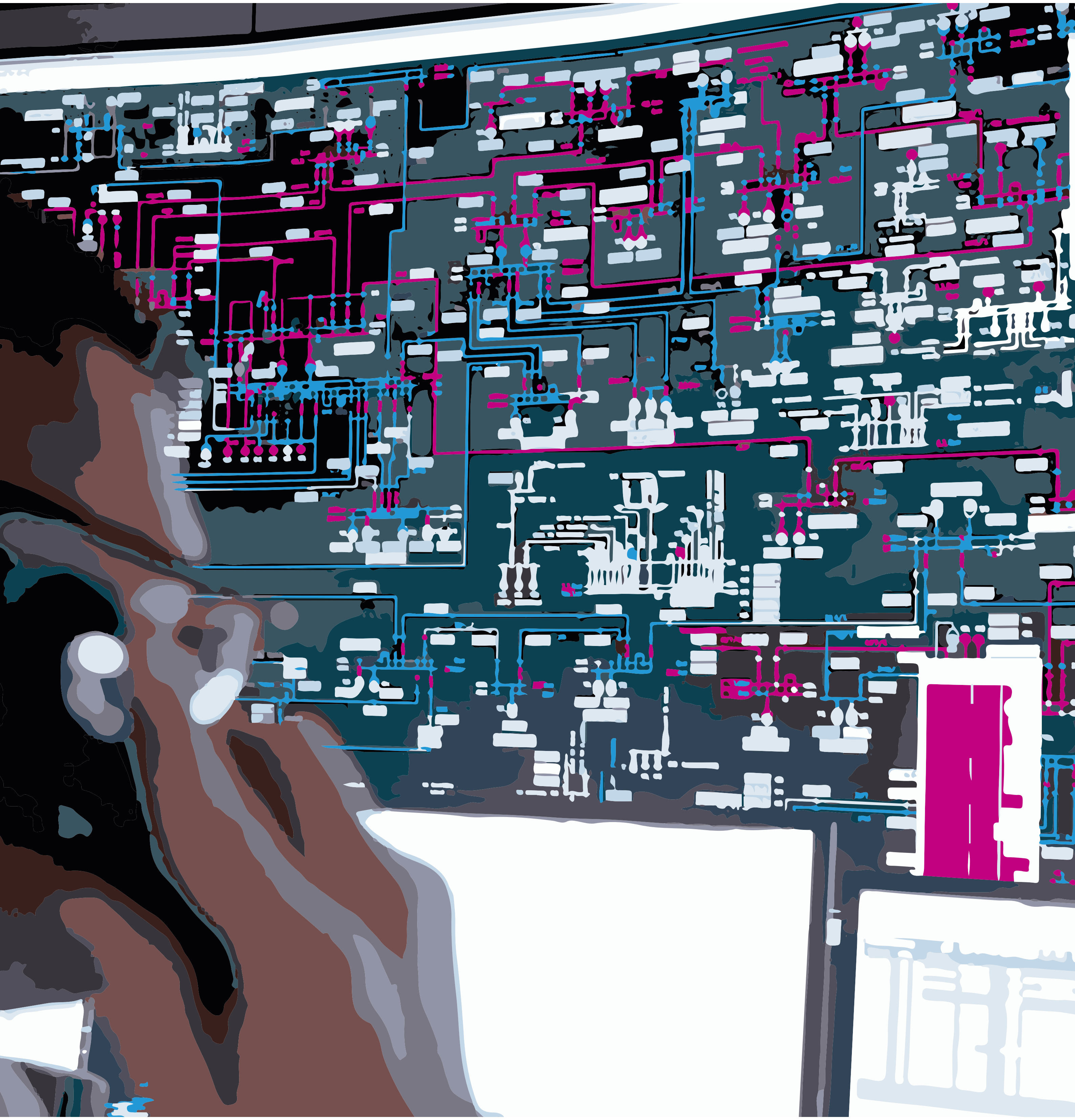
» Grid Incident in South-East Europe on 21 June 2024

ICS Investigation Expert Panel » Interim (factual) Report » 4 November 2024



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1 MANAGEMENT SUMMARY

1.1 Introduction

On Friday, 21 June 2024, a significant incident occurred in South-East Europe (SEE), leading to a major disruption in the Continental Europe (CE) power system. The incident resulted in a substantial loss of load and generation, affecting multiple countries including Albania (OST), Bosnia and Herzegovina (NOSBiH), Montenegro (CGES), and Croatia (HOPS). The event was characterised by a series of contingencies in the transmission network, which ultimately led to a (partial) blackout in these four countries.

Immediately after the incident, the Transmission System Operators (TSOs) in the affected South-East Europe initiated a coordinated response to manage the situation and restore normal operations. This management summary provides a detailed overview of the system conditions before the incident, the sequence of events during the incident, the restoration process, and the communication between coordination centres and TSOs. The summary also includes an analysis of the incident based on **the Incident Classification Scale (ICS) methodology** and outlines the next steps for the further investigation and improvement of the system performance.

The following chapters present the gathered facts, offering a comprehensive understanding of the incident and its impact on the power system in the Balkan region. In this report, all times are Central European Summer Time (CEST), which relates to UTC+02:00.

1.2 System and Market Conditions before the Incident

The outage planning is coordinated through TSOs and Regional Coordination Centres (RCCs), with annual and weekly meetings to harmonise maintenance plans. Several lines were disconnected according to the plan on 21 June 2024, including some of the 220 kV and 400 kV lines. No unplanned outages were reported by the affected TSOs[1] close to the initial outage of the incident in SEE.

June 2024 experienced record high temperatures globally and in Europe, with significant heatwaves in SEE. Temperatures over 40 °C were recorded in many places, contributing to increased power demand and other operational challenges.

Organized day-ahead market information is available in three out of four affected price zones, with significant cross-border market transactions based on explicitly allocated Cross-Zonal Capacity (CZC), which refers to the maximum amount of electricity that can be transmitted between two different price zones or regions without compromising the security of the electricity supply. The highest electricity price was in Albania at 176.32 €/MWh.

Load patterns reflected seasonal changes and increased due to tourism and similar weather conditions across the region. The daily load curve on 21 June was around 10 % higher than the working week average, with total consumption significantly increasing.

Significant differences between scheduled commercial exchanges and physical flows were recorded due to the highly meshed grid and bilateral Net Transfer Capacity (NTC) methodologies applied on all the borders between the affected TSOs.

Day-ahead and intra-day security analyses performed by the concerned TSOs did not indicate any critical contingency leading to a possible violation of the operational security. The analyses showed no major critical outages during the critical period, and remedial actions were in place for identified overloads.

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[1] The term "affected TSOs" refers to four TSOs (CGES, HOPS, NOSBiH and OST) that were affected by the incident of scale 2 or 3. More details can be found in chapter 7.1 of this report.

1.3 Evolution of System Conditions During the Event

The disturbance on 21 June 2024 involved multiple outages across various substations and voltage levels, primarily affecting 400 kV and 220 kV networks. The first trip occurred on the 400 kV line Ribarevine – Podgorica 2 at 12:09:16. The second trip occurred on the 400 kV line Zemblak – Kardia at 12:21:30. Both incidents were confirmed to be caused by insufficient clearance with vegetation. This resulted in the tripping of several other transmission lines and a voltage collapse in Bosnia and Herzegovina, Montenegro, Albania and Croatia. The event caused a substantial loss of load and generation, with a total generation loss of 2,214 MW and significant load losses across various TSOs within minutes. Transformer tap changers responded to voltage drops, with automatic voltage regulation observed mainly in the CGES (MNE), HOPS (HR), and NOSBiH (BIH) control areas, while OST (AL) had no automatic regulation.

1.4 RCC Analysis before the incident

The results of the various tasks performed by the RCCs before the incident on 21 June 2024 indicate that the grid was considered secure, and no major issues were detected in the affected area. The Outage Planning Coordination (OPC) task, conducted by SEleNe CC, SCC and TSCNET, showed no security alerts for the relevant grid elements. The Short-Term Adequacy (STA) analysis, led by SCC, confirmed that the available production capacity could meet the expected consumption. The security analysis performed by TSCNET, SCC and SEleNe CC, revealed no significant operational security risks, and the grid was deemed N-1 secure. Similarly, other RCC tasks like creation of the Common Grid Model (CGM), Coordinated Capacity Calculation (CCC) and consistency assessment of defence and restoration plans did not indicate any unsafe operation where and to the extend they have been performed (Capacity Calculation (CC), and Regional Grid Model).

1.5 Communication of Coordination Centres SAM and between TSOs

The communication began with TERNA informing CGES about the High Voltage Direct Current (HVDC) cable Monita tripping, followed by exchanges between CGES, NOSBiH, HOPS and OST regarding the incident details and support offers. Swissgrid played a significant role in post-blackout communications, coordinating with Amprion, ELES and OST to offer assistance and gather updates on the situation. RCCs communicated effectively during the incident. The European Awareness System (EAS) was used, detailing the changes in system states for each affected TSO during the incident, including normal, alert, emergency, blackout and restoration states.

1.6 Restoration Process

TSOs affected by the incident receved information by EAS and communications between affected TSOsabout voltage collapse and blackout in Albania, Montenegro, Bosnia and Herzegovina, and Croatia shortly after the disturbance, leading to immediate restoration planning.

Interconnections were used for a top-down restoration process, ensuring active power management on tie-lines according to agreements between TSOs.

- HOPS began restoring the Split area from the 220 kV voltage level due to a blackout and maintenance on a 400 kV line, followed by a series of reconnections and transformer activations to energise key substations.
- NOSBiH coordinated with neighbouring TSOs and initiated restoration from the Ugljevik substation, progressively reconnecting lines and substations, and addressing high voltage issues in the southern part of their system.
- CGES focused on restoration from the northern part of the country, starting with the reconnection of key lines and transformers, and resynchronising with OST.
- OST restored power by energising substations and synchronising with neighbouring grids, starting with IPTO and following with KOSTT and CGES.

The restoration process began with the first action at 12:33, and restoration process of the load for all TSOs was completed around 16 h.

1.7 Classification of the Incident based on the ICS Methodology

The ICS Methodology is based on the requirements of Regulation (EC) No 714/2009 and Commission Regulation (EU) 2017/1485 and aims to provide a realistic view of system states during incidents. The criteria for incident classification are ranked by priority, with the highest priority criterion determining the incident scale. An Expert Panel investigates incidents classified as scale 2 or 3. On 21 June 2024, the OB3 criterion was met in Albania, Bosnia-Herzegovina and Montenegro, while Croatia met the L2 criterion. The incident was classified as scale 3 due to the high demand loss. The RCC Investigation Threshold was met because multiple TSOs moved to emergency states, and the incident was confirmed as at least a scale 2 incident. Meeting the threshold prompts initiating an RCC investigation by the RCC Investigation Subgroup pursuant to Article 7 of the RCC Post-Operation and Post-Disturbances Analysis and Reporting Methodology

1.8 Next Steps

The incident on 21 June 2024 has been classified as a scale 3 event under the ICS methodology, requiring a detailed report by an Expert Panel. This will provide both a factual account and an evaluation of the incident, based on available and potentially additional data identified during the investigation. The RCCs' analysis under Article 7 of the RCC Post-Operation and Post-Disturbances Analysis and Reporting Methodology will be part of this report. The panel will analyse key aspects such as voltage collapse, technical details, root causes, and critical factors, and provide recommendations if necessary.

The Expert Panel, consisting of representatives from affected and unaffected TSOs, RCCs, ICS methodology representative, National Regulatory Authorities (NRAs) and ACER, began its investigation in July 2024. A final report is expected to be published on the ENTSO-E website by beginning of 2025.

2 SYSTEM AND MARKET CONDITIONS BEFORE THE INCIDENT

This chapter describes the system conditions in the four affected TSOs before the incident on 21 June 2024 at 12:09. It includes an overview of scheduled and real-time topology, weather conditions during the day, respective market environment, load and production patterns and trends in the period before the incident, as well as the results of security analysis, conducted before the initial outage.

2.1 Information on Topology

2.1.1 Planned Outages

Outage planning coordination in SEE is performed through the TSOs' and RCCs' collaboration within the South-East Europe Maintenance Group[2]. The group meets at least once a year (Annual SEE MG Meeting) to harmonise individual transmission grid elements maintenance plans.

Weekly outage coordination is performed during regular weekly operational teleconferences (WOPT), organised by RCCs (during 2024 this task is performed by SELENE CC). According to the Report on disconnections of relevant elements in the SEE region for the week 25 (2024-06-15 – 2024-06-21), scheduled topology in the region was as presented in Table 1 and in Figure 1.

Element	Start Date	Start Time	End Date	End Time
TIE 400 kV Bekescsaba (MAVIR) – Nadab (TEL) CKT 1	21.05.2024	7:00	12.07.2024	17:00
TIE 400 kV Arachthos (IPTO) – Galatina (TERNA) CKT 1	27.05.2024	8:00	23.06.2024	16:00
OHL 400 kV Bucuresti Sud (TEL) – Pelicanu (TEL) CKT 1*	28.05.2024	6:00	20.06.2024	17:00
OHL 400 kV Tirana 2 (OST) – Koman (OST) CKT 1	01.06.2024	0:00	30.09.2024	23:00
OHL 220 kV Kolacem (OST) – Tirana 2 (OST) CKT 1	01.06.2024	0:00	30.09.2024	23:00
TIE 400 kV Koman (OST) – Kosovo B (KOSTT) CKT 1	01.06.2024	0:00	30.09.2024	23:00
OHL 400 kV Cernavoda (TEL) – Medgidia Sud (TELA) CKT 1**	10.06.2024	6:00	21.06.2024	17:00
OHL 400 kV Bucuresti Sud (TEL) – Slatina (TEL) CKT 1	14.06.2024	5:00	20.06.2024	17:00
OHL 400 kV Paks (MAVIR) – Sandorfalva (MAVIR) CKT 1	15.06.2024	7:00	16.06.2024	17:00
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 2	15.06.2024	7:00	16.06.2024	17:00
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 3	15.06.2024	7:00	16.06.2024	17:00
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 1	17.06.2024	7:00	21.06.2024	15:30
OHL 400 kV Obrenovac (EMS) – Kragujevac 2 (EMS) CKT 1	17.06.2024	7:00	23.06.2024	18:00
TR 400/220 kV MARITZA IZTOK 3 (ESO) CKT 1	17.06.2024	7:00	28.06.2024	15:00
TIE 220 kV TE Sisak (HOPS) – Prijedor 2 (NOSBiH) CKT 1	17.06.2024	8:00	19.07.2024	17:00
OHL 400 kV Tuzla 4 (NOSBiH) – Ugljevik (NOSBiH) CKT 1	20.06.2024	8:00	21.06.2024	16:00

* excluded days: 08–09.06.2024 ** excluded days: 15–16.06.2024

Table 1: List of disconnections for relevant network elements in the SEE region for week 25 and for the voltage levels 220 kV and 400 kV (scheduled disconnections for 21 June highlighted).

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[2] Participating TSOs of the group are CGES, EMS, ESO EAD, HOPS, IPTO, KOSTT, MAVIR, MEPSO, NOSBiH, OST, TEİAS and Transelectrica

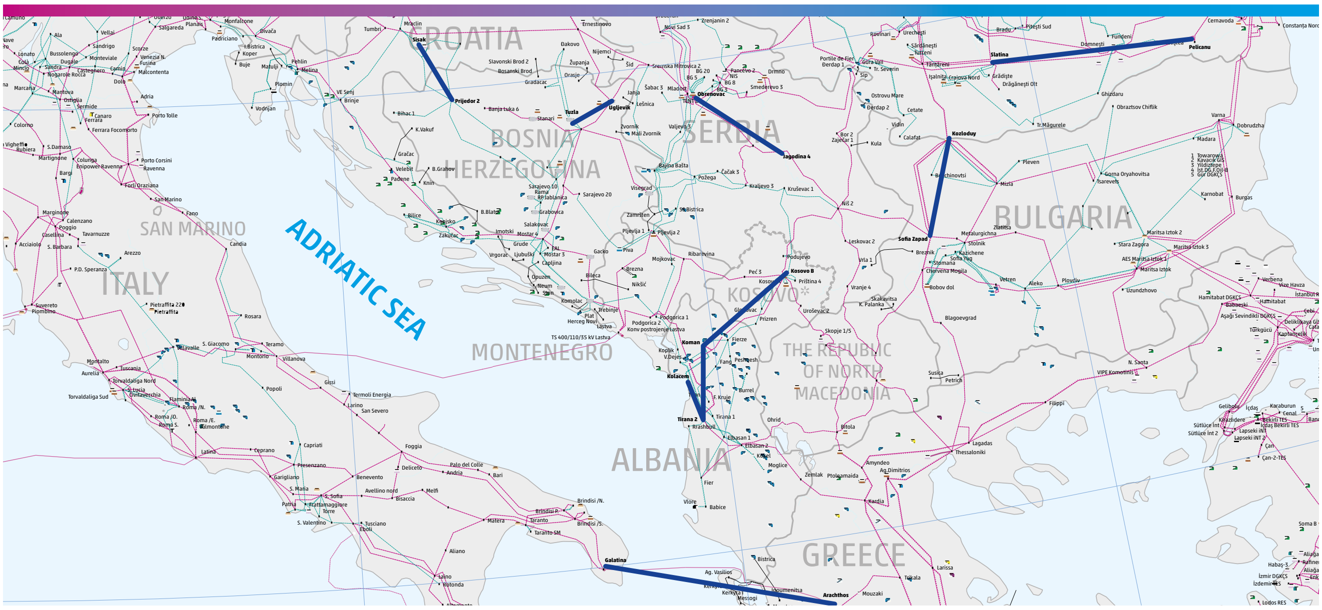

Figure 1: Planned disconnections of relevant elements in the SEE region for the week 25

In the affected area on 21 June, according to the above plan the following lines of interest were disconnected:

» TIE 220 kV TE Sisak (HOPS) – Prijedor 2 (NOSBiH)

» OHL 400 kV Tuzla 4 (NOSBiH) – Ugljevik (NOSBiH)

» TIE 400 kV Koman (OST) – Kosovo B (KOSTT)

» OHL 400 kV Tirana 2 (OST) – Koman (OST)

» OHL 220 kV Kolacem (OST) – Tirana 2 (OST)

In addition to the long-term planned disconnections above, within the affected area, there was also a planned disconnection of:

» OHL 400 kV Melina (HOPS) – Velebit (HOPS)

Due to the high voltage issues[3] in 400 kV node Višegrad (NOSBiH), an additional disconnection was announced within the Day-Ahead-Congestion-Forecast (DACF) individual grid models (IGM) preparation process. This is in line with the formal voltage management procedure established by ENTSO-E and agreed between all TSOs, whereby this is an acceptable measure for managing high voltage magnitudes in the electrical nodes, on the condition that the measure is coordinated with the considered TSOs:

» OHL 400 kV Tuzla 4 (NOSBiH) – Višegrad (NOSBiH)

While announced in the DACF process as disconnected, the line was announced as connected in the Intraday Congestion Forecasts (IDCF) process through the relevant IGMs.

All mentioned outages were fully implemented in the IGMs of affected TSOs and were the part of the CGM used for the day-ahead and intraday coordinated security analysis.

2.1.2 Unplanned Outages

In addition to weekly and day-ahead announcements, no unplanned outages were reported by the affected TSOs after the delivery time for DACF IGMs, within the timeframe relatively close to the initial outage of the incident (12:09:16).

2.1.3 Affected Area Topology at 12:00

The planned disconnections described in subchapter 2.1.1 were all realised, with the exception of the line OHL 400 kV Tuzla 4 (NOSBiH) – Ugljevik (NOSBiH) that remained in operation.

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[3] The SEE region typically faces high voltages on a seasonal basis. In addition to planned grid reinforcements that are expected to result in a permanent solution of the issue, TSOs are applying topological measures to minimise the effect of this phenomena.

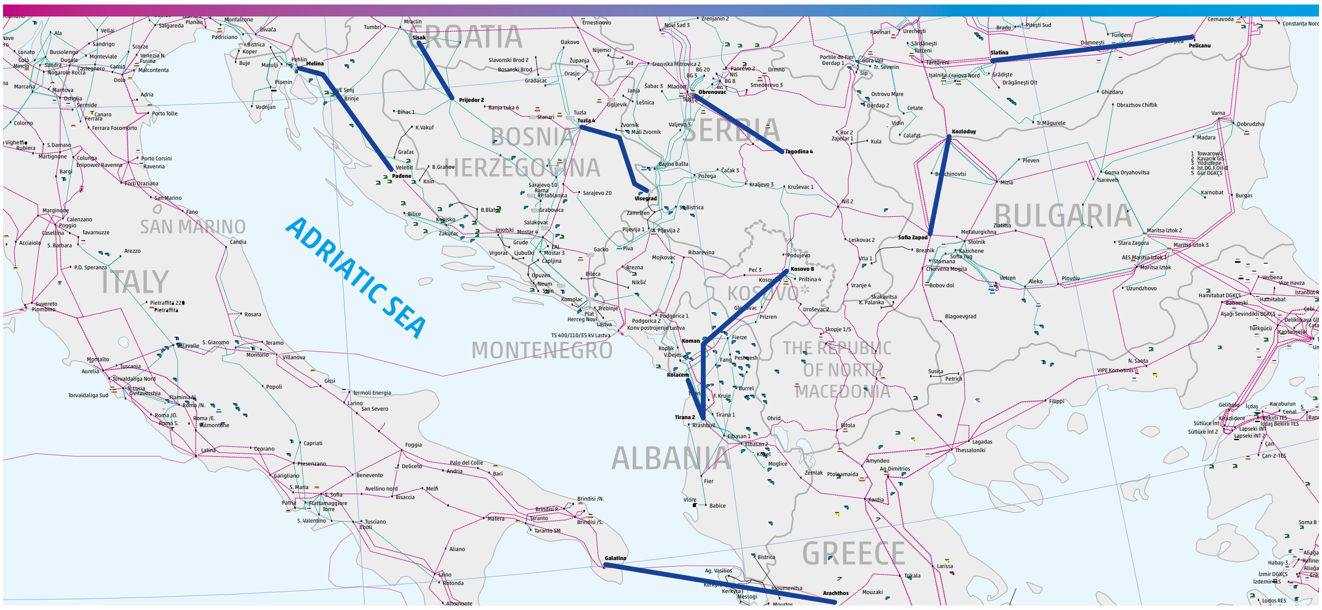

Figure 2: Affected area topology at 12:00

2.2 Weather Conditions

According to the Copernicus climate change service (CS3)[4], the average European temperature for June 2024 was 1.57 °C above the 1991–2020 average for June, making the month the joint-second warmest June on record for Europe.

In June 2024, air temperatures were well above their 1991–2020 average over southern Italy, southeast Europe and Turkey, reflecting the heatwaves that occurred in Cyprus, Greece and Turkey. Temperatures over 40 °C were recorded in many places and Athens had its hottest June in a data record going back to 1860, while Greece had its warmest June since 2010.

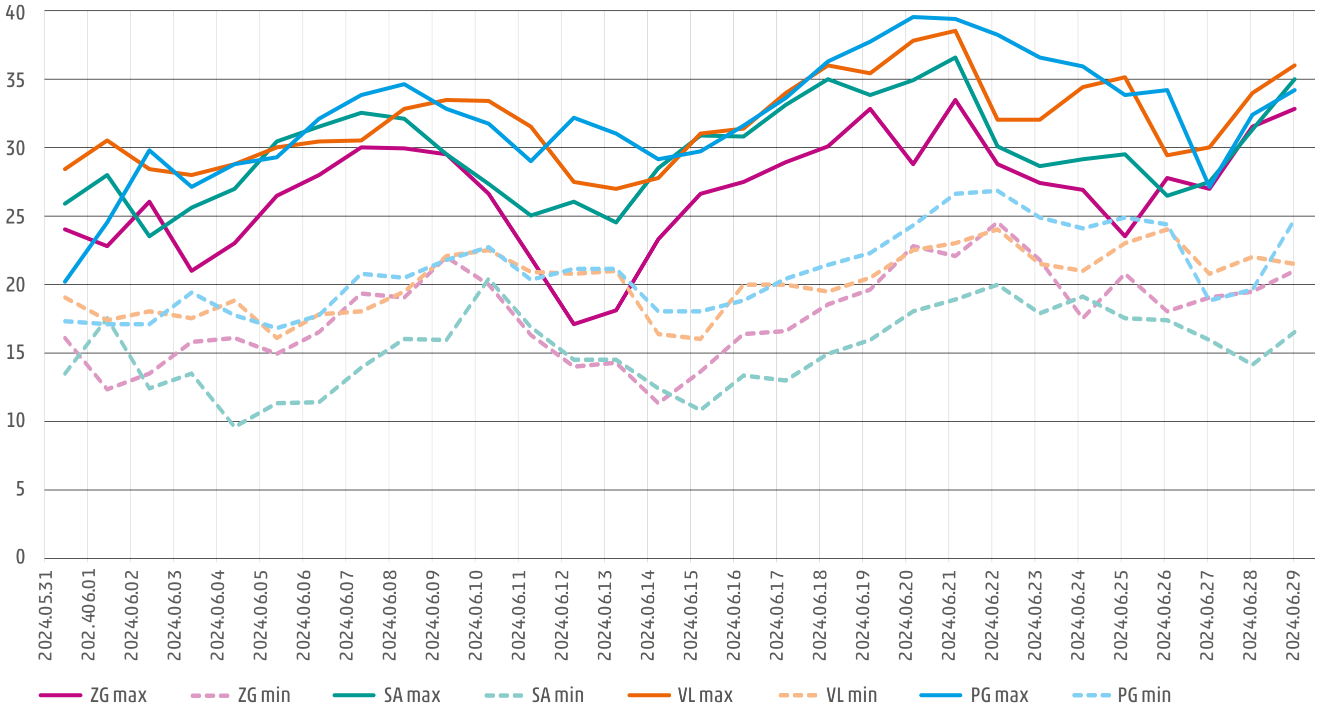

Figure 3: Maximal and minimal daily temperatures during June 2024 in Zagreb (HR), Sarajevo (BA), Podgorica (ME) and Vlore (AL)

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[4] C3S is one of six thematic information services provided by the Copernicus Earth Observation Programme of the European Union (**About us | Copernicus**)

The entire affected area was sharing the conditions present in the SEE region. According to the European Climate Assessment & Dataset (ECA&D)[5], on 21 June 2024 maximum temperatures were between 35 °C and 40 °C in Podgorica (ME), Sarajevo (BA) and Vlore (AL), while daily average temperatures were above 30 °C in Podgorica and Vlore and above 27 °C in Sarajevo and also in Zagreb (HR) (Figure 3).

An illustration of the average daily temperatures in the last 8 years in Podgorica (Figure 4) clearly shows the 21 June (as well as several previous days) was the hottest 21 June in the observed period (2017–2024).

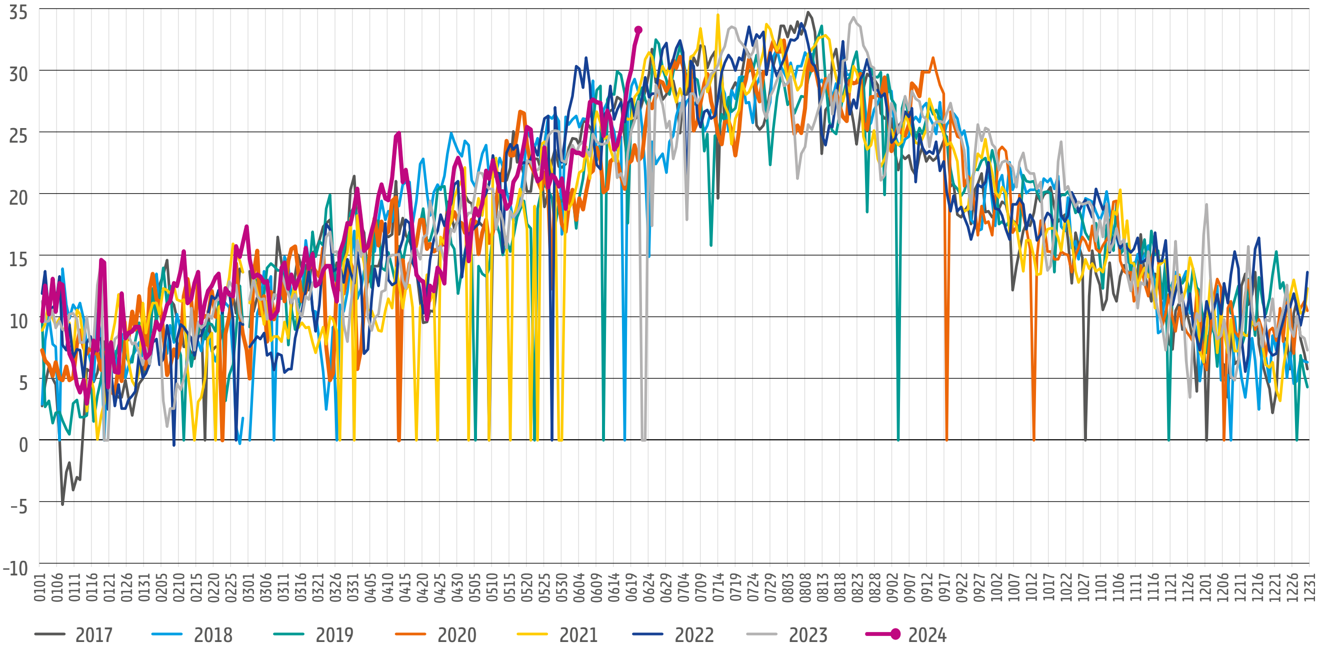

Figure 4: Average daily temperature in last 8 years in Podgorica in °C

While also bearing in mind the high levels of radiation all across the region, combined with very calm air (i. e. average daily wind speeds in Podgorica and Vlora are reported in the range between 1 and 2 m/s), the observed weather conditions were simultaneously a contributing factor to the several aspects of importance for power system operation:

- increased power demand (including additional reactive power demand) due to the increased need for climatisation,
- increased production from solar generating units, still unequally distributed across the region,
- increased power flows including cross-border exchange; and
- increased ambient temperature high-voltage overhead lines were operating in.

2.3 Market Information

Day ahead market information is available in 3 out of 4 affected price zones (systems). With the exception of Bosnia and Herzegovina, power exchanges are operational in all other countries, providing spot market price signals as described below.

Cross-border market transactions among affected TSOs (price zones) are based on the explicitly allocated CZCs by the regional coordinated capacity allocation platform SEE CAO.

During the incident, markets were not suspended in the affected areas.

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[5] Data and metadata available at **http://www.ecad.eu**

2.3.1 DAM Prices

Day ahead spot electricity prices in the region for the 13th hour of 21 June are as shown in Figure 5. The highest price was in Albania price zone reaching 176.32 €/MWh, followed by Montenegrin 124.82 €/MW. Northern and western parts of the region were settled around 100 €/MWh, while the lowest price was reached in Greece with 75 €/MWh.

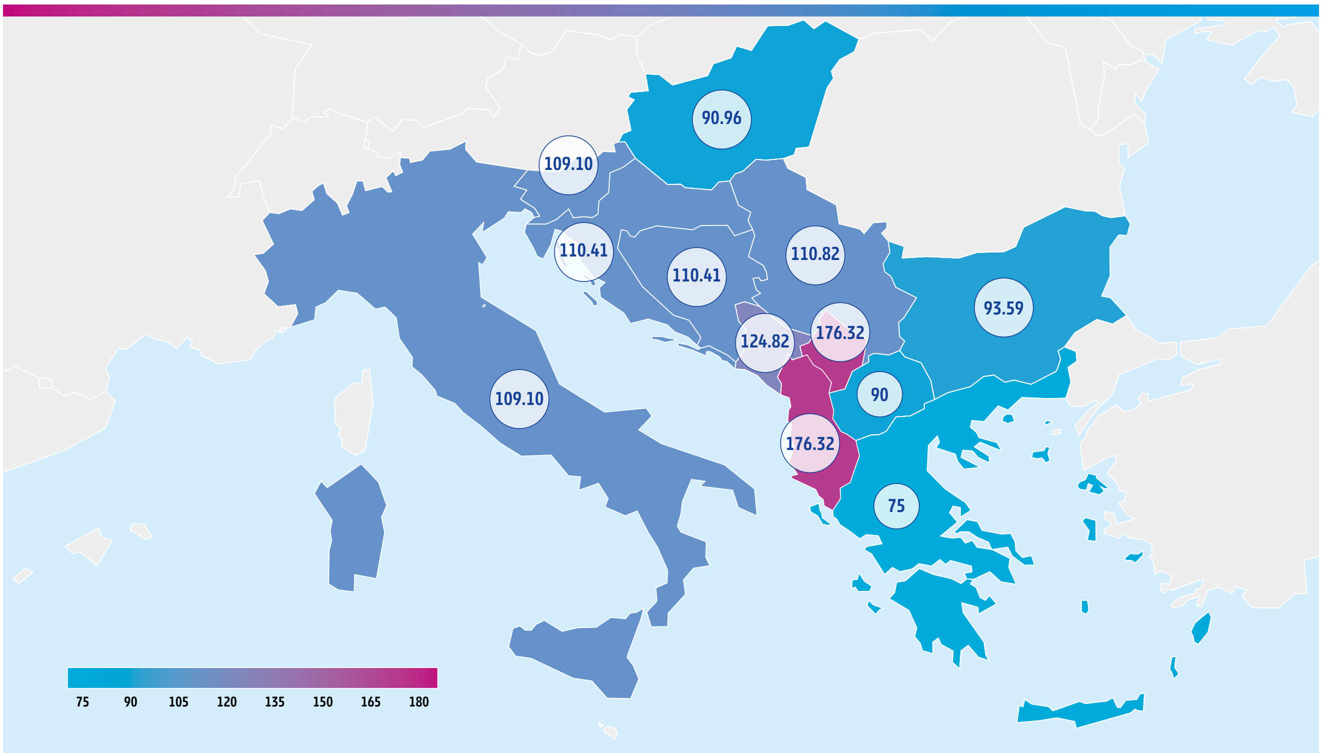

Figure 5: DAM Electricity prices for 13th hour, 21 June 2024

2.3.2 DA CBC Prices

According to the data available from SEE CAO platform, cross-zonal capacities prices allocated on daily level reflected the market conditions and price differences described above. The value of capacities varied from 1.33 €/MW on the Montenegro–Albania direction to 35 €/MW in the Greece–Albania direction.

Delivery period start	Border direction	Time-table	Offered Capacity - Daily auction (MW)	Total Requested Capacity - Daily auction (MW)	Total Allocated Capacity - Daily auction (MW)	Auction Clearing Price (€/MWh)
21.06.2024	HR-BA	12:00-13:00	599	917	599	2.55
21.06.2024	BA-ME	12:00-13:00	394	783	394	10.11
21.06.2024	ME-AL	12:00-13:00	206	335	206	1.33
21.06.2024	GR-AL	12:00-13:00	184	540	184	35.00

Table 2: Cross-zonal capacities prices, SEE CAO results, Day ahead auctions.

2.4 Power Flows before the Incident

Comparing the power flows on several borders of the affected TSOs, one can note a change of historical patterns. According to the comparison of the ENTSO-E Transparency Platform data about flows in June, July and August of 2022, 2023 and 2024, by the date of the incident it is evident that on some borders, total physical energy exchange has been significantly increased or has even changed the historically dominant direction of flows.

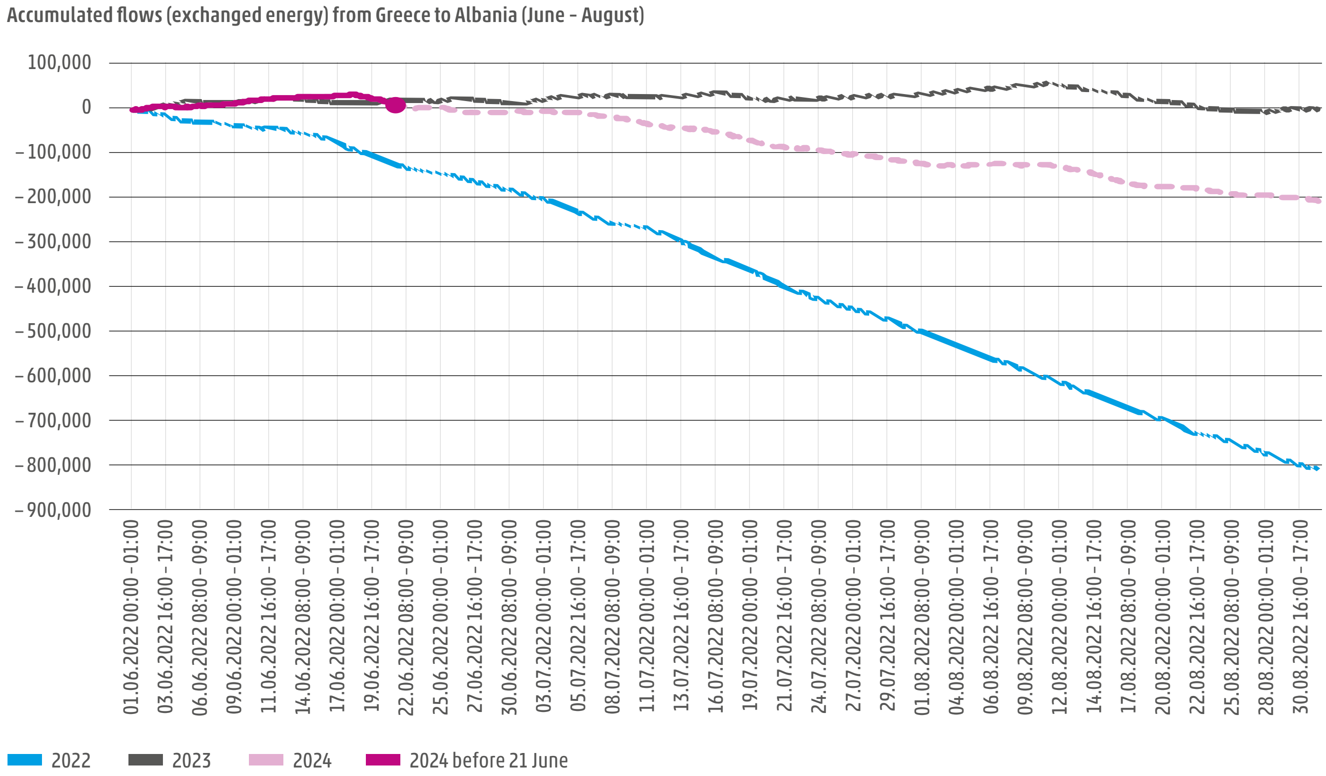
Accumulated flows (exchanged energy) from Greece to Albania (June – August)

Figure 6: Accumulated flows (exchanged energy) from Greece to Albania (June – August)

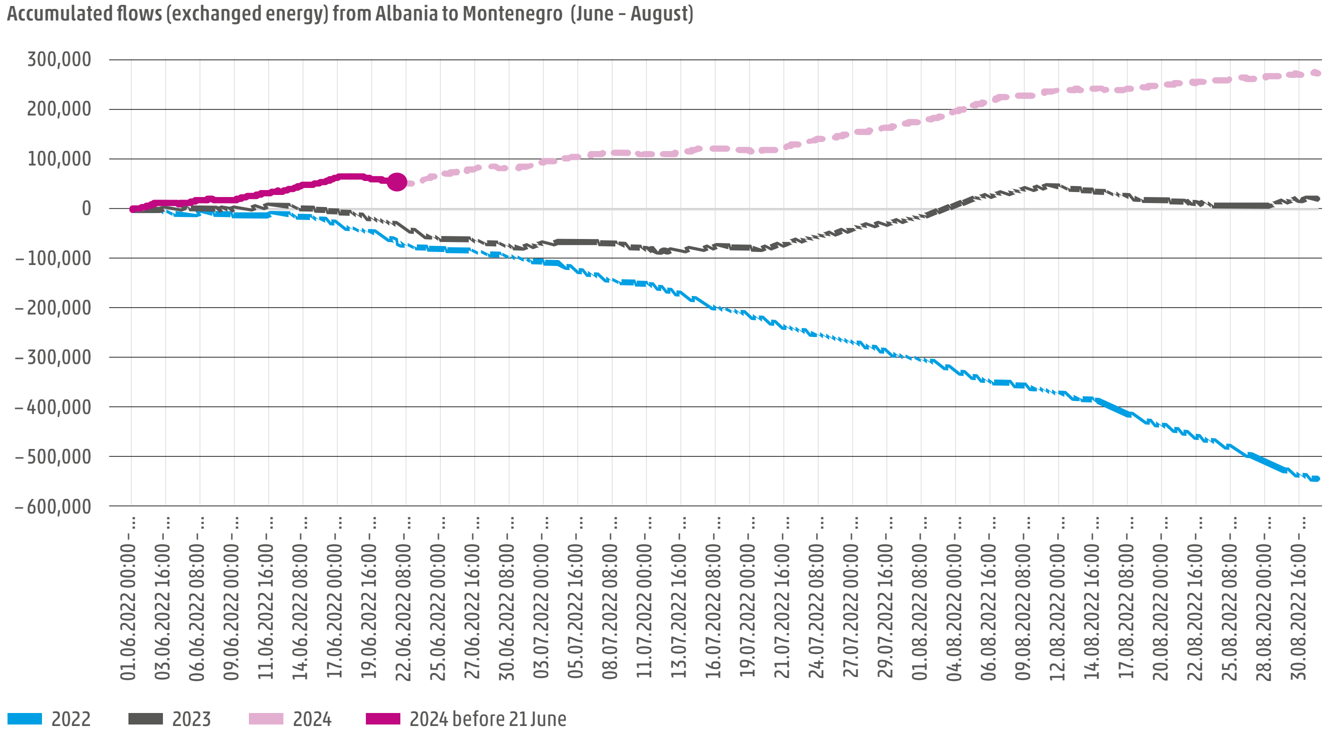
Accumulated flows (exchanged energy) from Albania to Montenegro (June – August)

Figure 7: Accumulated flows (exchanged energy) from Albania to Montenegro (June – August)

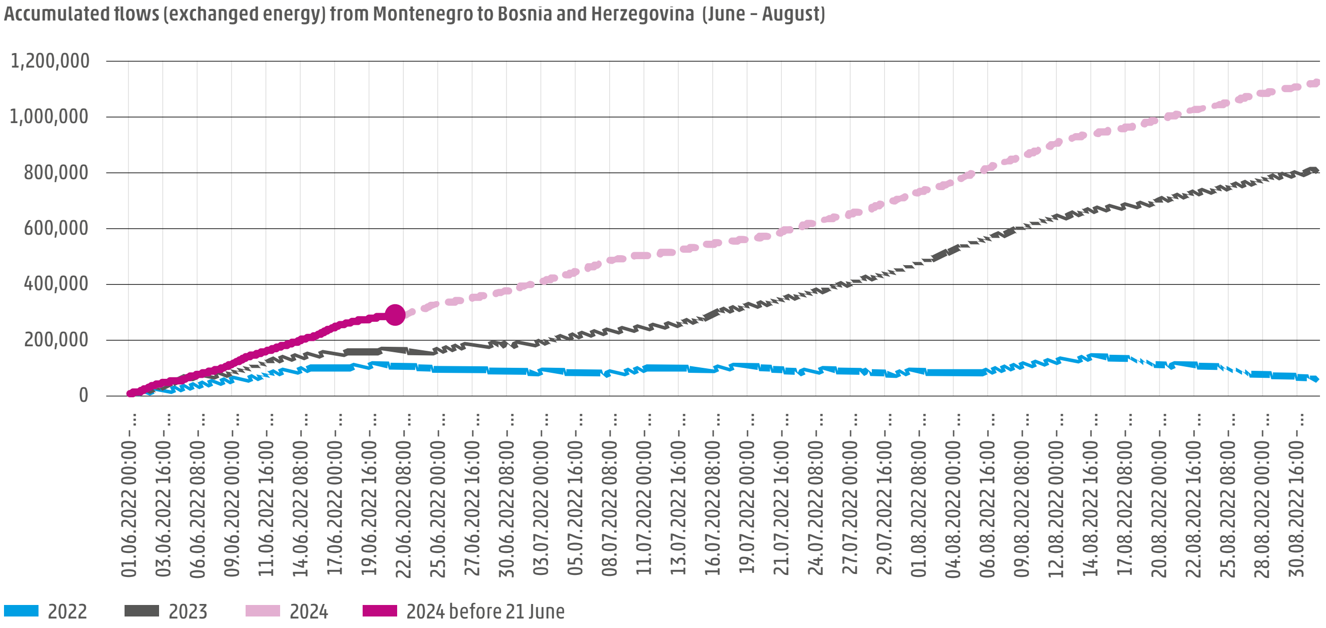

Figure 8: Accumulated flows (exchanged energy) from Montenegro to Bosnia and Herzegovina (June - August)

On the Albania–Greece border maximal daily flows from Albania to Greece were way above 2022 and 2023 levels for the same period of 2024 by 17 June, after which they also exceeded the values from 2022 and 2023 in the opposite direction.

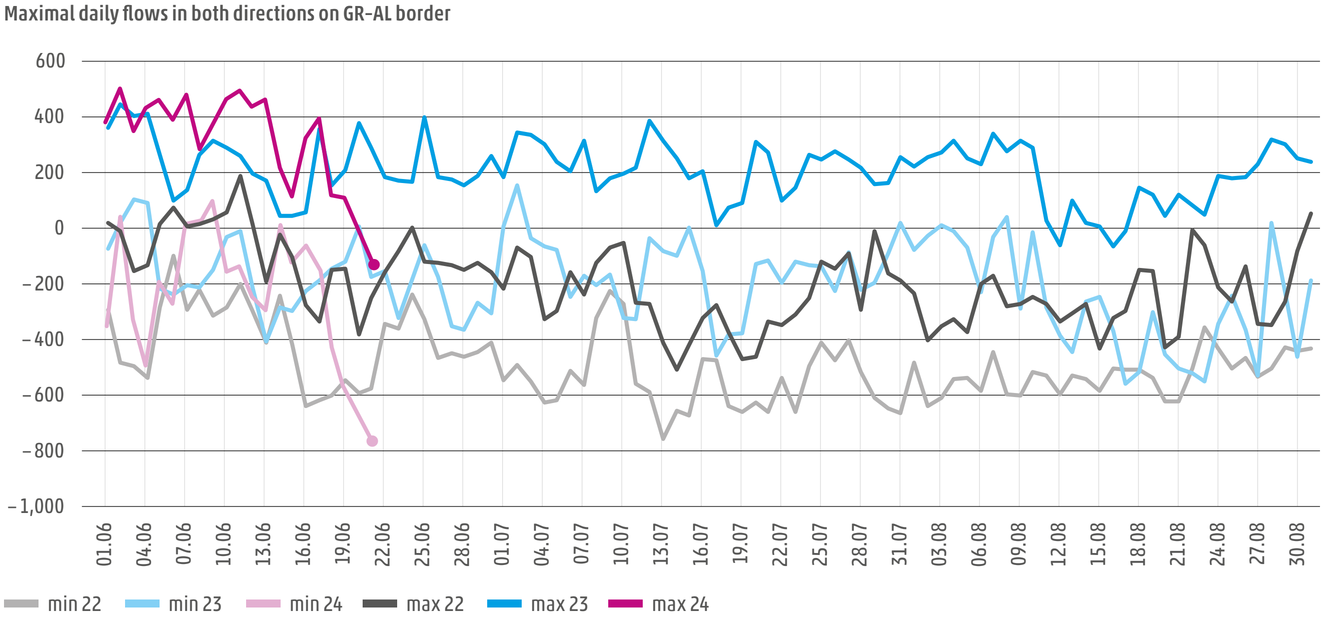

Figure 9: Maximal daily flows in both directions on GR - AL border

2.4.1 Load Patterns

According to the ENTSO-E Transparency Platform data, load patterns in the affected TSOs reflected the seasonal changes in the power systems of Albania, Montenegro, Bosnia and Herzegovina and Croatia. Bearing in the mind the share of tourism in overall economic activities of the affected systems as well as very similar weather conditions all across the region during the observed period, one can explain the daily growth of total consumption in four affected systems together ranging between 4 % and 6 %. The daily load curve on 21 June until the incident was well above the working week average (Figure 10), while total daily consumption, even with the blackout, was 7.8 % higher than on Monday of the same week and 10.3 % above the same day of the previous week (Friday 14 June).

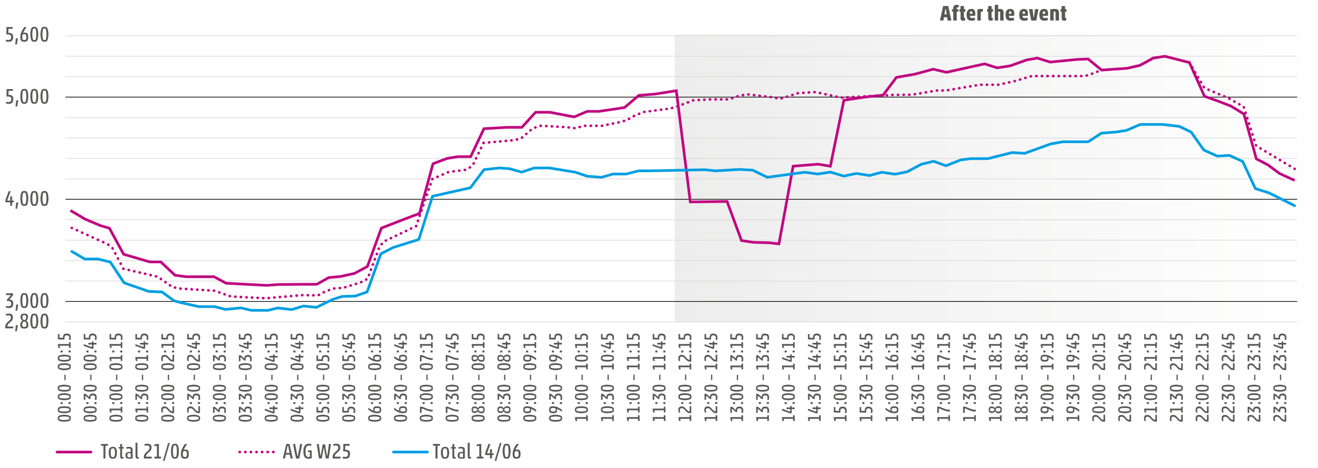

Figure 10: Aggregated daily load curves of 4 affected TSOs (OST, CGES, NOSBiH and HOPS) for the working week 25 (17 June – 21 June 2024) and 14 June 2024.

Individual load patterns in the affected TSOs were not significantly different to the aggregated one, so very similar trends of the load growth were recorded in all four systems.

2.4.2 Production Patterns

The generation structure of the affected systems have not significantly changed in the last several years (Figure 11), hence no unusual production patterns have been observed in the critical period inside the affected area. According to the ENTSO-E Transparency platform data, as updated at the beginning of the year[6], total installed capacity in all four systems has been increased by 558 MW in 2024 compared to 2023 levels. Half of that increase (275 MW) is related to the newly installed solar production, followed by the onshore wind (156 MW).

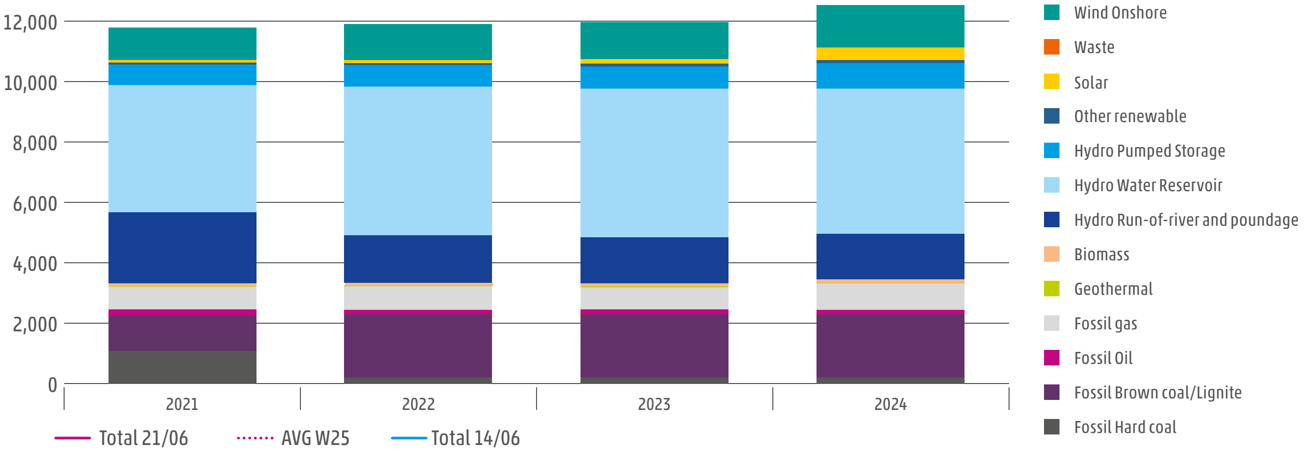

Figure 11: Generation structure of the affected systems during the past years.

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[6] Installed capacity data may differ for some countries depending on how frequently Transparency Platform is updated in that respect.

Geographical distribution of the newly installed production capacities mainly goes to Croatia (onshore wind and solar) and Albania (all solar).

However, aggregated production curves were still extremely responsive to the wholesale market price signals, reaching their maximum during the evening peak hours (Figure 12 and Figure 13).

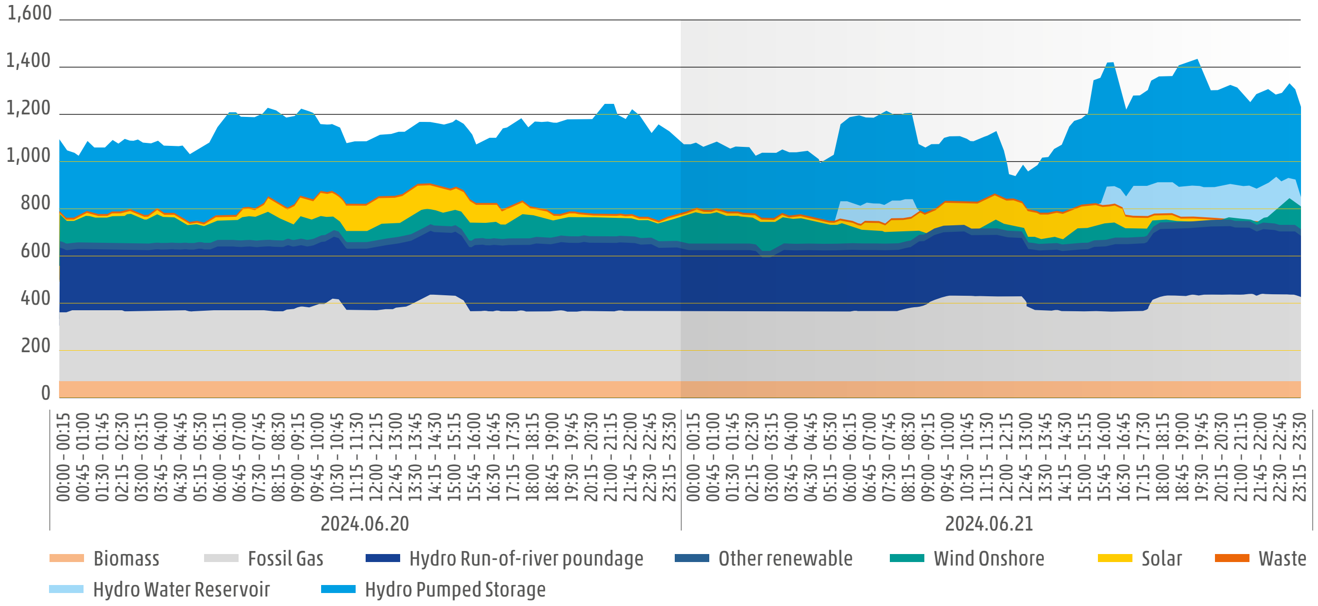

Figure 12: Production pattern in the affected systems – Croatia on 20 and 21 June 2024, by production type (MW)

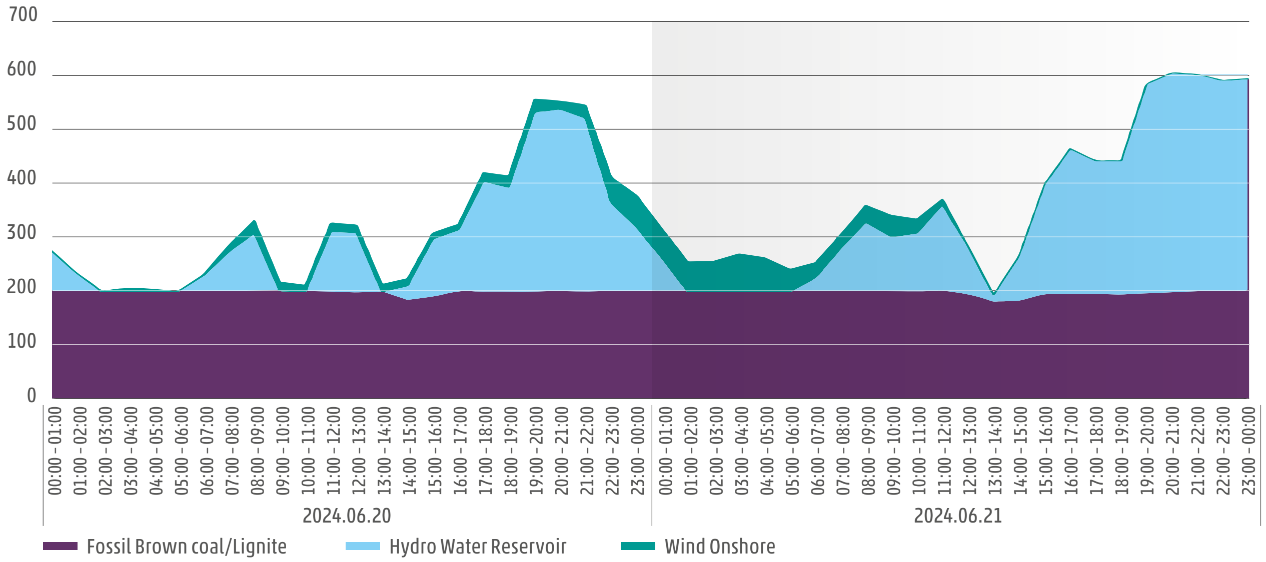

Figure 13: Production pattern in the affected systems – Montenegro on 20 and 21 June 2024, by production type (MW)

Like the affected systems, some neighbouring systems have also seen an increase of the production from solar and wind in 2024. In some cases, the increase is significant, i. e. a capacities increase from 2023 to 2024 in Greece amounts to 2,125 MW, of which 1,600 MW solar. In others it is rather moderate, as in Serbia where total new capacities amount to 139 MW, of which 36 MW is solar.

Consequently, the production curve in Greece followed the weather conditions during 21 June, as well as in the preceding days, reaching its maximum during the 12th and 13th hours local time.

In general, power flow patterns in the affected area were driven by the usual seasonal demand increase and usual seasonal lack of hydro-power production, as well as the predictable but newly established seasonal production increase related to the strong solar production, especially in the southern part of the SEE region.

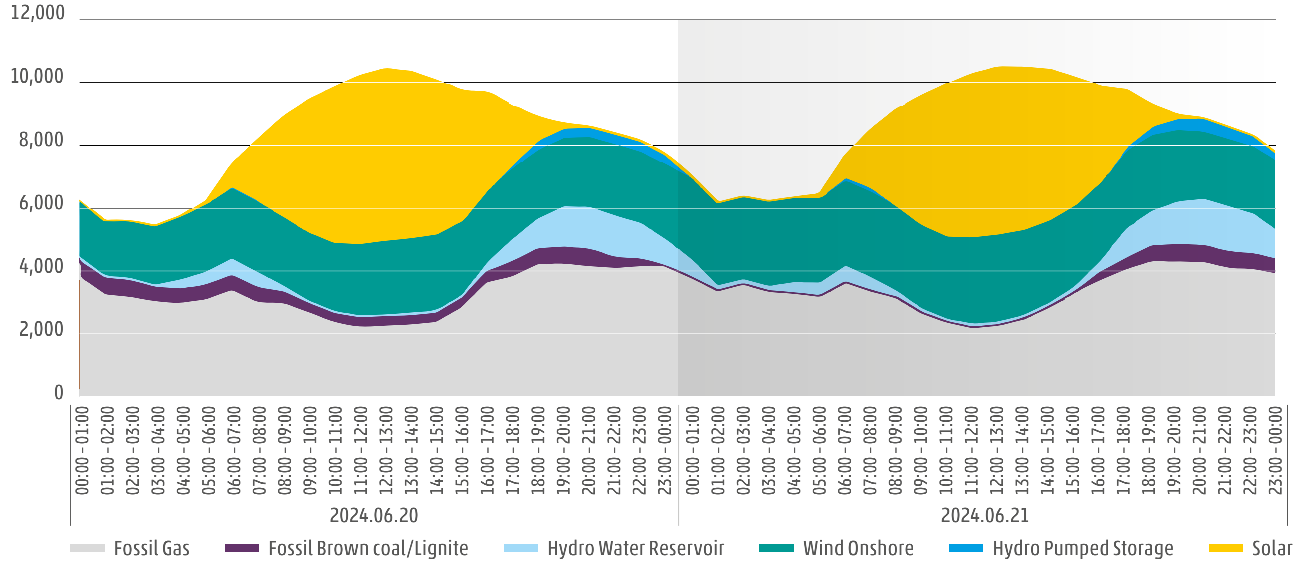

Figure 14: Production patterns in the neighbouring systems – Greece on 20 and 21 June 2024, by production type (MW)

2.4.3 Cross-Border Flows

During the day of the event, as with most of the time in the affected area, a significant difference between scheduled commercial exchanges and physical flows was recorded (up to 500 MW on some borders, as described below). This is explained with a highly meshed grid of SEE, particularly in the affected area, as well as by the fact that the CBC calculation between the affected TSOs is still based on bilaterally agreed results of NTC calculations and is performed mainly on the monthly level. It is assumed that this practice also influences the closest borders that are subject of coordinated capacity calculation

According to the Transparency platform data, from the beginning of 2024 by the date of the event, differences between scheduled and physical flows on several affected TSOs' borders were exceeding 300 MW in nearly 30 % of the time.

Capacity calculations are performed in accordance with established procedure, explained in detail in the Report for System Separation 8 January 2021:

» For the borders not attributed to any of the operational CCRs, TSOs have established a procedure for the creation of a CGM for monthly capacity calculation.

» The NTCs are calculated by each TSO on the SEE regional CGM of the respective border and harmonisation per border, is based on the minimum value proposed by each of the partners.

» The bilateral NTC calculation is conducted for the month ahead.

» The harmonisation of the base-case exchanges of SEE and model merging is performed by one of the involved TSOs in the area (TSO coordinator). The role of TSO coordinator rotates on a monthly basis according to an agreed yearly scheme.

In addition to the monthly calculation of NTCs, some TSOs in the region perform weekly calculations[7], which consider more precise estimations of the system conditions. This is an interim solution applied to improve quality of capacity calculation process and is seen to be used until coordinated capacity calculation on a daily level takes the place.

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[7] Bilateral weekly calculation of NTCs are performed on the EMS–CGES, CGES–KOSTT and OST–CGES borders

2.4.4 Scheduled Commercial Exchanges

Netted values of commercial exchanges between affected TSOs as well as between the affected area and the rest of the region were closely following market signals as reported in the sub-chapter 2.3. Significant commercial exchanges were reported on the East-West route along the Adriatic coast, as a consequence of the lower Day-ahead market prices on the most eastern and the most western price zones, comparing to those in Albania and Montenegro price zones.

Figure 15: Scheduled commercial exchanges for 12th hour, 21 June 2024

2.4.5 Cross-Border Physical Flows

While commercial exchanges followed the market signals, physical flows were significantly different and aligned with the production and load patterns.

Physical flows from Greece to Albania were 518 MW higher than commercial exchange (758 MW comparing to 240 MW). Scheduled export from Montenegro to Albania resulted in physical flows in the opposite direction of 241 MW from Albania to Montenegro. Similarly, the direction was opposite on the Bosnia and Hercegovina – Montenegro border (100 MW from Montenegro to Bosnia and Herzegovina instead of the scheduled 410 MW from Bosnia and Herzegovina to Montenegro), as well as on the Bosnia and Hercegovina – Croatia border (100 MW from Croatia to Bosnia and Herzegovina instead of the scheduled 364 MW from Bosnia and Herzegovina to Croatia). Finally, Croatian import from Slovenia was 617 MW lower than scheduled (406 MW of physical flows compared to 1,023 MW of scheduled commercial exchanges).

In essence, the difference between the scheduled and physical flows (mainly loop-flows, as no significant system disbalances were recorded during the day) alongside the Adriatic coast was present on all the borders in the amount of approximately 500 MW.

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

2.5 Daily Security Analysis

Day-ahead and intra-day analysis are the core of the regional security coordination in the affected area. While security analysis in the medium-term is also performed in a coordinated manner, seasonal outlooks that consider seasonal specifics (such as high temperatures or other seasonal added risks…) are not performed.

The operational security of any power system relies on respecting the operational security limits and on the application of the N-1 Operational Standard, which states that any single contingency should not endanger the system.

Contingency analyses in the affected area are performed by all affected TSOs and respective RCCs pursuant to SOGL Article 34 (Regulation 2017/1485 of the European Commission) that stipulates in particular that:

1. Each TSO shall perform a contingency analysis in its observability area to identify the contingencies which endanger or may endanger the operational security of its control area and to identify the remedial actions that may be necessary to address the contingencies, including the mitigation of the impact of exceptional contingencies.

2. Each TSO shall ensure that potential violations of the operational security limits in its control area which are identified by the contingency analysis do not endanger the operational security of its transmission system or of interconnected transmission systems.

3. Each TSO shall perform a contingency analysis based on the forecast of operational data and on real-time operational data from its observability area. The starting point for the contingency analysis in the N-Situation shall be the relevant topology of the transmission system, which shall include planned outages in the operational planning phases.

According to Agreements on the provision of operational services, which are concluded among SCC and its service users (CGES, OST and NOSBiH from the affected area), CGMs and security analysis results are prepared by SCC and delivered to the TSOs to the dedicated SFTP server.

The results of the security analysis presented in this chapter were extracted from SCCs regular reports, as well as from results for HOPS that belongs to another CCR and SOR.

According to regular procedures, all the elements from the monitoring lists of each TSO that are loaded above 90 % either in base case or after any contingency from the contingency area are listed below.

Presented here are the main results of the conducted security analysis, available to the affected TSOs. A detailed description of the regional security coordination activities and analysis of the results is provided later in the report (chapter 5).

2.5.1 DACF Results

During the critical period (13th hour), no major critical N-1 security violations have been identified in regular daily security analysis in any of the affected TSOs.

The contingency analysis for the Montenegrin system does not identify security violations for the 13th hour. The last contingency is recognised for earlier in the morning (9:30) with the tripping of internal OHL 400 kV Lastva – Podgorica leading to an overload of the tie-line with Albania 220 kV Podgorica 1 – Koplik (107 %), and internal Albanian OHL 220 kV Vau Dejes – Koplik (112 %). However, after that, no contingencies leading to a loading of 90 % and more have been identified until 19:30 of the same day. For all identified contingencies during the day, curative measures have been prepared.

Timestamp	CO Name	CB Name	Loading (%)	L. after (%)	L. after [%]	Snom (MVA)
09:30	OHL 400 kV Lastva - Podgorica 2	OHL 220 kV Vau Dejes - Koplik	67.52	111.68	710	
09:30	OHL 400 kV Lastva - Podgorica 2	TIE 220 kV Podgorica 1 - Koplik (AL)	63.81	106.87	720	
09:30	TIE 400 kV Tirana 2 - Podgorica 2	OHL 220 kV Vau Dejes - Koplik	67.52	96.90	710	
09:30	TIE 400 kV Tirana 2 - Podgorica 2	TIE 220 kV Podgorica 1 - Koplik (AL)	63.81	92.43	720	
19:30	TIE 220 kV Bajina Bašta - Pljevlja 2	TIE 220 kV TS Bistrica - Pljevlja 2 (RS)	73.64	94.79	720	
20:30	TIE 220 kV Bajina Bašta - Pljevlja 2	TIE 220 kV TS Bistrica - Pljevlja 2 (RS)	70.51	90.43	720	

Table 3: DACF Security analysis by SCC for CGES, 21 June 2024, N-1 sorted by time-stamp and loading.

In the Bosnia and Herzegovina system there were some identified overloads in the referent hour, but all referred to the elements at the 110 kV level. No loading after outage higher than 90 % was identified in the 220 kV and 400 kV network, except light overload of 400/220 kV transformers in Obrenovac (102 %), that are within the NOSBiH observability area, but not an internal NOSBiH element. Curative measures have been prepared for the remaining overloads in the 110 kV network.

Time stamp	CO Name	CB Name	Loading_BC (%)	Loading after outage (%)	Imax (A)	Snom (MW)
12:30	OHL 400 kV Lastva - Podgorica 2	OHL 110 kV Ugljevik - Lopare	83.41	114.26	468	
12:30	OHL 400 kV Lastva - Podgorica 2	OHL 110 kV Lopare - Tuzla 3	78.14	108.88	470	
12:30	OHL 110 kV Ugljevik - Bijeljina 2	OHL 110 kV Ugljevik - Lopare	83.41	105.75	468	
12:30	OHL 110 kV Bijeljina 1 - Bijeljina 2	OHL 110 kV Ugljevik - Lopare	83.41	105.37	468	
12:30	OHL 110 kV Ugljevik - Zvornik	OHL 110 kV Ugljevik - Lopare	83.41	103.79	468	
12:30	OHL 220 kV TE Tuzla G6 - Tuzla 4	OHL 110 kV Ugljevik - Lopare	83.41	102.90	468	
12:30	TR 400/220 kV Obrenovac (3)	TR 400/220 kV Obrenovac (2)	71.16	102.23		400
12:30	TR 400/220 kV Obrenovac (2)	TR 400/220 kV Obrenovac (3)	70.58	101.75		400
12:30	TIE 220 kV Međurić - Prijedor	OHL 110 kV Ugljevik - Lopare	83.41	100.50	468	
12:30	OHL 110 kV Ugljevik - Bijeljina 2	OHL 110 kV Lopare - Tuzla 3	78.14	100.26	470	
12:30	OHL 110 kV Bijeljina 1 - Bijeljina 2	OHL 110 kV Lopare - Tuzla 3	78.14	99.88	470	
12:30	OHL 110 kV Ugljevik - Zvornik	OHL 110 kV Lopare - Tuzla 3	78.14	98.30	470	
12:30	OHL 110 kV Bijeljina 3 - Bijeljina 1	OHL 110 kV Ugljevik - Lopare	83.41	98.23	468	
12:30	TR 400/110 kV Ugljevik	TIE 110 kV Županja - Orašje (HR)	66.65	98.00	439	
12:30	OHL 110 kV Ugljevik - Zvornik	OHL 110 kV Ugljevik - Bijeljina 2	72.72	97.82	600	
12:30	OHL 110 kV Banja L6 - Banja L1 (2)	OHL 110 kV Banja L6-Banja L1 (1)	55.16	97.72	468	
12:30	OHL 220 kV TE Tuzla G6 - Tuzla 4	OHL 110 kV Lopare - Tuzla 3	78.14	97.57	470	
12:30	TIE 220 kV Međurić - Prijedor	OHL 110 kV Lopare - Tuzla 3	78.14	95.18	470	
12:30	OHL 400 kV Ribarevine - Podgorica 2	OHL 110 kV Ugljevik - Lopare	83.41	94.82	468	
12:30	OHL 400 kV Kosovo B - Peć 3	OHL 110 kV Ugljevik - Lopare	83.41	94.67	468	
12:30	TIE 400 kV Peć 3 - Ribarevine	OHL 110 kV Ugljevik - Lopare	83.41	93.67	468	
12:30	OHL 220 kV Međurić - TPP Sisak	OHL 110 kV Ugljevik - Lopare	83.41	93.61	468	
12:30	TIE 220 kV Sarajevo 20 - HE Piva	OHL 110 kV Ugljevik - Lopare	83.41	93.26	468	
12:30	TR 400/220 kV Sarajevo 20 (1)	OHL 110 kV Ugljevik - Lopare	83.41	93.26	468	
12:30	OHL 110 kV Bijeljina 3 - Bijeljina 1	OHL 110 kV Lopare - Tuzla 3	78.14	92.87	470	
12:30	OHL 110 kV Brčko 2 - Bijeljina 3	OHL 110 kV Ugljevik - Lopare	83.41	92.40	468	
12:30	OHL 400 kV Bor 2 - HE Đerdap 1	OHL 110 kV Ugljevik - Lopare	83.41	92.34	468	
12:30	TR 400/110 kV Ugljevik	TIE 110 kV Županja - Orašje (BA)	62.26	91.54	470	
12:30	OHL 400 kV Bor 2 - Niš 2	OHL 110 kV Ugljevik - Lopare	83.41	90.77	468	
12:30	OHL 220 kV Konjsko - VE Krš-Pađene	OHL 110 kV Ugljevik - Lopare	83.41	90.40	468	
12:30	OHL 400 kV TE Gacko - Mostar 4	OHL 110 kV Ugljevik - Lopare	83.41	90.29	468	
12:30	OHL 220 kV Brinje - VE Krš-Pađene	OHL 110 kV Ugljevik - Lopare	83.41	90.18	468	

Table 4: DACF Security analysis by SCC for NOSBiH, 21 June 2024, N-1 sorted by time-stamp and loading.

In the Albanian system, there were some more identified overloads in the referent hour, but again most of them referred to the elements on the 110 kV level. The only loading after an outage higher than 90 % identified in the 220 kV and 400 kV network refers to the 220/110 kV transformers in substation Tirana 2. This overload, as well as the overload of the 150 kV TIE Mourtos (GR) – Bistrica (AL) that was identified in the case of the outage of TIE 400 kV Zemlak – Kardia (133 %), has no propagation potential and only impacts the local consumption. Curative measures have been prepared for all the identified overloads.

It is worth noting that most of the internal 400 kV elements of all affected TSOs are parts of the contingency lists of the neighbouring TSOs (e. g. internal Montenegrin OHL 400 kV Ribarevine-Podgorica 2 is part of the contingency lists of CGES, OST, EMS, NOSBiH and MEPSO).

Time stamp	CO Name	CB Name	Loading_BC (%)	Loading after outage (%)	Imax (A)	Snom (MVA)
12:30	OHL 110 kV Tirana 1 - Traktora	OHL 110 kV Ibe - Farke	57.65	158.90	336	
12:30	OHL 110 kV Tirana 1 - Traktora	OHL 110 kV Ibe - Elbasan 1	53.07	142.74	383	
12:30	OHL 400 kV Zemlak - Elbasan 2	OHL 110 kV Krahes - Memaliaj	49.22	137.78	383	
12:30	OHL 400 kV Zemlak - Elbasan 2	OHL 110 kV Ballsh - Krahes	47.83	136.44	383	
12:30	TIE 400 kV Kardia - Zemlak	TIE 150 kV Mourtos - Bistrica (AL)	64.60	133.55	360	
12:30	TIE 400 kV Kardia - Zemlak	TR 150/110 kV Bistrica	61.73	124.88		100
12:30	OHL 110 kV Tirana 1 - Traktora	OHL 110 kV Traktora - Farke	29.49	120.92	336	
12:30	TR 220/110 kV Tirana 2 (1)	TR 220/110 kV Tirana 2 (2)	74.15	111.62		120
12:30	TR 220/110 kV Tirana 2 (2)	TR 220/110 kV Tirana 2 (1)	74.15	111.62		120
12:30	TIE 400 kV Kardia - Zemlak	TIE 150 kV Mourtos - Bistrica (GR)	51.91	106.89	450	
12:30	OHL 110 kV Tirana 2 - Kombinat	OHL 110 kV Selite - Tirana 2	41.77	99.43	645	
12:30	400 kV Elbasan 2 busbar fault	TIE 150 kV Mourtos - Bistrica (AL)	64.60	98.68	360	
12:30	OHL 400 kV Zemlak - Elbasan 2	TIE 150 kV Mourtos - Bistrica (AL)	64.60	97.42	360	

Table 5: DACF Security analysis by SCC for OST, 21 June 2024, N-1 sorted by time-stamp and loading.

In the Croatian power system, no loading higher than 90 % has been identified in the 220 kV and 400 kV network, while curative measures have been prepared for the remaining light overloads in the 110 kV network.

In general, it may be concluded that the day-ahead security analysis process was not implying a more critical than usual system state in the affected area. In particular, DACF analyses have shown that an outage of OHL 400 kV Ribarevine – Podgorica 2 was not causing any critical branch loading in Montenegro as well as in Albania. Hence, the outage was not identified as critical in either of the two concerned systems.

2.5.2 IDCF Security Analysis Results

Following the DACF process, each considered TSO participates in the IDCF process, receiving security analysis based on the intra-day grid models. On 21 June, no major changes in power flows and the results of the IDCF Security analysis were noted. The similarity of the results is checked by comparing final – CB–CO lists of the DACF and IDCF analysis.

2.5.3 Security Analysis accuracy

The accuracy of all the conducted regional security analysis is supported by the results of conducted individual TSOs security analysis as well as by comparison of realised real-time power flows and calculated base-case flows.

Selected examples from 9:30 on 21 June do confirm the quality of the DACF Common Grid Model (Figure 17) as the difference was fairly within the operationally acceptable margin.

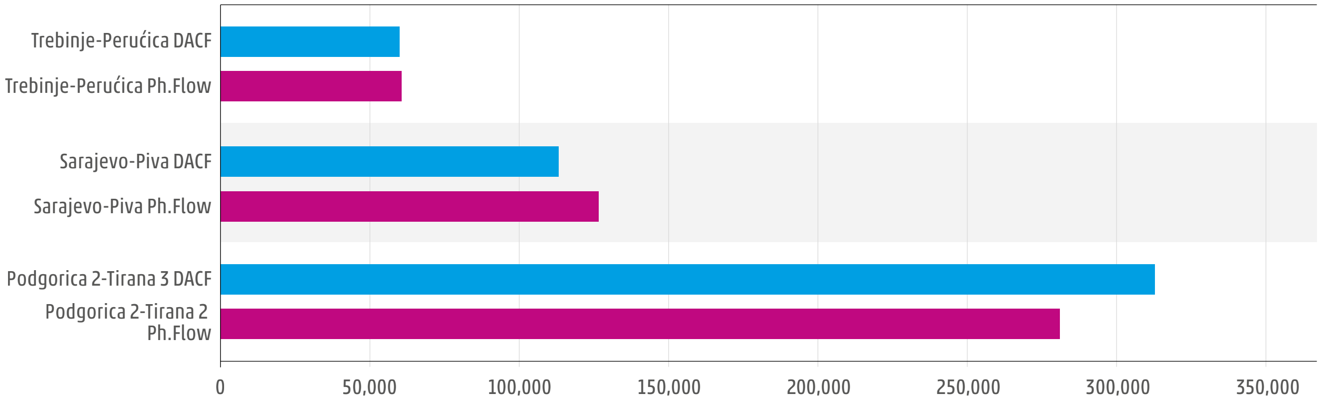

Figure 17: Comparison of realised physical power flows (orange) and DACF calculated base-case flows (green) at 9:30 on 21 June 2024 [MW]

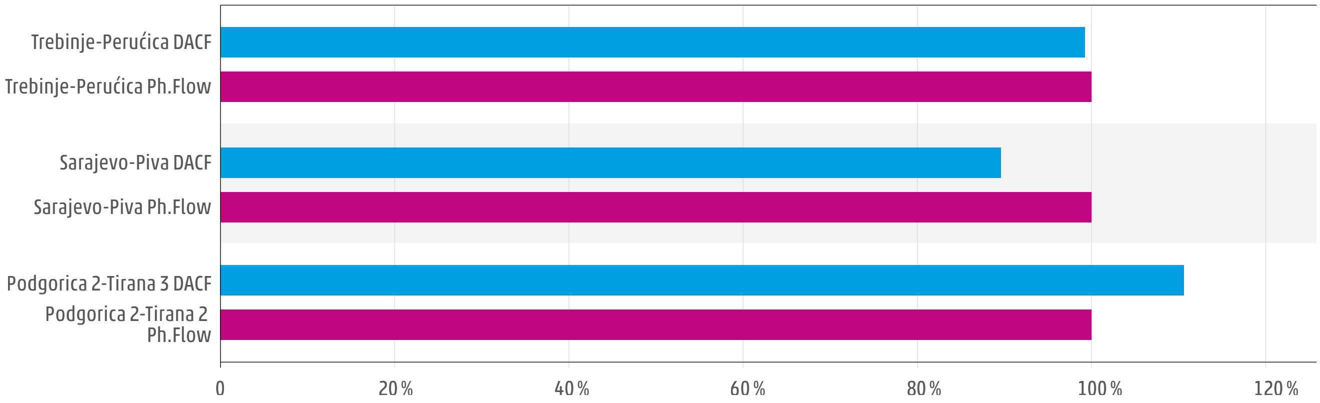

Figure 18: Difference between realised physical power flows and DACF calculated base-case flows at 9:30 on 21 June 2024 (%)

2.5.4 Real-Time Security Analysis Results

only in the 110 kV networks of the affected TSOs. Some convergence issues have been observed only after 12:20.

It should be noted here that individual observability zones of the affected TSOs do not cover all the critical elements of the event. In particular, NOSBiH observability area ends on the CGES–OST border, while CGES observability area ends on OST–IPTO interconnection 400 kV Zemblak – Kardia, modelling it only as a power-flow injection to the network equivalent. Hence, in both of those cases the outage of the TIE 400 kV Zemblak – Kardia was not part of the contingency analysis. Internal CGES' 400 kV OHL Ribarevine – Podgorica 2 is within OST's observability area. However, this outage was not indicated as critical in OST's real-time security analysis.

2.5.5 Remedial Actions Coordination for DACF/IDCF/RT

No specific topological measures were implemented as preventive measures to cope with the specific condition described in this chapter before the initial outage.

TSOs of the region that are SCC service users do have an established procedure for extraordinary daily operational planning teleconferences (DOPT) in case critical outages are identified. During 21 June until the incident, the conditions for the organisation of DOPT were not met.

3 EVOLUTION OF SYSTEM CONDITIONS DURING THE EVENT

3.1 Factual Sequence of Events

This section presents the factual evolution of the disturbance that unfolded on 21 June 2024.

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

Table 6: Factual sequence of (significant) events; * indicates outages in HOPS on 110 kV network that led to loss of voltage on 220 kV; abbreviations: OHL…overhead line, OHL-TIE…overhead line tie line, DCC-TIE…DC cable tie line, UV…under-voltage, OC…overcurrent, DIFF…differential protection, DIST…distance protection, MAN.. Manual Disconnection

The draft version of **Blackout sequence video (link1 +link2)** represents the sequence of events as recorded on SCADA/EMS display of JSC EMS during the period between 12:08 and 12:26. Time of recording can be seen on the top of the display.

The geographical map of the region in Figure 19 visualises the sequence of events. The colour indicates the time of disconnection. The number shows the exact order of outages and is linked to the Outage IDs of Table 7. The planned outages disconnected prior to the disturbance are highlighted in grey and designated by the capital letter M (maintenance). The disconnection of OHL Višegrad–Tuzla 4 is marked as O (other), due to the OHL being disconnected because of high voltages in the NOSBiH grid the previous night.

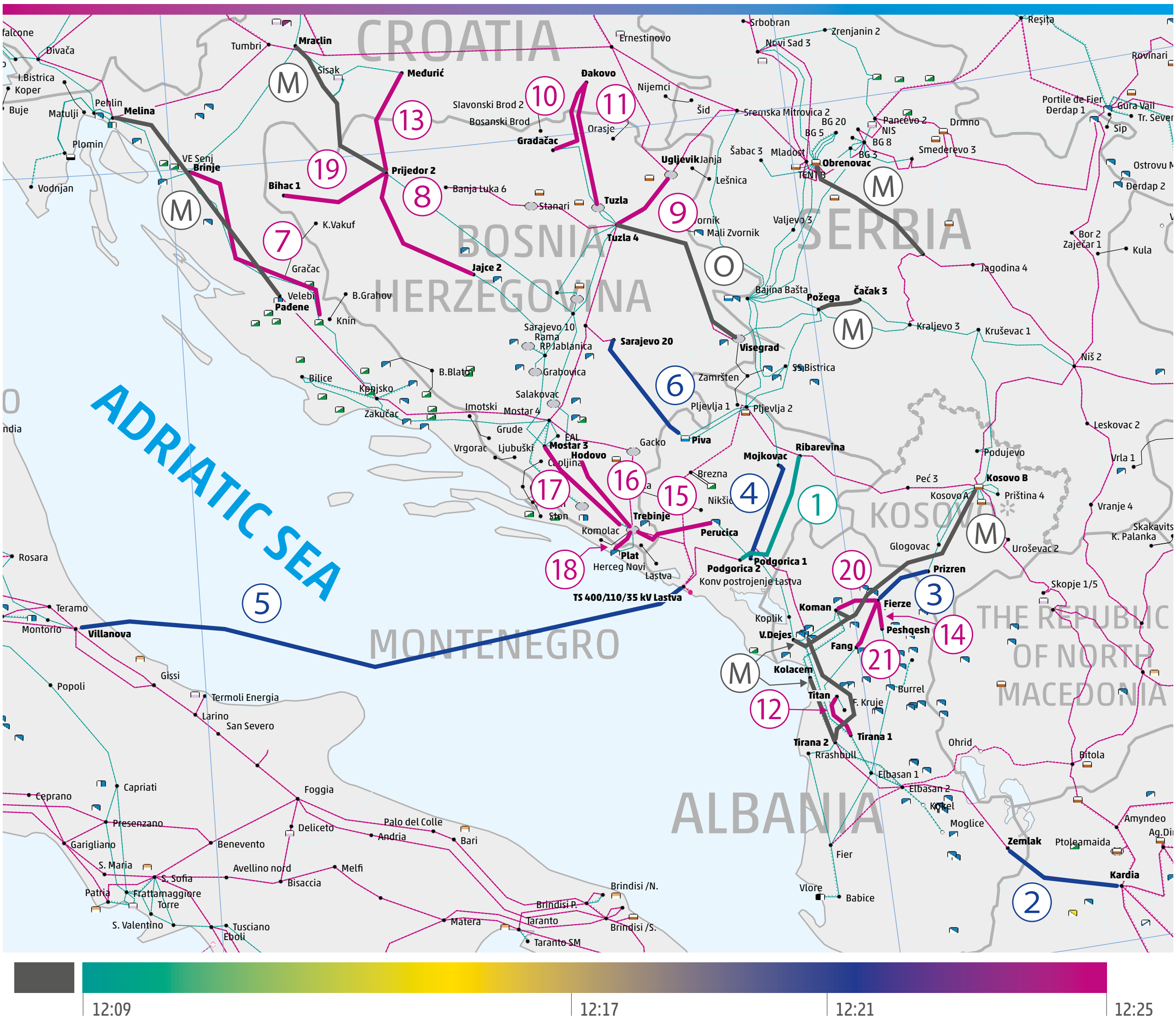

Figure 19: Map with outages indicated in different colours related to their respective outage times; grey means that the lines have already been disconnected prior to the event due to maintenance (M) or other (O) reasons.

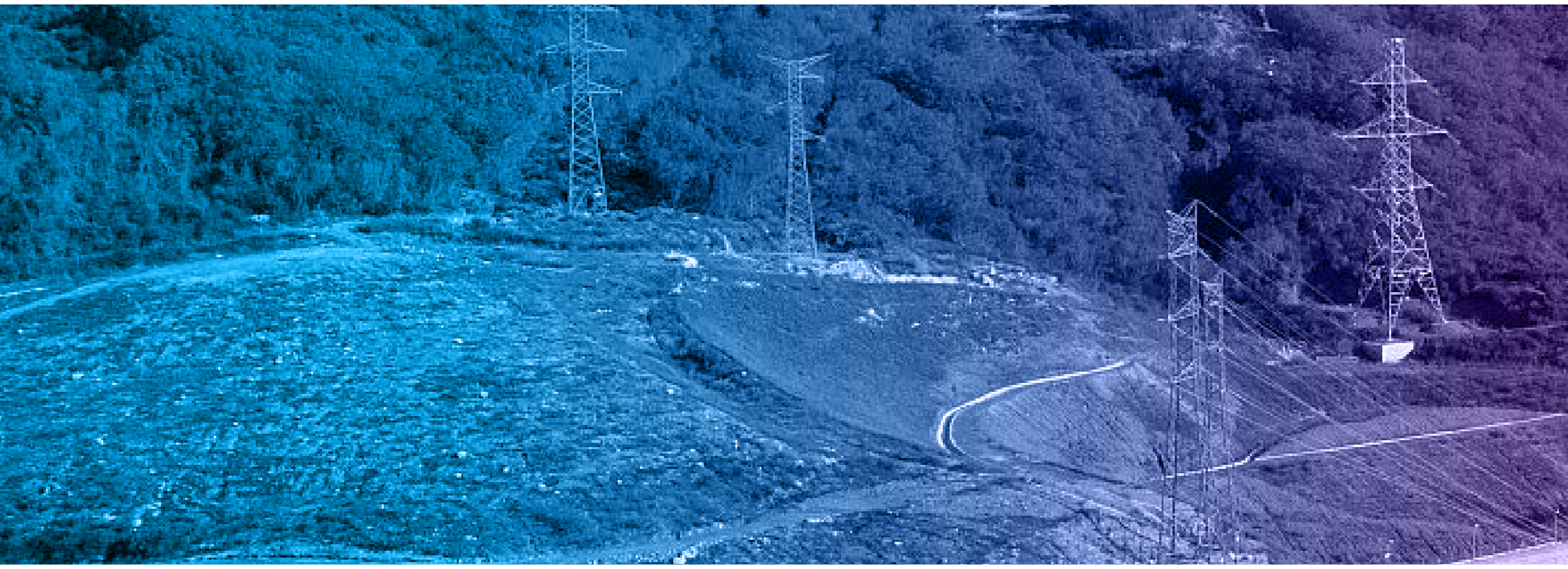

Figure 20 shows the sequence of events together with the voltage trajectory in substation Trebinje (NOSBiH) and in substation Tumbri (HOPS).

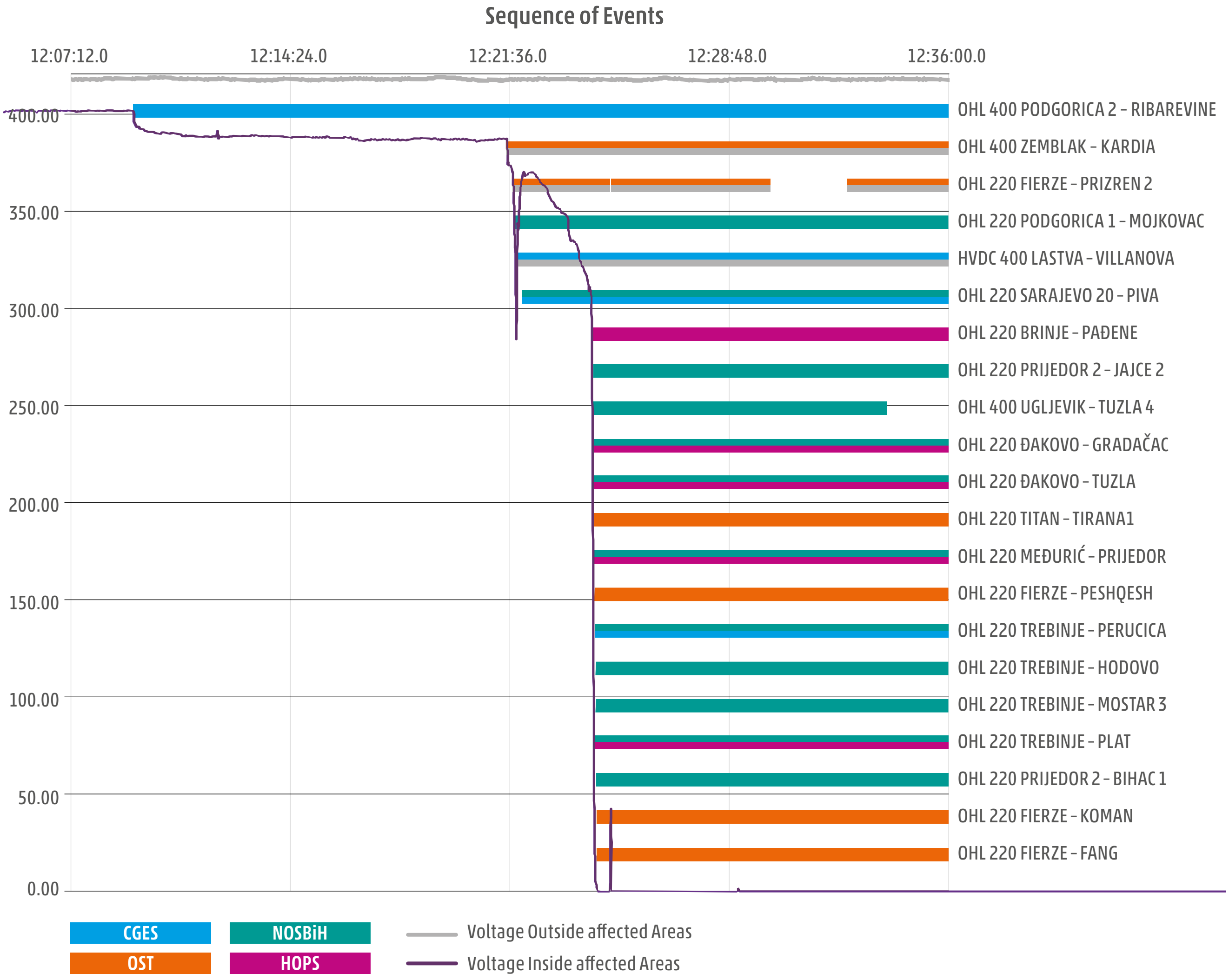

Figure 20: Sequence of Events plotted over voltage in substation Trebinje (NOSBiH) PMU data (purple) and voltage in substation Tumbri (HOPS); the length of the horizontal bars indicates the duration of the outage; two-colour bars indicate tie-lines (OHL 220 kV Fierze–Prizren, the separation of the bar indicates switching during restoration).

3.2 Generation and Load

This section presents details on the loss of load and generation during the event. Before the blackout, the affected area had an estimated active power dispatch of 2.2 GW.

Figure 21 shows the loss of generation in a chronological order.

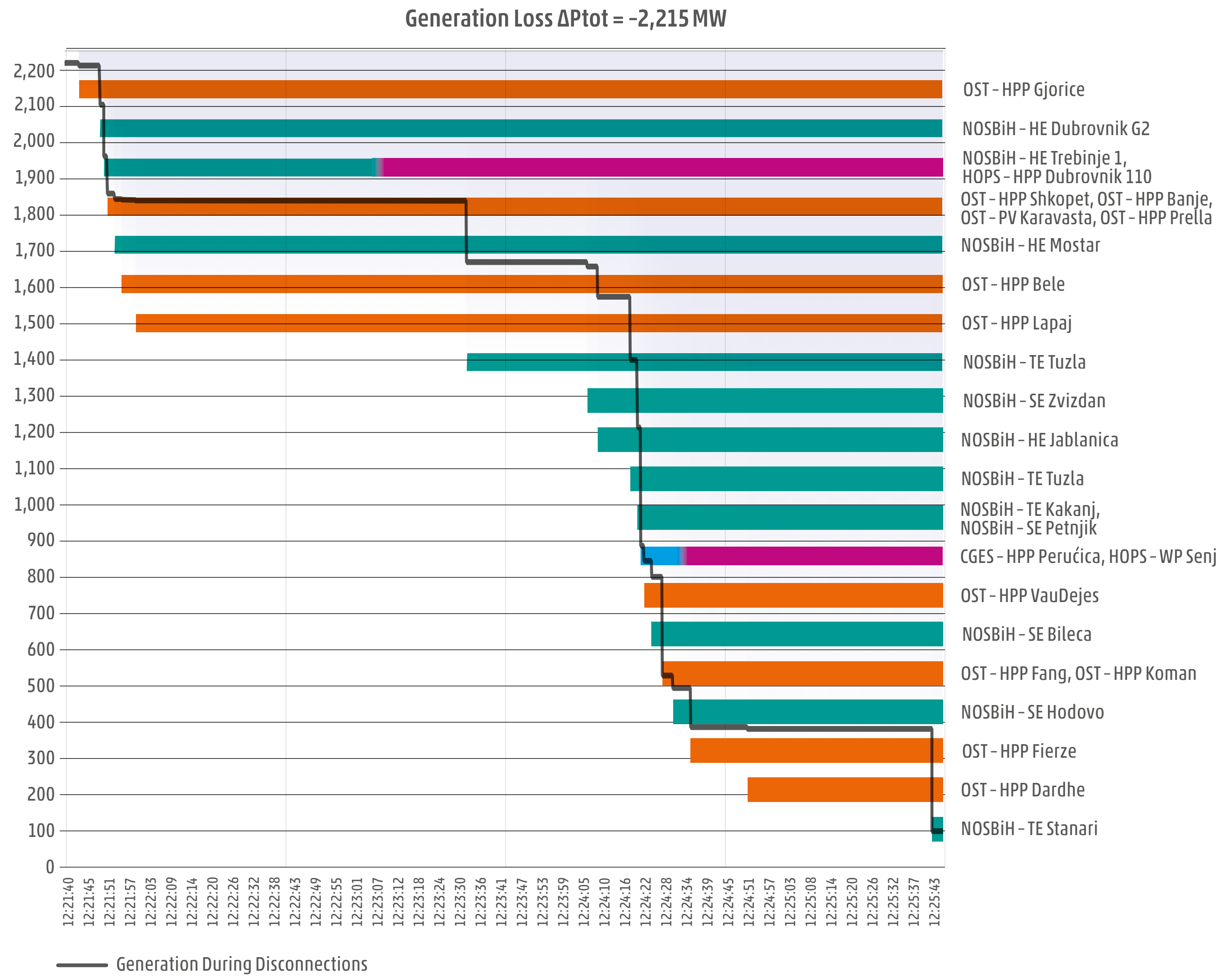

Figure 21: Loss of generation in chronological order.

Figure 22 shows the loss of generation for the affected TSOs.

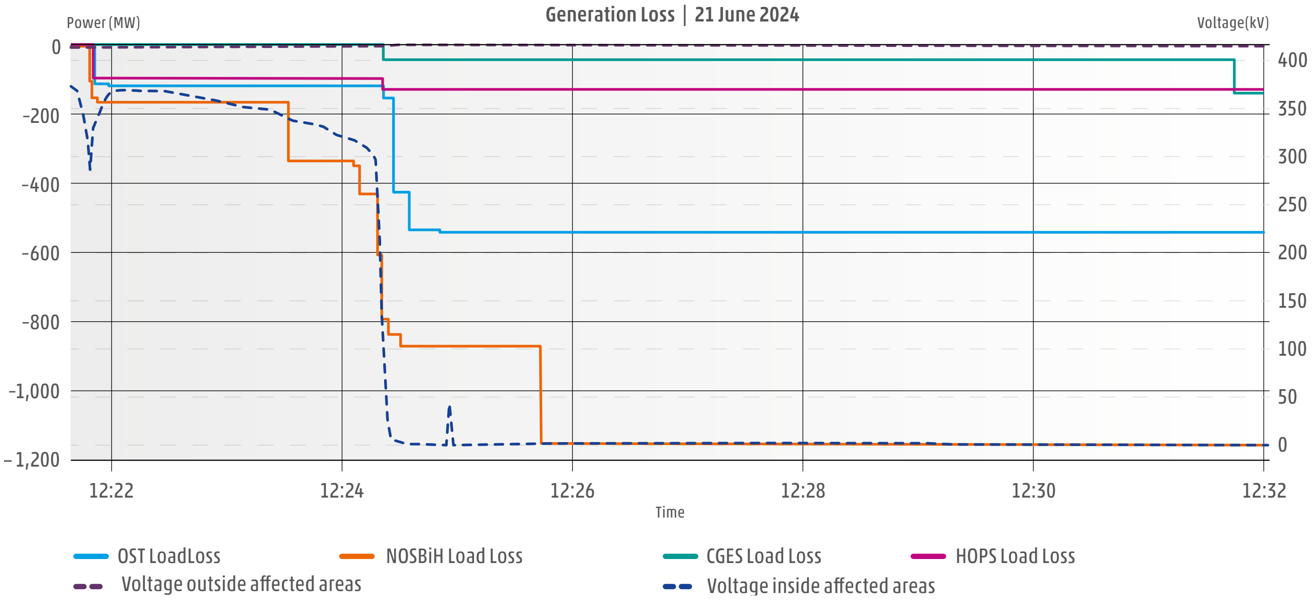

Figure 22: Loss of generation of different affected TSOs; including exemplary voltage within and outside of the affected area.

Following the occurrence of three outages within a brief interval, OHL 400 kV Ribarevine–Podgorica 2 at 12:09:16, OHL 400kV Zembla–Kardia at 12:21:33 and Fierze–Prizren at 12:21:43, a rapid voltage drop resulted in a significant loss of generation in the affected area. At 12:21:52, OST had a generation loss of 109 MW and at 12:21:54 NOSBiH recorded a generation loss of 167 MW, while HOPS recorded a generation loss of 97 MW and CGES reported a generation loss of 113 MW.

The voltage drops at 12:24 resulted in a substantial loss of load in the affected area. Subsequently, at 12:24:21, a severe voltage drop that reduced voltage to zero resulted in a generation loss of 2,214 MW in the affected area.

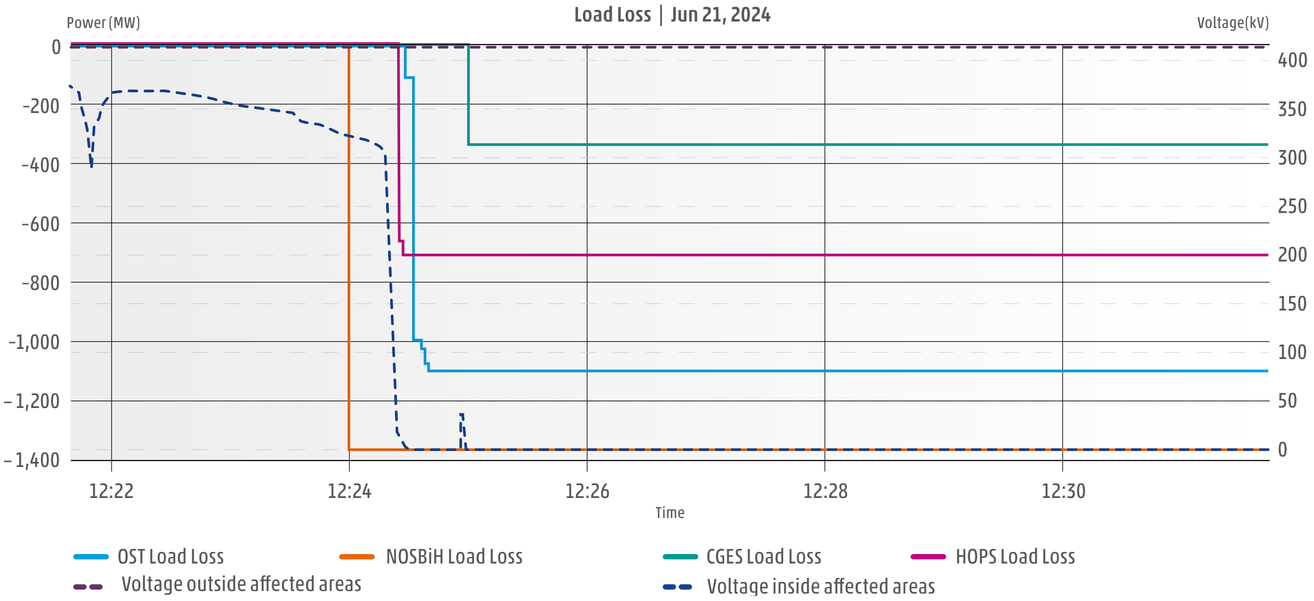

Figure 23: Loss of load of different affected TSOs; including exemplary voltage within and outside of the affected area.

3.2.1 List of Generation Units Disconnected

Table 8 shows the list of generation units with an installed capacity >25 MW, which disconnected during the event.

TSO	Generation Type	Powerplant	Actual Generation (MW)	Gen Unit	Time of disconnection	Reason of disconnection
OST	Hydro	HPP Fierze	109	G1	12:24:36	Voltage Control Overcurrent Protection, Impedance Protection
OST	Hydro	HPP Vau Dejes	40	G5	12:24:23	Pole Slip
OST	Hydro	HPP Fang	61	G1	12:24:28	Impedance Protection, Overcurrent Protection, Undervoltage Protection, Over frequency protection
				G2	12:24:28	Over frequency protection
OST	Hydro	HPP Koman	211	G1	12:24:28	Overcurrent Protection
				G4	12:24:28	Overcurrent Protection
OST	Solar	PV Karavasta	94	N/A	12:21:52	Undervoltage protection
CGES	Hydro	HPP Perucica	113	G2	12:24:22	overcurrent protection
				G3	12:24:22	impedance protection
				G4	12:24:22	overcurrent protection
HOPS	Wind	WPP Senj	33.8	N/A	12:24:22	Undervoltage protection
HOPS	Hydro	HPP Dubrovnik	97	G1	12:21:48	Overcurrent protection of connecting line
NOSBiH	Hydro	HPP Dubrovnik	107	G2 (G2 is working for NOSBiH)	12:21:51	Undervoltage protection
NOSBiH	Hydro	HPP Trebinje 1	46	G3	12:21:51	Undervoltage protection
NOSBiH	Thermal	TPP Tuzla	169	G5	12:23:33	Undervoltage protection
NOSBiH	Hydro	HPP Jablanica	85	G4	12:24:10	Voltage-dependent overcurrent protection
NOSBiH	Thermal	TPP Tuzla	173	G4	12:24:19	Undervoltage protection
NOSBiH	Thermal	TPP Kakanj	81	G5	12:24:21	Undervoltage protection
NOSBiH	Thermal	TPP Kakanj	85	G6	12:24:21	Undervoltage protection
NOSBiH	Solar	SPP Bileca	45	G1	12:24:25	Undervoltage protection
NOSBiH	Solar	SPP Hodovo	34	G1	12:24:31	Undervoltage protection
NOSBiH	Thermal	TPP Stanari	282	G1	12:25:44	Undervoltage protection

Table 7: List of generation units above 25 MW that disconnected.

3.2.2 Loss of Load

NOSBiH experienced a load loss of approximately 1,365 MW at 12:24. At 12:24:21, HOPS reported a load loss of approximately 700 MW. At 12:25, CGES observed a load loss of approximately 338 MW, while OST recorded a load loss of approximately 1,102 MW at 12:24:24. The data indicate that all affected TSOs experienced the load loss within a duration of less than one minute. The total load loss was approximately 3.5 GW.

3.2.3 Other Consequences of the Blackout

The TSOs affected by the blackout did not report any personal injuries or property damages due to the event. None of the TSOs have conducted an economic estimation of the economic loss of the blackout.

3.2.4 Load Shedding

There was no low frequency or undervoltage demand disconnection (LFDD, LVDD) during the incident. Moreover, no manual load shedding was applied.

3.3 Functioning of the Transformers during the Incident

In this chapter, the functioning of the transformer during the incident is analysed, and to do so, some of the most important information related to the voltage levels used in each control area, and for the transformers that connect these levels, are listed.

The transmission network under the control of CGES consists of 400 kV, 220 kV and 110 kV voltage levels, while voltage levels of 35 kV and below are under the responsibility of the distribution system operator. All transformers connecting transmission voltage levels (400/220 kV, 400/110 kV and 220/110 kV) are regulated manually, while transformers connecting transmission and distribution networks (110/x kV) are regulated mostly automatically, whereby the lower voltage level is regulated.

The transmission network under the control of HOPS consists of 400 kV, 220 kV and 110 kV voltage levels, while voltage levels of 35 kV and below are under the responsibility of the distribution system operator. Transformers 400/220 kV are regulated manually, and transformers 400/110 kV are regulated automatically, whereby the lower voltage level is regulated. Transformers 220/110 kV are regulated manually in some substations, and in others automatically (the lower voltage level is regulated), depending on the needs of a specific location in the network. Transformers connecting transmission and distribution networks (110/x kV) are regulated automatically, whereby the lower voltage level is regulated.

The transmission network under the control of NOSBiH consists of 400 kV, 220 kV and 110 kV voltage levels, while voltage levels of 35 kV and below are under the responsibility of the distribution system operators. Transformers 400/220 kV and 400/110 kV are regulated manually. Transformers 220/110 kV are regulated manually in all substations except in SS Mostar 4, where they are regulated automatically, whereby the lower voltage level is regulated. Transformers connecting transmission and distribution networks (110/x kV) are regulated automatically, whereby the lower voltage level is regulated.

The transmission network under the control of OST consists of 400 kV, 220 kV, 150 kV and 110 kV voltage levels, while voltage levels of 35 kV and below are under the responsibility of the distribution system operator. All transformers connecting transmission voltage levels (400/220 kV, 400/110 kV, 220/110 kV and 150/110 kV) and transformers connecting transmission and distribution networks (220/x kV and 110/x kV) are regulated manually

In summary, the reaction of automatic voltage regulation could be expected only at the following transformers:

- **CGES control area:** the greater part of transformers 110/x kV;
- **HOPS control area:** all transformers 400/110 kV, some transformers 220/110 kV and all transformers connecting transmission and distribution network;
- **NOSBiH control area:** transformers 220/110 kV in SS Mostar 4 and all transformers 110/x kV; and
- **OST control area:** none of the transformers.

In the following, the reaction of the transformer is described in correlation with certain events from the sequence of events, as listed in chapter 3.1. However, not every correlation can be confirmed with complete certainty, considering that some other events with an impact on the system could have occurred at the same time, which do not fall within the scope of the data analysed here.

Before the initial event, it was a steady state situation, with only a few changes in the position of the transformer tap changers, which can be considered normal daily operation.

3.3.1 Outage 1: 12:09:16: 400 kV Ribarevine – Podgorica 2

The consequence of this outage is a drop in the voltage level in the southern part of the CGES control area up to 10 kV in the 400 kV network (SS Podgorica 2: 404 kV → 394 kV), up to 6 kV in the 220 kV network (SS Podgorica 1: 227 kV → 221 kV) and up to 3 kV in the 110 kV network. That caused the change of the position of some transformers 110/x kV tap changers (here and after, it is always a change to a higher position, which means that for a reduced voltage on the high voltage side, an attempt is made to maintain the same voltage on the low voltage side), and the situation stabilised in a new stationary state.

In the HOPS control area, the consequences of this outage were felt only at the southern end of the network around the city of Dubrovnik, which is electrically stronger connected to the southern part of the NOSBiH control area than to the rest of the HOPS control area. Transformer tap changers 220/110 kV in SS Plat changed their position by 2 or 3 steps. In the same substation transformer tap changers 110/35 kV changed their position by 1 step and those were the only changes that can be related with this outage.

In the NOSBiH control area, the transformer tap changers 220/110 kV in SS Mostar 4 responded to a voltage change of about 2 kV moving by one step. Transformer tap changers in substations 110/x kV in the southern part of the NOSBiH control area reacted by changing their position by 1 step and/or they did not react at all.

In the OST control area, a voltage drop was relatively significant, up to 7 kV in the 400 kV network, up to 5 kV in the 220 kV network and up to 3 kV in the 110 kV network, but as none of the transformers are in automatic voltage regulation and also the operators did not change any tap changer manually, there were no changes of the position of any transformer tap changers.

3.3.2 Outage 2: 12:21:33 400 kV Zemblak – Kardia

The consequence of this outage was a drop in the voltage level in the southern part of the CGES control area up to 15 kV in the 400 kV network (SS Podgorica 2: 388 kV → 373 kV), up to 11 kV in the 220 kV network (SS Podgorica 1: 221 kV → 210 kV) and up to 6 kV in the 110 kV network. Transformer tap changers in substations 110/x kV where automatic voltage regulation is applied reacted by changing the tap position, but not more than one step.

In the HOPS control area, the consequences of this outage were a drop in the voltage level in Dalmatia up to 8 kV in the 400 kV network, up to 5 kV in the 220 kV network and up to 2 kV in the 110 kV network. There was a very small voltage drop in the continental part of Croatia. Not a single transformer in automatic voltage regulation reacted to these voltage changes.

In the NOSBiH control area, voltage drop was up to 12 kV in the 400 kV network near to CGES control area (SS Trebinje: 396 kV → 384 kV), up to 4 kV in the 220 kV network (SS Trebinje: 227 kV → 223 kV) and up to 3 kV in the 110 kV network. There was no reaction of transformer tap changers in SS Mostar 4. Transformer tap changers in substations 110/x kV where automatic voltage regulation is applied mostly did not react.

In the OST control area, a voltage drop several seconds after the outage was up to 23 kV in the 400 kV network (SS Zemblak: 414 kV → 391 kV), up to 12 kV in the 220 kV network and up to 7 kV in the 110 kV network. Because one of the transformers are in automatic voltage regulation and also the operators did not change any tap changer manually, there were no changes of the position of any transformer tap changers.

3.3.3 Outages 3, 4, 5 and 6: 12:21:43 220 kV Fierze – Prizren, 12:21:45 220 kV Podgorica 1 – Mojkovac, 12:21:51 MONITA cable and 12:22:02 220 kV Sarajevo 20 – Piva

As these four outages occurred in a short period and considering the speed of changing the position of the transformer tap changers, the transformer reaction was analysed as a reaction to all events simultaneously. Furthermore, on the basis of high-resolution data from the PMUs, it is known that the first two outages caused a voltage drop, while the MONITA cable outage briefly increased local voltages.

In the CGES control area there was a further voltage drop in all voltage levels, where, with a local short-term recovery after the MONITA cable outage, by the time of the next outage the voltages dropped slightly to around 310 kV in the 400 kV network, to around 180 kV in the 220 kV network and to around 85–90 kV in the 110 kV network. In almost all substations 110/x kV where automatic voltage regulation is applied, transformer tap changers reacted by changing tap position.

In the HOPS control area, in Dalmatia, voltages decreased; in addition, and with a local short-term recovery after the MONITA cable outage, by the time of the next outage the voltages dropped in the 400 kV network (SS Velebit: 270 kV), to around 150 kV in the 220 kV network, and to levels 80–90 kV in the 110 kV network. Voltage drop also occurred in the continental part of Croatia, so voltages decreased in SS 400/110 kV Ernestinovo to 368 kV and in SS 220/110 kV Međurić to 198 kV. In all substations where automatic voltage regulation is applied, transformer tap changers reacted by changing tap position, often reaching the final step.

In the NOSBiH control area a further voltage drop occurred at all voltage levels as well, to the values slightly higher than in the southern parts of the CGES and HOPS control areas. Transformer tap changers in substations 110/x kV where automatic voltage regulation is applied reacted by changing tap position by several steps.

In the OST control area, an interesting situation occurred that after the voltage drop after outages 3 and 4, the MONITA cable outage (outage 5) recovered voltages locally mostly to levels higher than before the outage 3. Nevertheless, by the time of the next outage the voltages dropped in the 400 kV network to around 340 kV, in the 220 kV network to 175–190 kV and in the 110 kV network to 85–95 kV. Because none of the transformers are in automatic voltage regulation and also the operators did not change any tap changer manually, there were no changes of the position of any transformer tap changers.

3.3.4 Outage 7, 8 and 9: 12:24:22 220 kV Brinje – Pađene, 400 kV Ugljevik – Tuzla 4 and 220 kV Prijedor 2 – Jajce 2

In 3–4 seconds, before the moment of no voltage in all control areas, a sudden drop in voltage occurred. Transformer tap changers in substations where automatic voltage regulation is applied and which were not previously in the final step reacted automatically, but due to the short period this did not happen in all substations.

3.3.5 Post-Blackout

In substations where automatic voltage regulation is applied that remained under voltage and are located near the area where the blackout occurred (the northern part of CGES control area and the bigger part of HOPS control area), the transformer tap changers reacted automatically so that they again took on a new stationary state, ensuring voltage within normal limits.

3.4 Evolution of Electrical Quantities

This chapter shows the evolution of relevant electrical quantities shortly before and during the incident. The plots here are limited to the 220 kV and 400 kV networks.

3.4.1 Active and Reactive Power Flows

This subchapter deals with the flows of active and reactive power on relevant tie lines in the 400 kV and 220 kV network. Figure 24 shows the line loadings of the lines with outage ID1 and ID2 that triggered the cascading disconnections of the subsequent lines and assets. The loadings of each line are given relative to their maximum thermal capacity. Broadly speaking, apparent power in AC power systems is the total power supplied by the source, combining both the actual usable power (called active power) and the extra power that flows back and forth and cannot be used directly (reactive power).

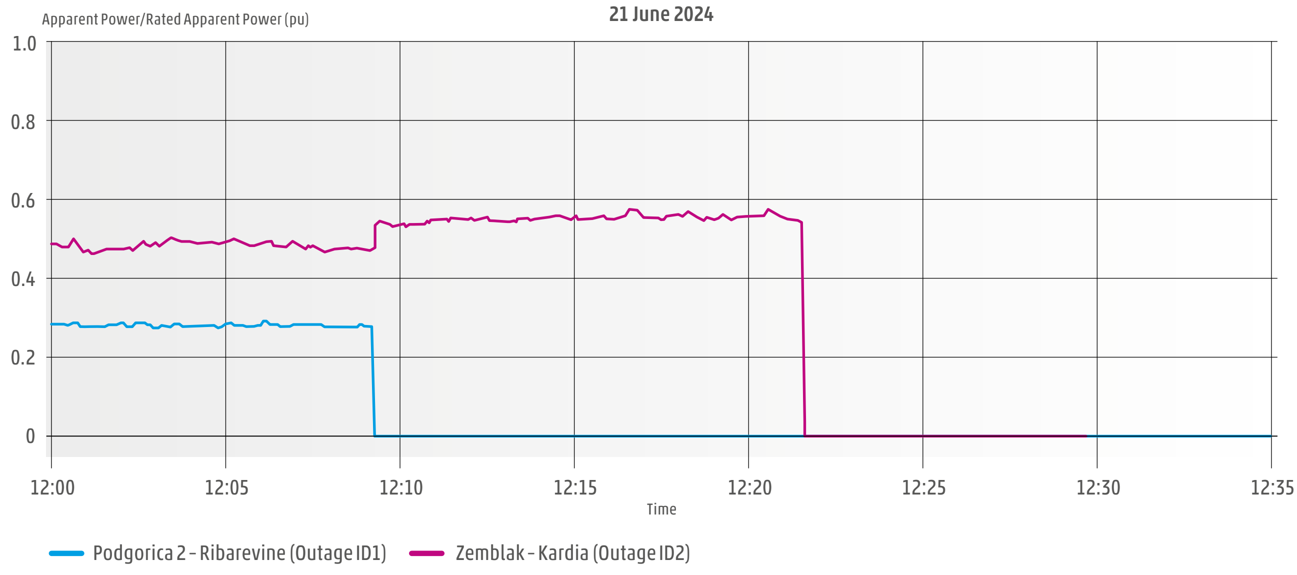

Figure 24: Evolution of line loadings (apparent power) of the lines with outage ID1 and ID2 whose outages triggered the cascading disconnections.

3.4.1.1 CGES (Montenegro)

Figure 25 and Figure 26 show the line loadings within the CGES control area relative to their thermal capacity limits.

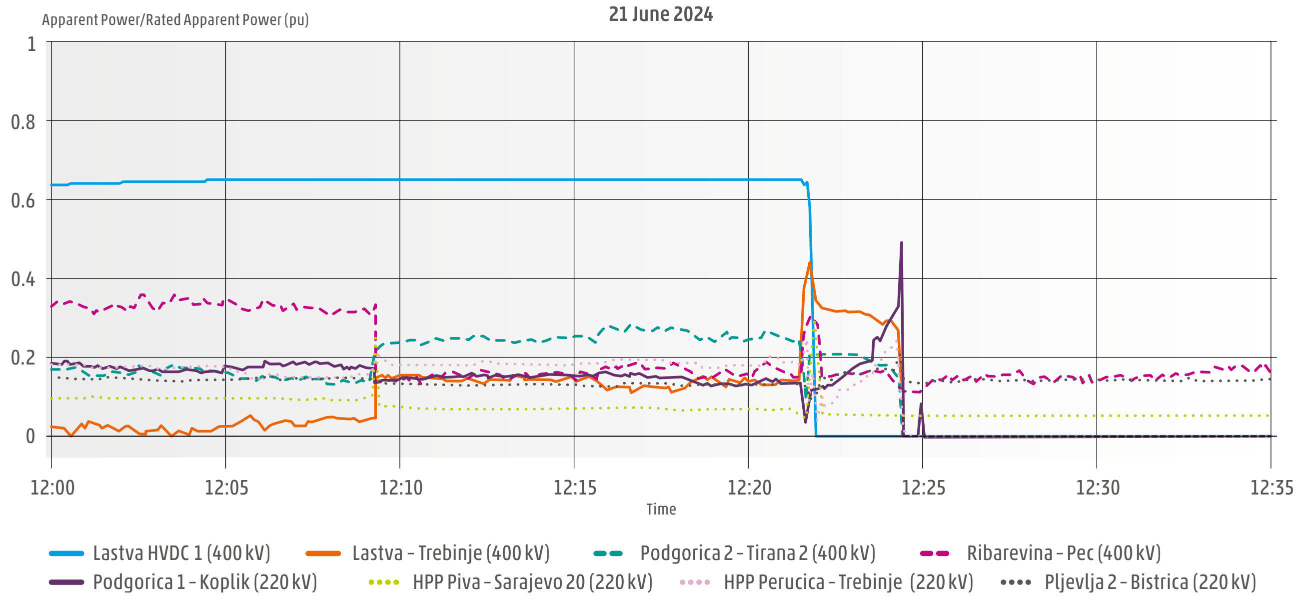

Figure 25: Evolution of line loadings (active power) in the CGES network.

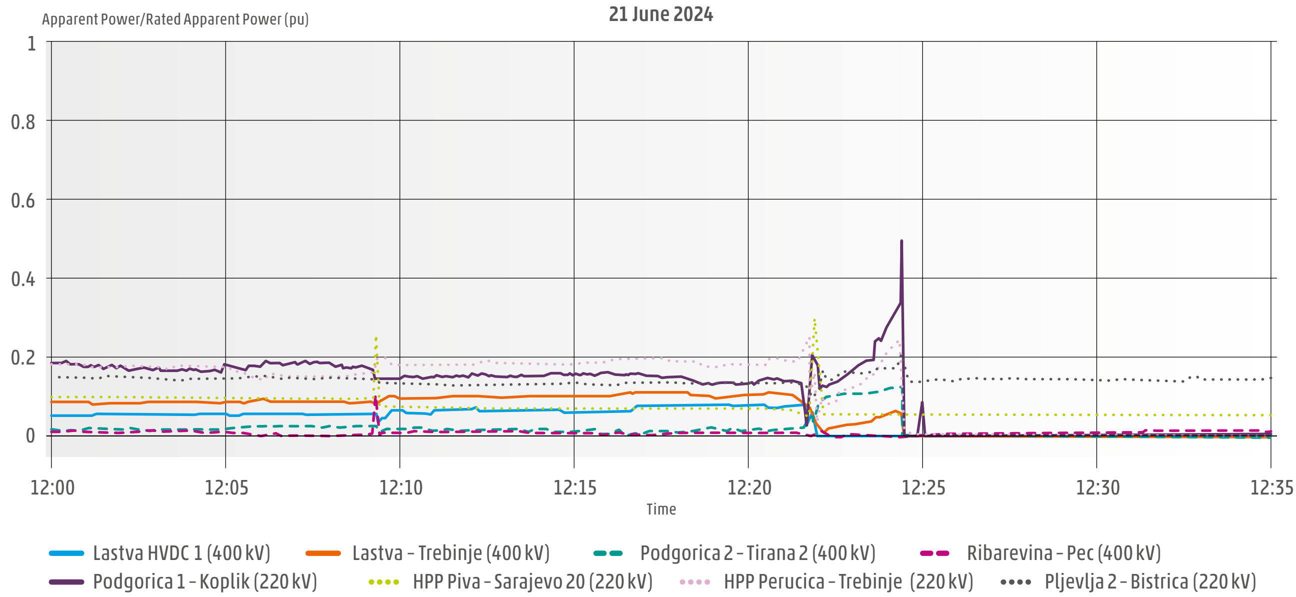

Figure 26: Evolution of line loadings (reactive power) in the CGES network.

3.4.1.2 HOPS (Croatia)

Figures 27 and Figure 28 show the line loadings within the HOPS control area relative to their thermal capacity limits.

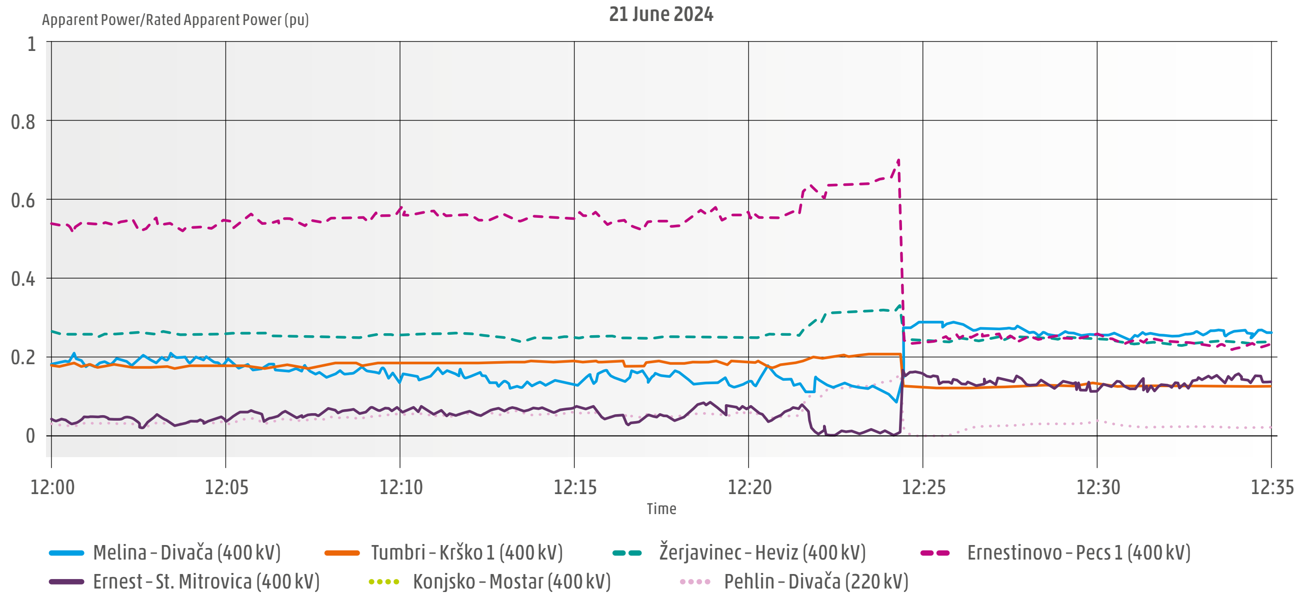

Figure 27: Evolution of line loadings (active power) in HOPS network.

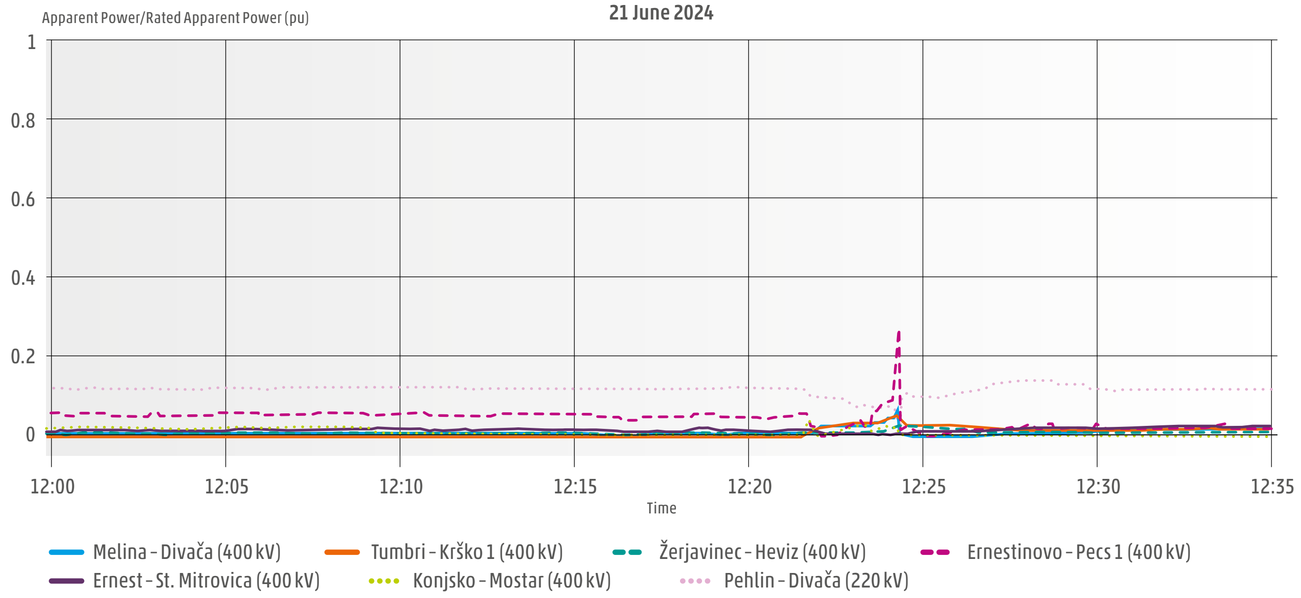

Figure 28: Evolution of line loadings (reactive power) in HOPS network.

A detailed evolution of the system conditions can be seen in the **video recording of HOPS SCADA overview**. The video shows active power flows and significant voltage measurements in the HOPS control area and also the active power flows in parts of the neighbouring systems. The **second video** shows reactive power flows in HOPS SCADA overview during the disturbance.

3.4.1.3 MONITA HVDC

While the MONITA HVDC link tripped due to undervoltage protection system intervention at Kotor end, reactor "F4" inside of the converter facility remained connected to the grid until the end of cascading. Reactor "F4" consumed approximately 72 Mvar, which decreased in value as the voltage continued to drop.

As can be seen in Figure 25, the reactor "F4" is part of the external reactive power compensation devices which function is to modulate reactive power according to HVDC needs, limiting the reactive power exchange with the grid to ±50 MVAr.

There is no possibility of reactive support from the HVDC link by regulating the reactive power due to the fact that the link is based on LCC[8] HVDC technology.

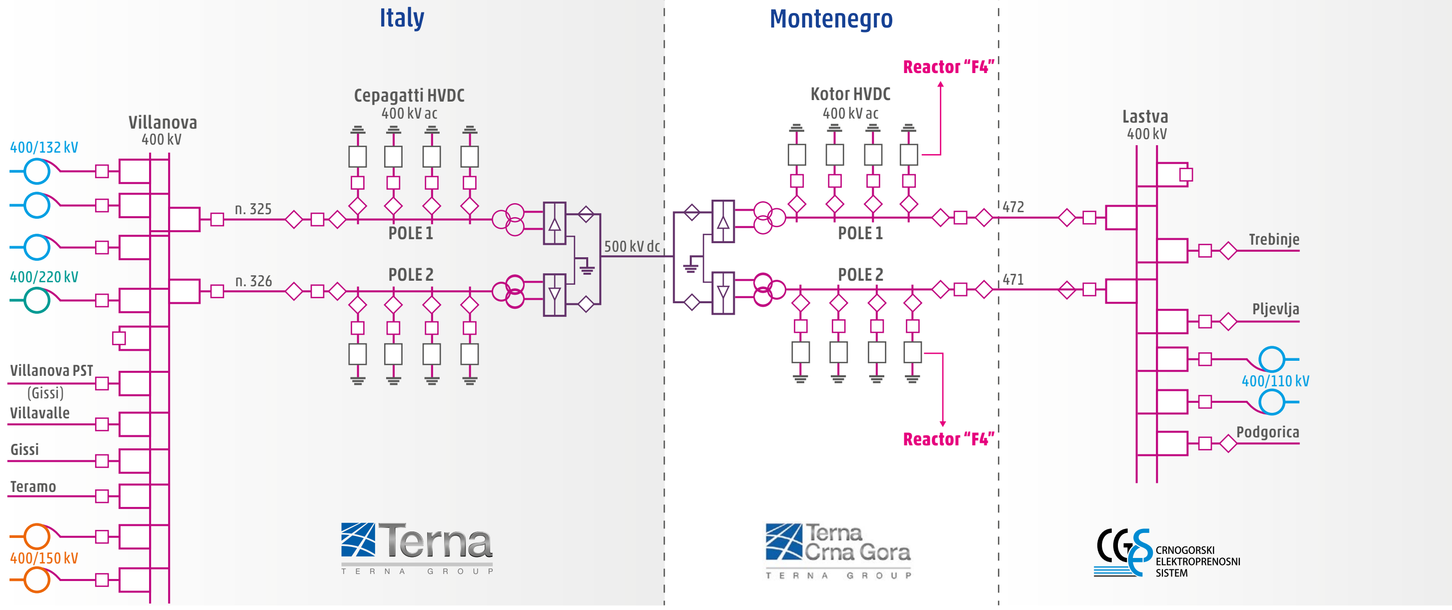

Figure 29: Simplified single line diagram of the 400 kV tie-line at the border between Terna and CGES

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[8] Line-Commutated Converter (LCC) HVDC systems cannot regulate reactive power effectively due to their significant reactive power requirements at both the rectifier and inverter sides. This is caused by the delayed firing of thyristors, which leads to a lag between current and voltage waveforms, resulting in high reactive power consumption. LCC HVDC systems require external reactive power compensation devices, such as capacitors and reactors, to manage their reactive power needs. This dependence on external devices limits their ability to regulate reactive power independently.

3.4.1.4 NOSBiH (Bosnia and Herzegovina)

Figure 30 and Figure 31 show the line loadings within the NOSBiH control area relative to their thermal capacity limits.

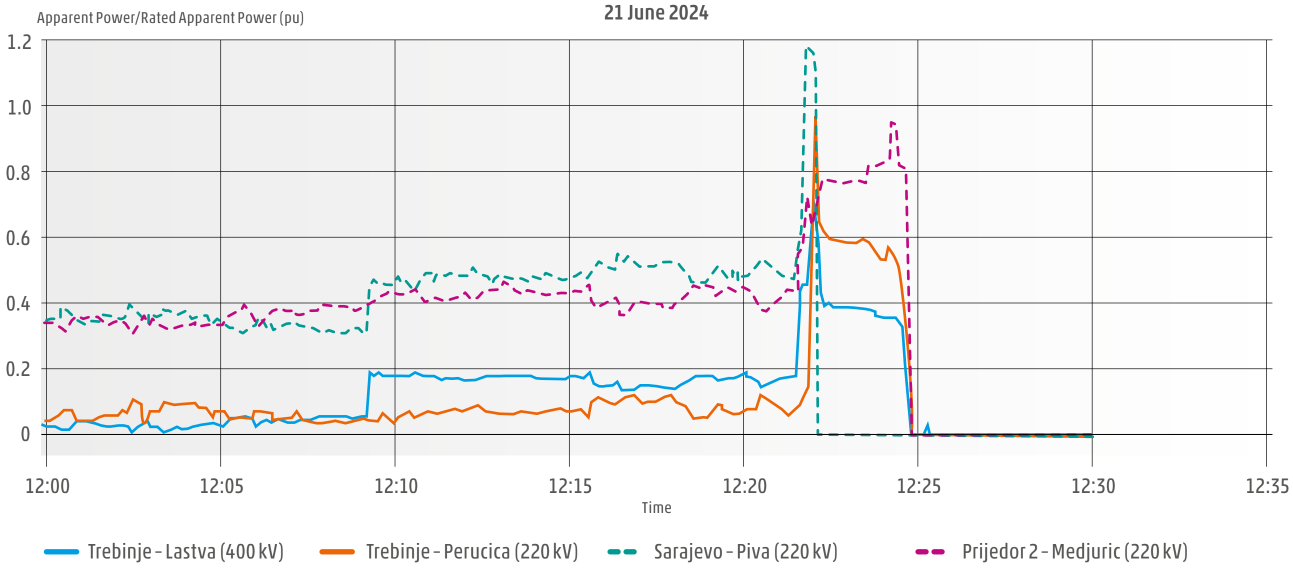


Figure 30: Evolution of line loadings (active power) in NOSBiH network; "Sarajevo" refers to "Sarajevo 20".

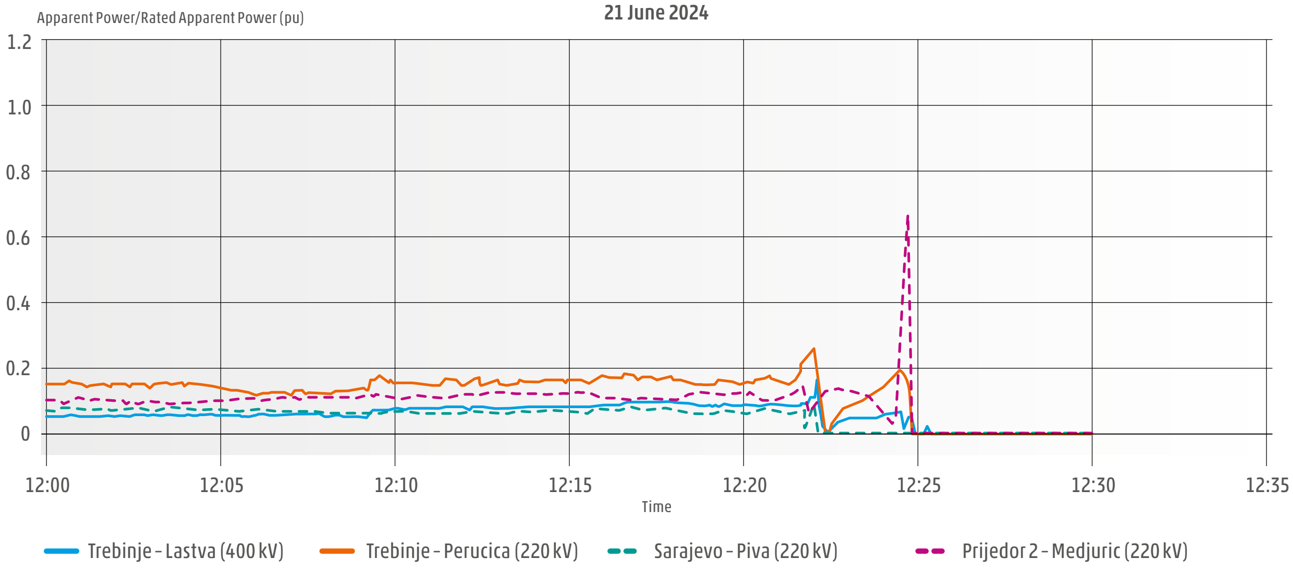


Figure 31: Evolution of line loadings (reactive power) in NOSBiH network; "Sarajevo" refers to "Sarajevo 20".

3.4.1.5 OST (Albania)

Figure 32 and Figure 33 show the line loadings within the OST control area relative to their thermal capacity limits.

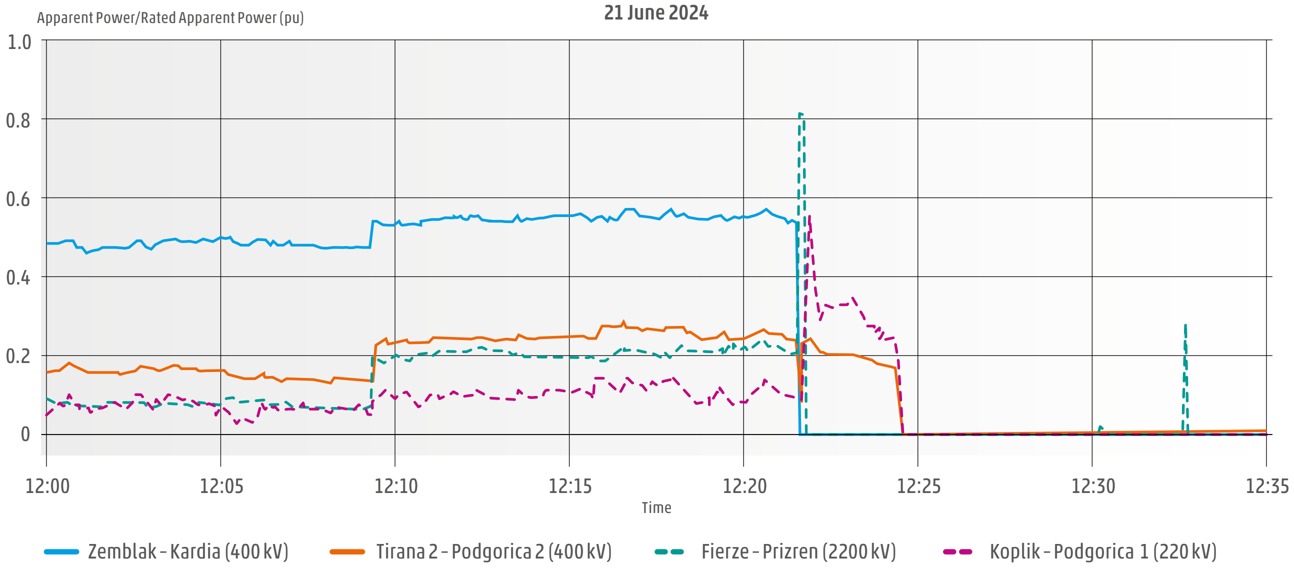


Figure 32: Evolution of line loadings (active power) in the OST network. The value for line Fierze - Prizren (220 kV is estimated, due to pick up time of OC protection, which is shorter than SCADA interval of 4 second)

The outage of OHL TIE 400 kV Zemblak–Kardia due to distance protection caused an overload of OHL TIE 220 kV Fierze – Prizren 2, which resulted in the disconnection of this line due to overcurrent protection. These outages caused a voltage drop that resulted in the disconnection of OHL TIE 400 kV Tirana 2 – Podgorica 2 and OHL TIE 220 kV Koplik – Podgorica 1. Parts of the OST system remained connected to the neighbouring system via TIE line 150 kV Bistrice – Mourtos.

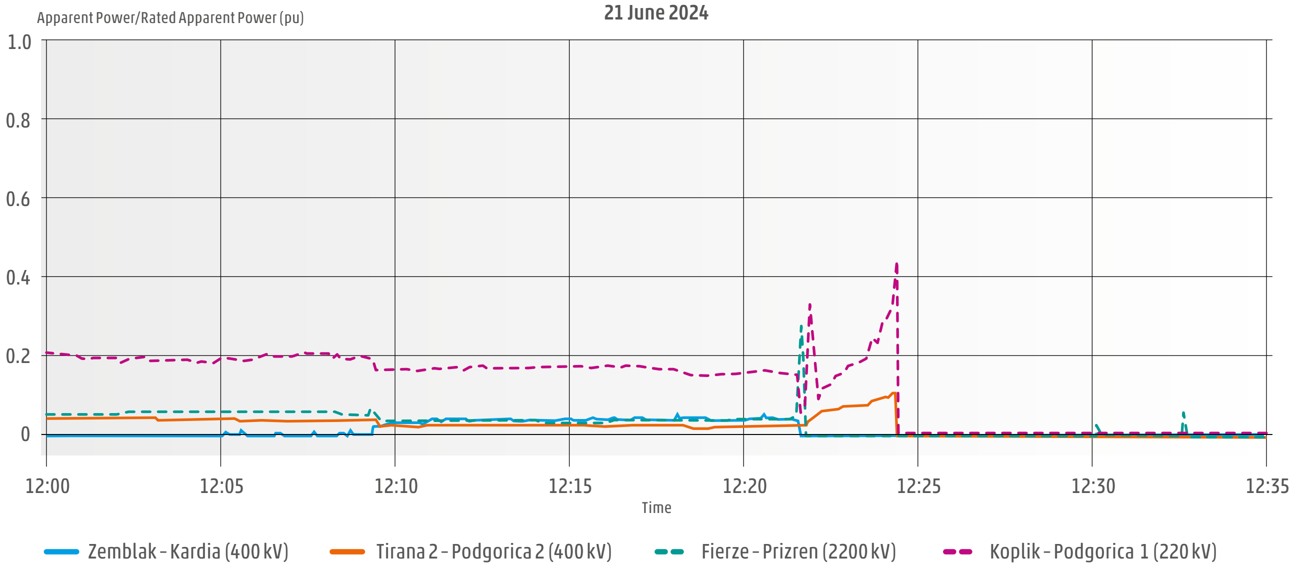


Figure 33: Evolution of line loadings (reactive power) in the OST network.

3.4.2 Voltages

This chapter presents the evolution of the voltages in the different affected areas shortly before and during the incident.

3.4.2.1 CGES (Montenegro)

Figure 34 and Figure 35 represent voltage measurements from selected 400 kV and 220 kV substations within the CGES control area. The initial outage of OHL Podgorica 2 – Ribarevine (ID 1) did not cause a critical drop in voltage in the CGES control area. Although the drop in voltage was 14 kV, voltages remained within the normal range. After the voltage collapse, parts of the CGES system remained connected to neighbouring systems, which can be observed by the presence of voltage in SS Ribarevine even after the disturbance.

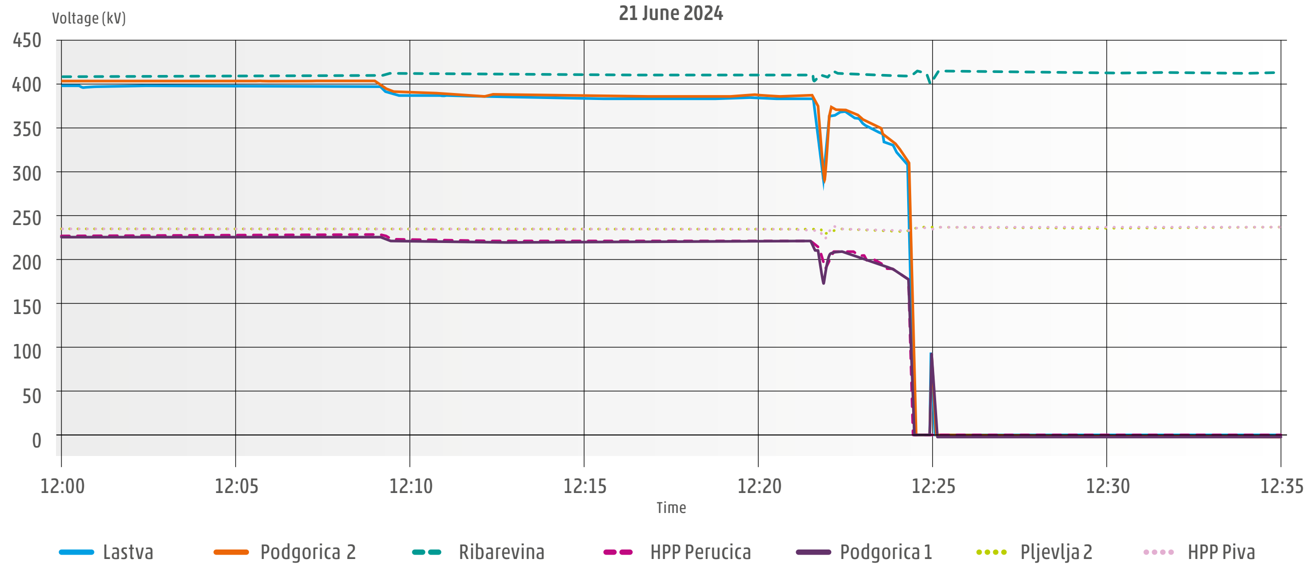


Figure 34: Voltage evolution in CGES network on the 400 kV and 220 kV levels.

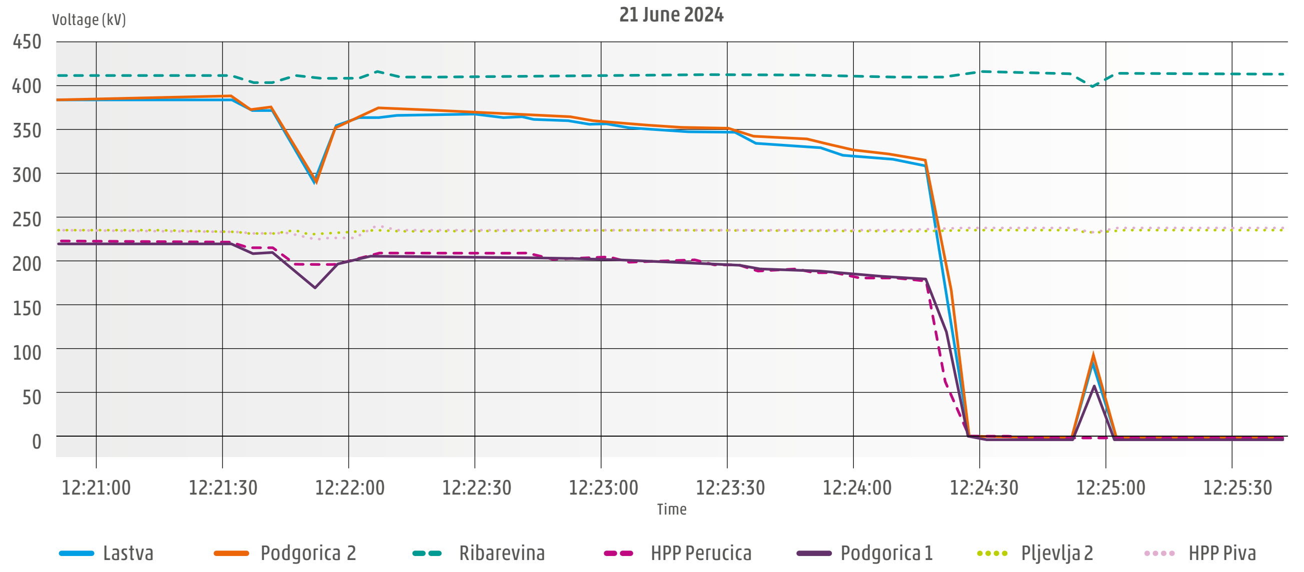


Figure 35: Voltage evolution in the CGES network on the 400 kV and 220 kV levels, the spike in voltage at 12:25:00 shows the reconnection attempts of the TSO (zoomed)

3.4.2.2 HOPS (Croatia)

Figure 36 and Figure 37 show the voltage trajectories in the HOPS control area.

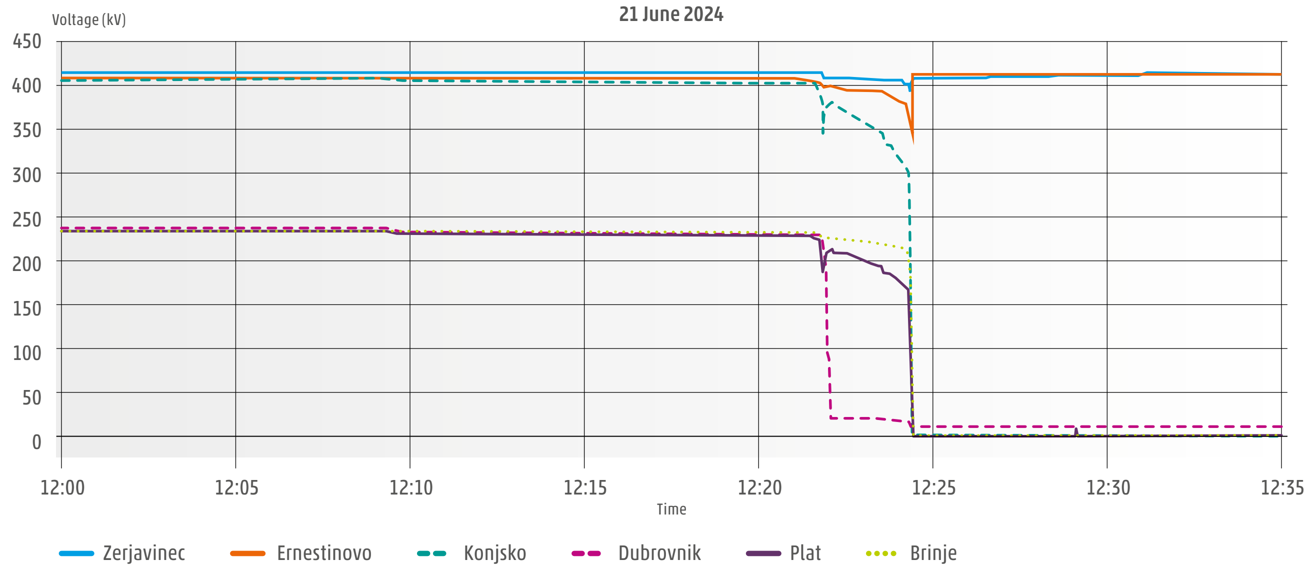


Figure 36: Voltage evolution in the HOPS network on the 400 kV and 220 kV level.

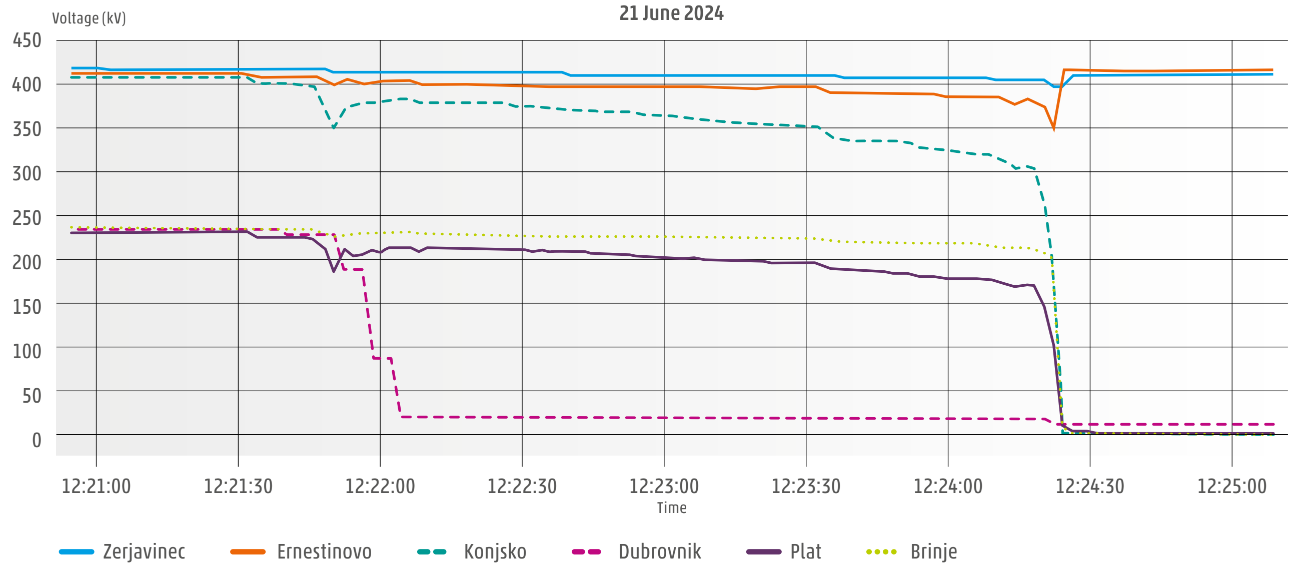


Figure 37: Voltage evolution in HOPS network on the 400 kV and 220 kV level (zoomed)

3.4.2.3 NOSBiH (Bosnia and Herzegovina)

Figure 38 and Figure 39 show the voltage trajectories in the NOSBiH control area.

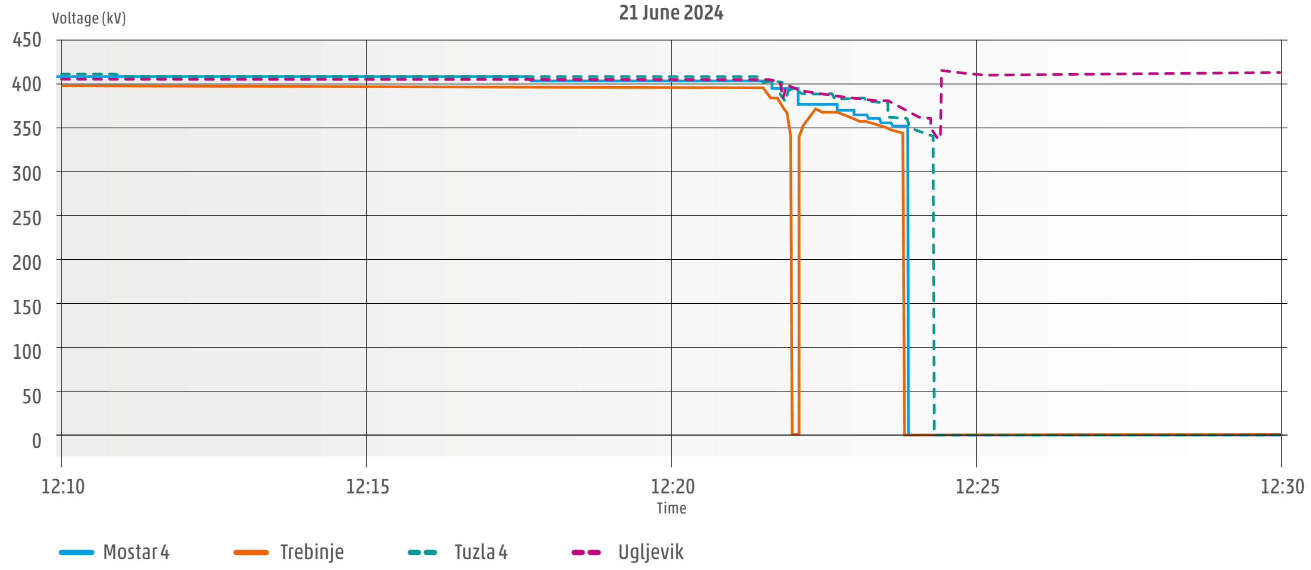


Figure 38: Voltage evolution in the NOSBiH network on the 400 kV and 220 kV levels; the dip to 0 kV at approximately 12:22 (dashed orange line) is due to faulty data and not real.

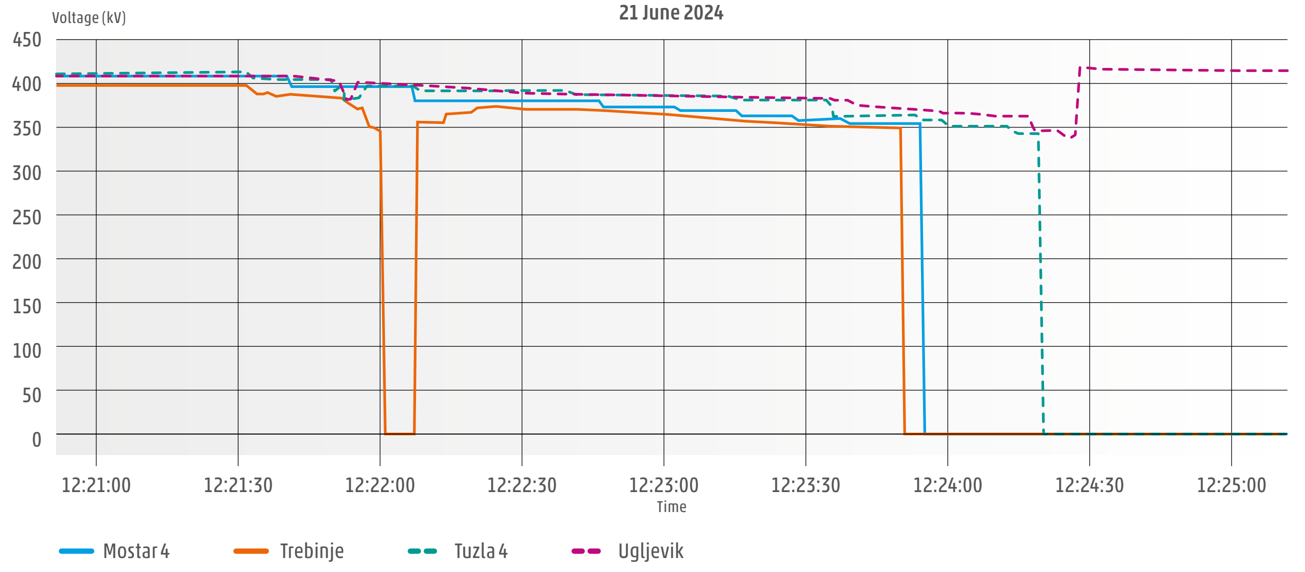


Figure 39: Voltage evolution in the NOSBiH network on the 400 kV and 220 kV levels (zoomed); the dip to 0 kV at approximately 12:22 (dashed orange line) is due to faulty data and not real. Substation Ugljevik remained with voltage in 400 kV busbars

3.4.2.4 OST (Albania)

Figure 40 and Figure 41 show the voltage trajectories in the OST control area.

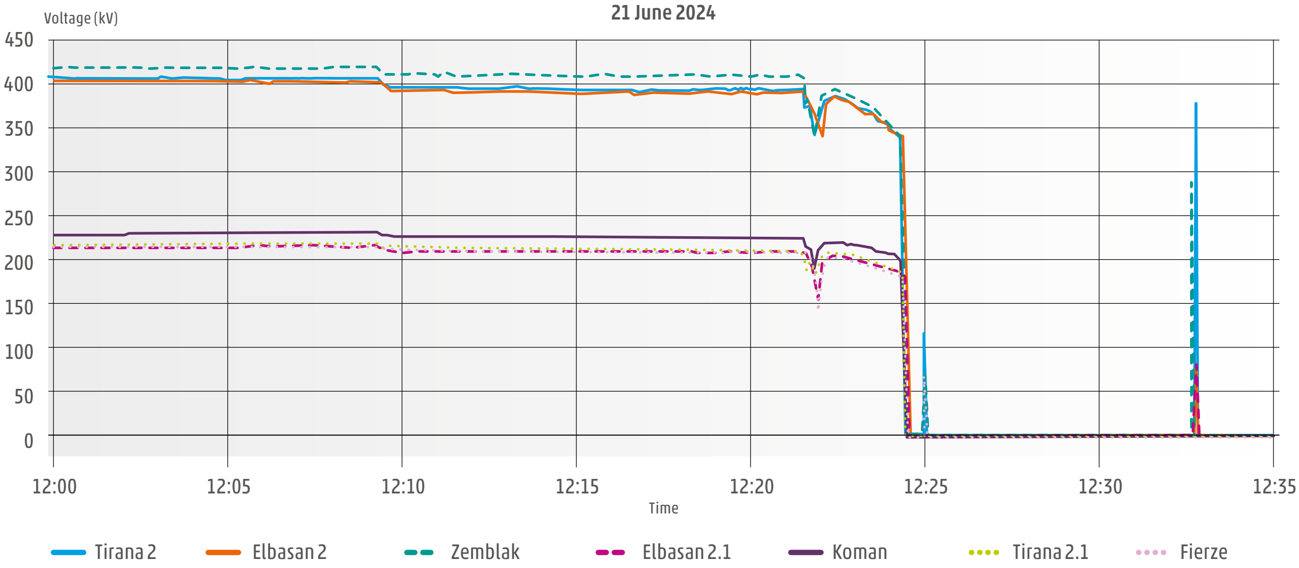


Figure 40: Voltage evolution in the OST network on the 400 kV and 220 kV levels.

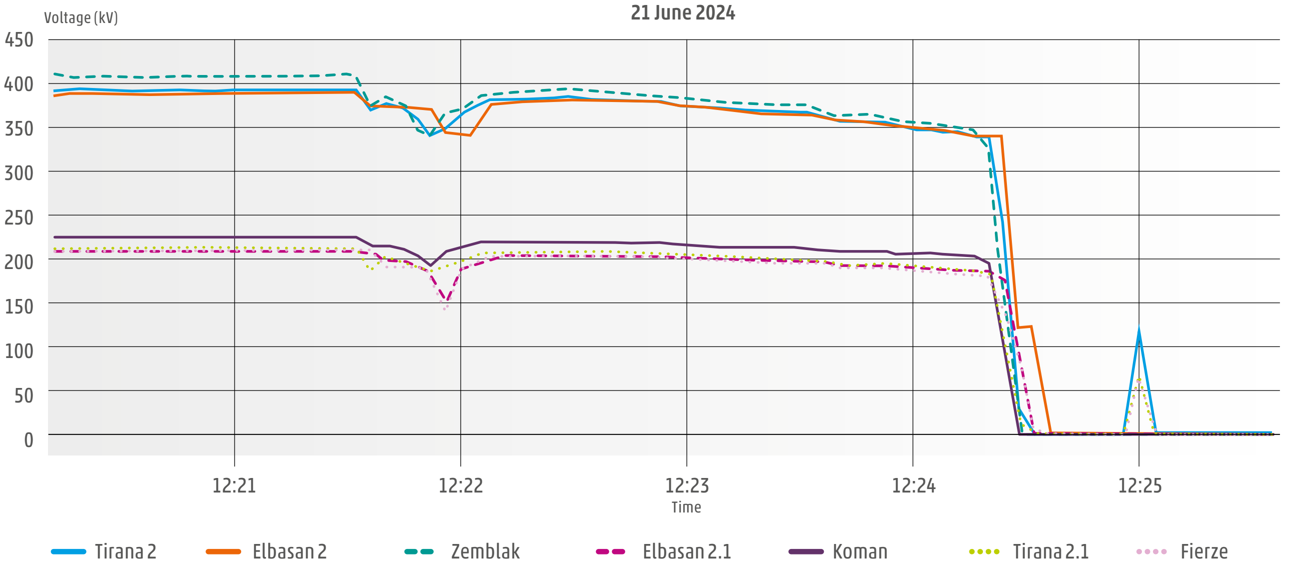


Figure 41: Voltage evolution in the OST network on the 400 kV and 220 kV levels (zoomed)

3.4.3 Voltage Angles

Figure 42 and Figure 43 show the voltage angles of some selected nodes with different temporal zooms. For plotting purposes, the voltage angles were unwrapped (not toggling between –180 ° and +180 °) and put in relation to a distant voltage angle in Switzerland (Soazza). Thereby, it is easier to identify relative movements of certain nodes to each other. It can be seen that there is a change in voltage angles around 12:24 with a maximum of approx. 50 ° in substation "Sarajevo 20". Voltage angles changes were observed in the whole CE area, even in Portugal.

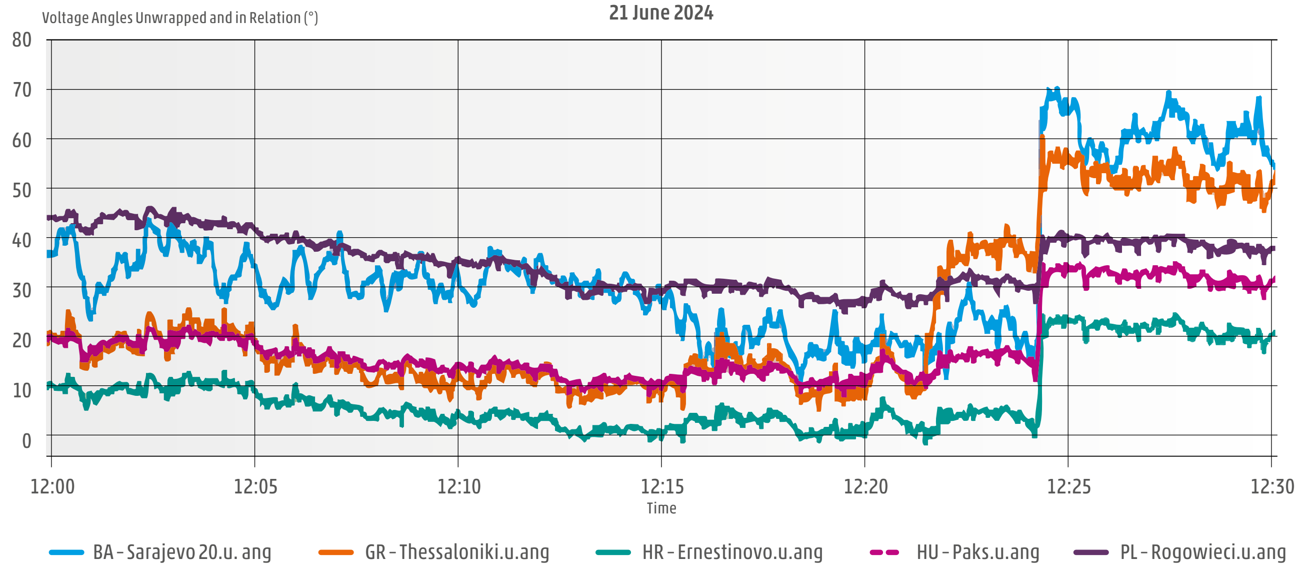


Figure 42: Unwrapped voltage angles relative to Soazza (CH)

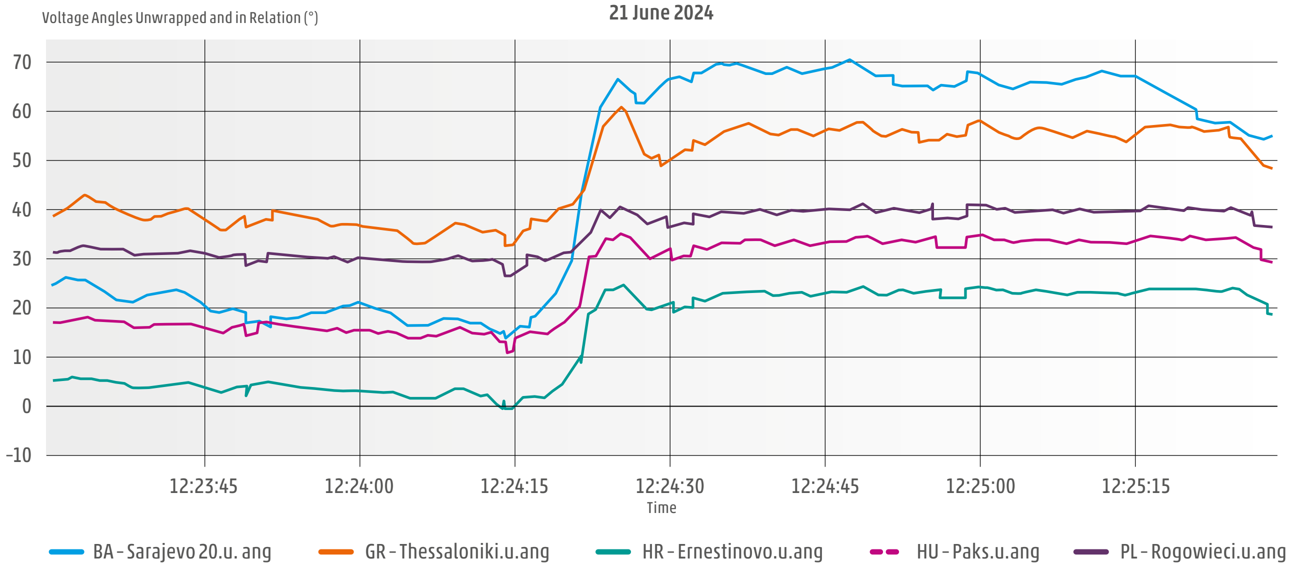


Figure 43: Unwrapped voltage angles relative to Soazza (CH) (zoomed)

3.4.4 Frequency

Figures 44 to Figure 45 show the frequency trajectory of some selected nodes with different temporal zooms. Though it is visible that frequency is affected by the incidents in the grid (e.g. around 12:24), the event was not triggered by frequency stability issues and did not result in any. The frequency inside and outside the affected area always remained in an uncritical range and synchronous.

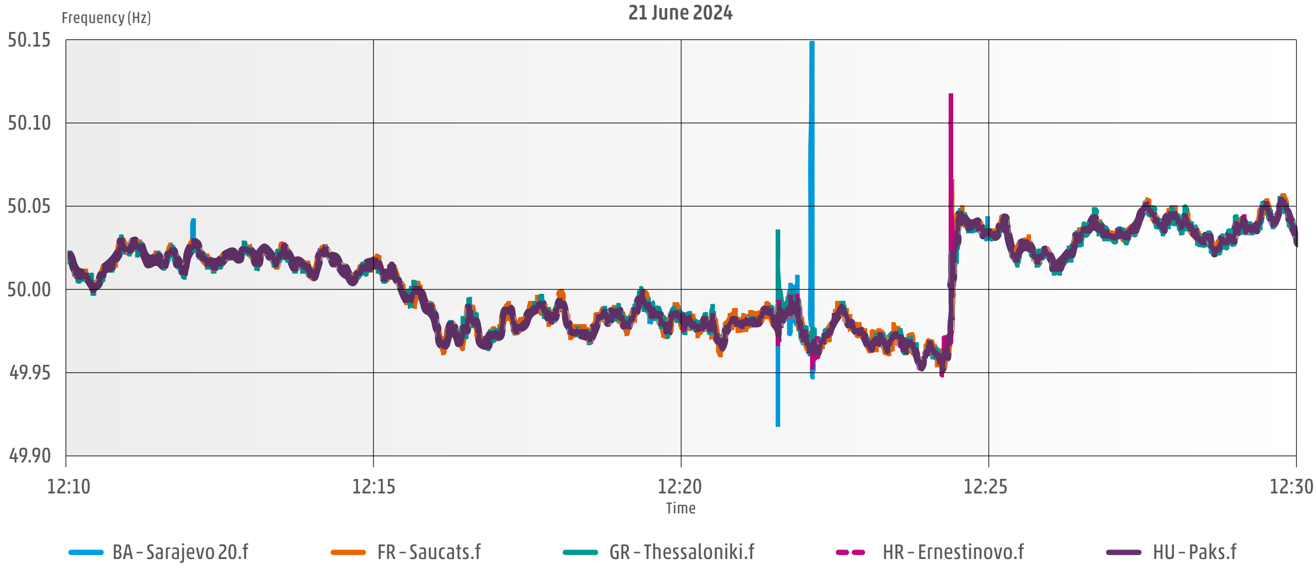


Figure 44: Frequency.

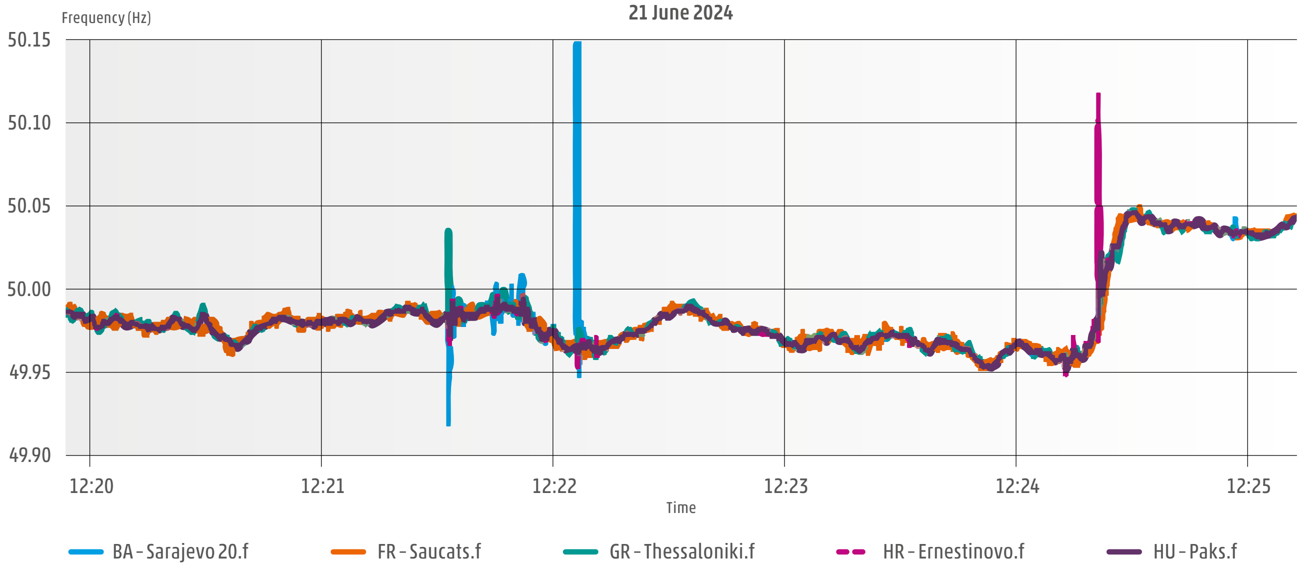


Figure 45: Frequency (zoomed)

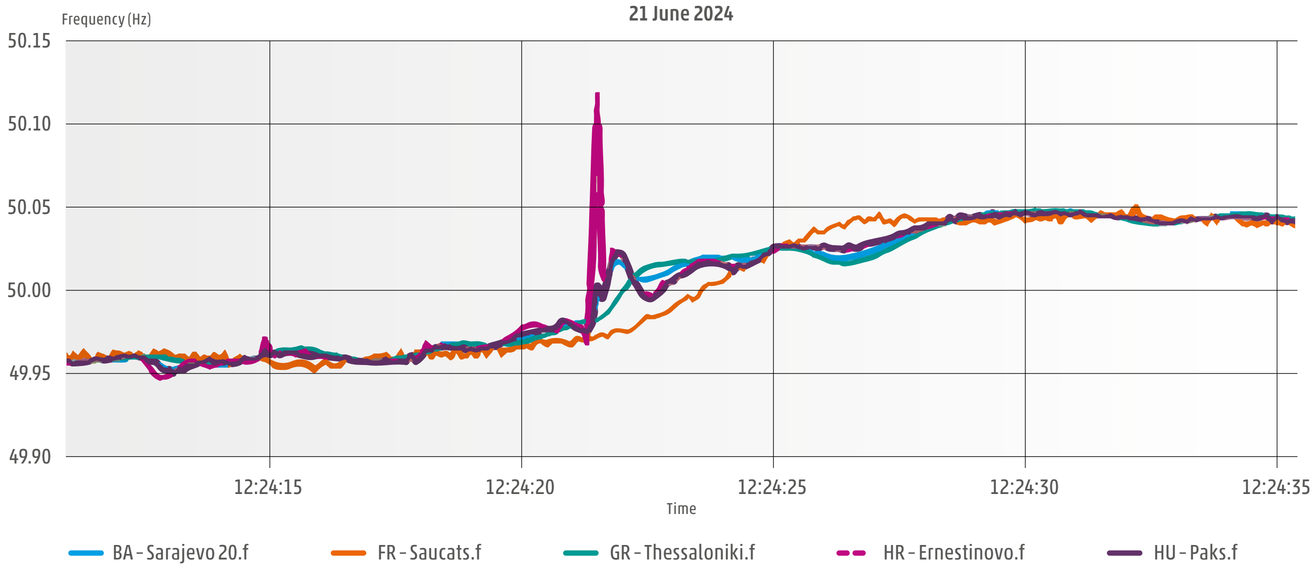


Figure 46: Frequency (zoomed to frequency jump)

3.5 Performance of the Protection System

In large interconnected power systems, just as in any electrical system, the basic objectives that one aims to achieve with the design, setup and maintenance of a protection system are: to avoid dangerous situations for people, to limit the damage to the components of the electrical system when an anomaly or failure occurs, to minimise the consequences of the discontinuity of service in any network situation and to mitigate the risk of transient instability in the transmission network.

Reconstructing the operation and checking it in relation to the expected calibration and the settings of the devices is critical in the case of the analysis. Events such as the blackout on the 21 June 2024 shall be analysed and investigated to understand the causes, the events and finally to determine the corrective actions, if any, that can be taken to avoid such events in the future.

In this section the protection's operation (tripping) will be analysed, using the available data: mainly the SCADA event lists and the disturbance fault recordings (DFRs).

The events which will be analysed are listed in Table 8. The outage IDs in this table and in the following subchapters are in line with the outage IDs from Table 6.

Outage ID	Time (CEST)	Voltage Level (kV)	Asset Type	Relay Trigger	Cause of Tripping	Tripped Phases	Relay Parameter Settings	Relay Tripped According its Settings
1	12:09:16:213	400	OHL	DIFF	vegetation - line to ground fault	first only L3; secondly all 3 phases	Stage 1 = 480 A; 0 ms time delay	YES
2	12:21:33:200	400	OHL-TIE	DIST	vegetation - line to ground fault	first only L2; secondly all 3 phases	Zemblak: Z1 - R1 = 7.66 Ω X1 = 23.86 Ω 0 ms; Kardia: Main 1 Time EF stage IN1 >= 3I0 = 165 % *Inom = 2640 A, 300 ms	YES
3	12:21:44:000	220	OHL-TIE	OC	overload	all 3 phases	I = 720 A, 10 s time delay	YES
4	12:21:45:774	220	OHL	OC	overload	all 3 phases; tripped only in Podgorica 1	Stage 1 = 840 A, 1700 ms time d.	YES
5	12:21:51:446	500	DCC-TIE	UV	voltage drop	tripped only in Kotor	UV function V = 400 kV DC with a t = 2 s time delay	YES
6	12:22:06:012	220	OHL-TIE	OC	overload	all 3 phases; tripped only in Sarajevo 20	Stage 3 = 808 A; 20 s time delay	YES
7	12:24:21:587	220	OHL	DIST	voltage drop	all 3 phases	Z3 of the distance relay X = 107.9 Ω	YES
8	12:24:22:341	220	OHL	OC	overload	all 3 phases; tripped only in Prijedor 2	Zone 3 of OC = 786 A; 1200 s time delay	YES
9	12:24:22:350	400	OHL	OC	overload	all 3 phases; tripped only in Ugljevik; manual CB switch off in Tuzla 4	trip by directional earth fault protection: I0 = 11 % *Inom = 176 A, U0 = 55 % *Unom = 220 kV; 3 s time delay	YES
10	12:24:22:959	220	OHL-TIE	UV	voltage drop	all 3 phases	Automatic CB opening in no voltage condition	YES
11	12:24:22:959	220	OHL-TIE	UV	voltage drop	all 3 phases	Automatic CB opening in no voltage condition	YES
12	12:24:23:000	220	OHL	DIST	voltage drop	all 3 phases, tripped only in Titan	Z1 of the distance relay R1 = 13.567 Ω X1 = 7.97 Ω with 0 ms time delay	YES
13	12:24:23:089	220	OHL-TIE	DIST	voltage drop	all 3 phases	Međurić: Z3 are X = 99.9 Ω; RFPP = 92.4 Ω with 1000 ms time delay	YES
14	12:24:24:000	220	OHL	MAN	manual CB switch off	3 phases manual CB switch off	no protection trip	N/A
15	12:24:26:558	220	OHL-TIE	UV	voltage drop	all 3 phases; tripped only in Trebinje; manual CB switch off in Perucica	no protection trip in Perucica; in Trebinje the settings for Loss of Voltage function is U < 0.7 *Un time delay 10 s	YES
16	12:24:26:579	220	OHL	UV	voltage drop	all 3 phases; tripped only in Trebinje; manual CB switch off in Hodovo	no protection trip in Hodovo; in Trebinje the settings for Loss of Voltage function is U < 0.7 *Un time delay 10 s	YES
17	12:24:26:583	220	OHL	UV	voltage drop	all 3 phases; tripped only in Trebinje; manual CB switch of in Mostar 3	no protection trip in Mostar 3; in Trebinje the settings for Loss of Voltage function is: U < 0.7 *Un time delay 10 s	YES
18	12:24:26:593	220	OHL-TIE	UV	voltage drop	all 3 phases; tripped only in Trebinje	no protection trip in Plat; in Trebinje the settings for Loss of Voltage function is U < 0.7 *Un time delay 10 s	YES
19	12:24:27:694	220	OHL	UV	voltage drop	all 3 phases; tripped only in Prijedor 2; manual CB switch off in Bihac 1	no protection trip in Bihac 1; in Prijedor Zone 3 of distance protection tripped	YES
20	12:24:28:000	220	OHL	MAN	N/A	3 phases manual CB switch off	no protection trip	N/A
21	12:24:28:000	220	OHL	DIST	voltage drop	3 phases; tripped only in Fierze	Z1 of the distance relay R1 = 4.82 Ω X1 = 24.85 Ω with 0 ms time delay	YES

Table 8: Performance of the protection system in the sequence of events

3.5.1 Outage ID 1: OHL 400 kV Ribarevine (CGES) – Podgorica 2 (CGES)

At **12:09:16.213 CEST the Ribarevine (CGES) – Podgorica 2 (CGES)** 400 kV OHL tripped. Line differential protection function tripped the OHL; the cause was a line-to-ground fault which occurred in phase L3 because of vegetation under the OHL. The relay protection system of the OHL operated according to its settings, the Stage1 of the line differential protection (settings 480 A) operated without any time delay (0 ms). As this was a permanent fault, after the failed auto reclosing there was a definite three phase trip and the OHL remained out of service.

3.5.2 Outage ID 2: OHL 400 kV Zemblak (OST) – Kardia (IPTO)

At **12:21:33:200 the Zemblak (OST) – Kardia (IPTO)** 400 kV OHL tie line tripped. The distance protection function tripped the OHL first from Zemblak (OST) side in phase L2 and IN1> earth-fault over current protection function of Main 1 protection from Kardia (IPTO) side in all three phases, then at Zemblak (OST) substation there was an unsuccessful auto reclosing in the L2 phase which ended with a three-phase definite trip. The cause of the relay protection trip was the distance shortening to vegetation under the line, with this causing a fault in phase L2 near Zemblak (OST) substation – at 19.2 % of the line. At the time of the event, the CB 1-pole auto reclosure at Kardia P940 (Zemblak) bay was out of service. Due to this, all trips were 3-pole. The parameter settings are: Zemblak (OST): Z1 function – R1 = 7.66 Ω X1 = 23.86 Ω 0 ms time delay; Kardia (IPTO): in Main 1 protection device the Time EF stage IN1> function IN1> = 3I0 = 165 % × (1,60 0 A/1 A) = 2,640 A, 300 ms. At the time of the fault, the tele-protection scheme of the line was also out of service. Therefore, at the Kardia (IPTO) substation no transfer trip could be received from Zemblak (OST); thus, the trip of the Z2 function which started was not accelerated. The IN1> earth-fault overcurrent function at Kardia (IPTO) has approximately the same reach as the Z2 distance protection function and has a shorter time delay than the Z2, which is why it operated before the Z2 function. We can state that the relay protection system of the OHL operated according to its settings.

3.5.3 Outage ID 3: OHL 220 kV Fierze (OST) – Prizren 2 (KOSTT)

At **12:21:44:000 the Fierze (OST) – Prizren 2 (KOSTT)** 220 kV OHL tie line tripped. The overload protection function (overcurrent protection with lower amper settings) tripped the OHL in three phases. The settings of the overload protection in Fierze (OST) substation are I = 720 A with a 10 s time delay. The relay protection system of the OHL operated according to its settings.

3.5.4 Outage ID 4: OHL 220 kV Podgorica 1 (CGES) – Mojkovac (CGES)

At **12:21:45.774, the Podgorica 1 (CGES) – Mojkovac (CGES)** 220 kV OHL line tripped. The overload protection function (overcurrent protection with lower amper settings) tripped the OHL in three phases in the Podgorica 1 (CGES) substation. The settings of the overload protection in Podgorica 1 (CGES) substation are Stage 1 = 840 A with a 1,700 ms time delay. The overload protection function is only installed on one side of the line, which is the usual situation in the area. The relay protection system of the OHL operated according to its settings.

3.5.5 DCC 500 kV Lastva (CGES) – / Kotor DC convertor station (Terna) /– Villanova (Terna)

At **12:21:51:446, the Lastva (CGES) – / Kotor DC convertor station (Terna) / Villanova (Terna)** 500 kV DCC-TIE cable was blocked in Kotor Convert SS. On the Lastva (CGES) side (AC), there was no protection trip. The DC converter was blocked by undervoltage (UV) protection of the DC cable. The cause of this was the voltage drop on the AC side from Lastva. The settings of the UV are V = 400 kV DC with a t = 2 s time delay. The relay protection system of the DC operated according to its settings. The DC link is a LCC converting system which cannot support voltage, in the event of voltage drop on the AC side the power flow is blocked.

3.5.6 Outage ID 6: OHL-TIE 220 kV Sarajevo 20 (NOSBiH) – Piva (CGES)

At **12:22:06:012, the Sarajevo 20 (NOSBiH) – Piva (CGES)** 220 kV OHL-TIE tripped. The overload protection function (overcurrent protection with lower amper settings) tripped the OHL in three phases in Sarajevo 20 (NOSBiH) substation. The settings of the overload protection in Sarajevo 20 (NOSBiH) substation are Stage 3 = 808 A with a 20 s time delay. Overload protection function is only installed on one side of the line, which is the usual situation in the area. The relay protection system of the OHL operated according to its settings.

3.5.7 Outage ID 7: OHL 220 kV Brinje (HOPS) – Pađene (HOPS)

At **12:24:21:587, the Brinje (HOPS) – Pađene (HOPS)** 220 kV OHL tripped in three phases. The distance protection function in Zone 3 on the Brinje (HOPS) side of the line tripped because of voltage drop. The settings of Z3 of the distance relay are X = 107.9 Ω. There was no protection trip on the Pađene (HOPS) side of the line. The relay protection system of the OHL operated according to its settings.

3.5.8 Outage ID 8: OHL 220 kV Prijedor 2 (NOSBiH) – Jajce 2 (NOSBiH)

At **12:24:22:341, the Prijedor 2 (NOSBiH) – Jajce 2 (NOSBiH)** 220 kV OHL tripped. The overload protection function (overcurrent protection with lower amper settings) tripped the OHL in three phases in the Prijedor 2 (NOSBiH) substation. The settings of the overload protection in Prijedor 2 (NOSBiH) substation are Zone 3 = 786 A with a 1,200 s time delay. Overload protection function is only installed on one side of the line; this is the usual situation in the area. The relay protection system of the OHL operated according to its settings.

3.5.9 Outage ID 9: OHL 400 kV Ugljevik (NOSBiH) – Tuzla 4 (NOSBiH)

At **12:24:22:350, the Ugljevik (NOSBiH) – Tuzla 4 (NOSBiH)** 400 kV OHL tripped. Directional earth fault protection tripped the OHL in three phases in the Ugljevik (NOSBiH) substation. The settings of the directional earth fault protection in Ugljevik (NOSBiH) substation are I0 = 11 % × Inom = 176 A, U0 = 55 % × Unom = 220 kV; with a 3 s time delay. In Tuzla4 (NOSBiH) the circuit breakers were switched off manually. The relay protection system of the OHL operated according to its settings.

3.5.10 Outage ID 10 and 11

At **12:24:22:959** there were outages in HOPS' 110 kV network which led to a no voltage condition of OHL TIE 220 kV Đakovo – Tuzla and OHL TIE 220 kV Đakovo – Gradačac. Recognising zero voltage condition in SS Đakovo all circuit breakers opened automatically.

3.5.11 Outage ID 12: OHL 220 kV Titan (OST) – Tirana 1 (OST)

At **12:24:23:000 Titan (OST) – Tirana 1 (OST)** the 220 kV OHL line tripped in three phases in the Titan (OST) substation. The distance protection Zone 1 (Z1) tripped the line in Titan (OST), and in Tirana 1 (OST) substation there was no protection trip. The parameter settings of the distance protection Z1 are R1 = 13.567 Ω X1 = 7.97 Ω with a 0 ms time delay. The cause of the trip was the voltage drop on the line. The relay protection system of the OHL operated according to its settings.

3.5.12 Outage ID 13: OHL 220 kV Međurić (HOPS) – Prijedor 2 (NOSBiH)

At **12:24:23:089 the Međurić (HOPS) – Prijedor 2 (NOSBiH)** 220 kV OHL-TIE line tripped in three phases. The distance protection Zone 3 (Z3) in Međurić (HOPS) substation tripped the line in three phases. In Međurić (HOPS) substation the parameter settings of the distance protection Z3 are X = 99.9 Ω; RFPP = 92.4 Ω with a 1,000 ms time delay. The relay protection system in Međurić (HOPS) substation operated according to its settings.

3.5.13 Outage ID 14: OHL 220 kV Fierze (OST) – Peshqesh (OST)

At **12:24:24:000 the Fierze (OST) – Peshqesh (OST)** 220 kV OHL was switched off manually. No protection tripping occurred.

3.5.14 Outage ID 15: OHL-TIE 220 kV Trebinje (NOSBiH) – Perucica (CGES)

At **12:24:26:558 the Trebinje (NOSBiH) – Perucica (CGES)** 220 kV OHL-TIE line tripped. There was no relay protection trip on the Perucica (CGES) side of the line; the line was manually switched off there.

In Trebinje (NOSBiH) on the 220 kV voltage level in the event of loss of voltage the UV (undervoltage) function of the bay trips the line in all three phases. This is a definite trip (no auto reclosing). The settings of the UV function are: U < 0.7 × Un with a 10 s time delay The disturbance records show that there was a sever voltage drop. The relay protection system in Trebinje (NOSBiH) substation operated according to its settings.

3.5.15 Outage ID 16: OHL 220 kV Trebinje (NOSBiH) – Hodovo (NOSBiH))

At **12:24:26:579 the Trebinje (NOSBiH) – Hodovo (NOSBiH)** 220 kV OHL line tripped. There was no relay protection trip on the Hodovo (NOSBiH) side of the line; the line was manually switched off there.

In Trebinje (NOSBiH) on the 220 kV voltage level in the event of loss of voltage the UV (undervoltage) function of the bay trips the line in all three phases. This is a definite trip (no auto reclosing). The settings of the UV function are: U < 0.7 × Un with 10 s time delay The disturbance records show that there was a sever voltage drop. The relay protection system in Trebinje (NOSBiH) substation operated according to its settings.

3.5.16 Outage ID 17: OHL 220 kV Trebinje (NOSBiH) – Mostar 3 (NOSBiH))

At **12:24:26:583 the Trebinje (NOSBiH) – Mostar 3 (NOSBiH)** 220 kV OHL line tripped. There was no relay protection trip on the Mostar 3 (NOSBiH) side of the line; the line was manually switched off there.

In Trebinje (NOSBiH) on , the 220 kV voltage level in the event of loss of voltage the UV (undervoltage) function of the bay trips the line in all three phases. This is a definite trip (no auto reclosing). The settings of the UV function are: U < 0.7 × Un with 10 s time delay. The disturbance records show that there was a sever voltage drop. The relay protection system in Trebinje (NOSBiH) substation operated according to its settings.

3.5.17 Outage ID 18: OHL-TIE 220 kV Trebinje (NOSBiH) – Plat (HOPS)

At **12:24:26:593 the Trebinje (NOSBiH) – Plat (HOPS)** 220 kV OHL-TIE line tripped. There was no relay protection trip on the Plat (HOPS) side of the line.

In Trebinje (NOSBiH) on the 220 kV voltage level in the event of loss of voltage the UV (undervoltage) function of the bay trips the line in all three phases. This is a definite trip (no auto reclosing). The settings of the UV function are: U < 0.7 × Un with 10 s time delay. The disturbance records show that there was a sever voltage drop. The relay protection system in Trebinje (NOSBiH) substation operated according to its settings.

3.5.18 Outage ID 19: OHL 220 kV Prijedor 2 (NOSBiH) – Bihac 1 (NOSBiH)

At **12:24:27:694 the Prijedor 2 (NOSBiH) – Bihac 1 (NOSBiH)** 220 kV OHL line tripped. There was no relay protection trip on the Bihac 1 (NOSBiH) side of the line; the line was manually switched off there. Distance protection function Zone 3 (Z3) tripped the line in three phases in Prijedor 2 (NOSBiH) substation. The cause of the distance protection Z3 trip was the voltage drop on the line. The relay protection system of the OHL operated according to its settings.

3.5.19 Outage ID 20: OHL 220 kV Fierze (OST) – Koman (OST)

At **12:24:28:000 the Fierze (OST) – Koman (OST)** 220 kV OHL was switched off manually. No protection tripping occurred.

3.5.20 Outage ID 21: OHL 220 kV Fierze (OST) – Fang (OST)

At **12:24:28:000 the Fierze (OST) – Fang (OST)** 220 kV OHL tripped. Distance protection function Zone 1 (Z1) tripped the line in three phases in Fierze (OST) substation. There was no relay protection trip in Fang substation. In Fierze (OST) substation the parameter settings of the distance protection Z1 are R1 = 4.82 Ω X1 = 24.85 Ω with a 0 ms time delay. The distance protection tripped because of the voltage drop. The relay protection system of the OHL operated according to its settings.

3.6 Important Alarms in Control Centres

All voltage violations referenced are based on alarm thresholds defined by each TSO, not on the thresholds defined in Annex II of the SO GL. All the affected TSOs used 380 kV as the low voltage limit for issuing alarms, which gave out alerts before reaching the low voltage limit of 360 kV defined in SO GL.

3.6.1 HOPS

The HOPS alarm list shows no significant alarms prior to the start of cascading outages.

The first instance of a low voltage alarm in the 220 kV part of the grid happened at 12:21:49:644 in substation Plat, measuring a voltage of 192.6 kV.

Real Time Security Analysis

HOPS N-1 results for the period between 12:00 and 12:23 show no N-1 violations for the 400 kV and 220 kV grid elements. Only after the outage do ID6 potential overloads of 220 kV grid elements appear on the list inside of HOPS SCADA/EMS real time calculations. After this outage there are also multiple divergences within the HOPS SCADA/EMS, but most are for the outages near the endpoint of the HOPS observability area, located in nodes in other control areas and not important for the analysis of the event.

3.6.2 NOSBiH

The NOSBiH alarm list shows that the first instance of a low voltage alarm happened in HPP Višegrad at 12:09:16, measuring the voltage of 377.8 kV, but his alarm was deactivated one second later after the voltage recovered to 386.6 kV. Only after the outages of OHL Zemblak – Kardia and OHL Piva – Sarajevo multiple low voltage alarms were issued during the period between 12:21:33 and 12:22:03.

Real Time Security Analysis

There are no real time N-1 results available for the NOSBiH control area during the period between outage ID1 and ID2 because there is no possibility to archive the N-1 results after each run of the real time contingency analysis. The NOSBiH observability area ends on the CGES–OST border and, therefore, does not include outage ID2 as a part of the contingency analysis.

3.6.3 CGES

The CGES alarm list shows that the first alarm issued regarding low voltage on 400 kV level happened in substation Lastva at 12:12:02; the voltage measured was 376.7 kV. Shortly after that, the voltage in substation Lastva recovered to 385 kV. Next low voltage alarms started appearing at 12:21:33 after the ID2 outage.

Outage ID1 generated appropriate alarms about the nature of the fault and the time of the OHL disconnection.

Real Time Security Analysis

CGES had no N-1 violations in the 400 kV and 220 kV parts of the grid. In addition, CGES observability zone ends on the OST–IPTO border and OHL Zemblak – Kardia is modelled as an equivalent power flow injection, which was not included as a part of the real time contingency analysis.

3.6.4 OST

The OST alarm list shows that the first alarm issued regarding 220 kV low voltage value was at 12:21:33 in substation Fierze. The voltage measured was 195.5 kV. From that point on there were many low voltage alarms issued as the voltage collapse started.

Real Time Security Analysis

The EMS system inside the the OST control room did not show any real time N-1 violations for the OST control area during the period between outage ID1 and ID2. The OST observability area includes CGES network but does not include the NOSBiH and HOPS network.

3.6.5 IPTO

There were no significant alarms for the 400 kV and 150kV grid elements between 12:00 and 12:30.

Real Time Security Analysis

IPTO real time N-1 calculations showed no significant results for the affected area between outage ID1 and ID2.

3.6.6 EMS

There were no significant alarms for the 400 kV and 220 kV grid elements between 12:00 and 12:30.

Real Time Security Analysis

Real time N-1 calculations within EMS applications of NCC showed no significant results for the affected area between outage ID1 and ID2, as the outages of elements outside the JSC EMS control area are used to calculate the loadings of internal JSC EMS elements and tie lines only. After the cascading started there was a divergent estimation solution at 12:25 for the affected part of the grid model used inside of SCADA/EMS system. The following state estimation at 12:26 converged without issues.

3.7 Conclusion

The sequence of events started with the outage of OHL Podgorica 2 – Ribarevine at 12:09 (outage ID1) which tripped due to the short circuit caused by s the hortening of the distance to the vegetation beneath the OHL. This outage caused an initial drop in voltages across the affected region, but the voltages stabilised quickly.

The second outage was the tripping of OHL TIE Zemblak – Kardia at 12:21. The short circuit that led to the outage was caused by shortening the distance to the vegetation beneath the OHL, same as the first outage.

The cascading event continued with 220 kV lines and HVDC Monita disconnected also due to under voltage protection at Lastva side, then the affected areas lost voltage at 12:24.

During the incident, automatic voltage regulation was applied as written in subchapter 3.3 and all transformers reacted properly, considering regulated voltage set points. There was no manual change of transformer tap changers nor manual disconnection of loads.

The relay protection systems of each high voltage element affected operated according to its parameter settings, based on information collected.

Based on the information gathered from the TSOs of the affected region. there were no real time N-1 violations detected in the 400 kV and 220 kV grid during the period between outage ID1 and ID2.

Furthermore, there were no remedial actions identified or applied in any of the affected TSOs during the period between the first two outages.

4 RCC ANALYSIS BEFORE THE INCIDENT

4.1 RCC Tasks

There are five RCCs and one Regional Security Coordinator (RSC) in Europe, covering different regions and serving different groups of TSOs. The RCCs are: Baltic RCC, TSCNET, SEleNe CC, Coreso and Nordic RCC, and the RSC is SCC.

The services delivered by the RSC are described in System Operational Guidelines (EU Reg 2017/1485). The tasks for RCCs are described in the Electrical Regulation (EU Reg 2019/943 art 37). In this report, both RSC and RCCs will be referred to as RCC for ease of reading the document, and the word "task" will be used for both RSC services and RCC tasks.

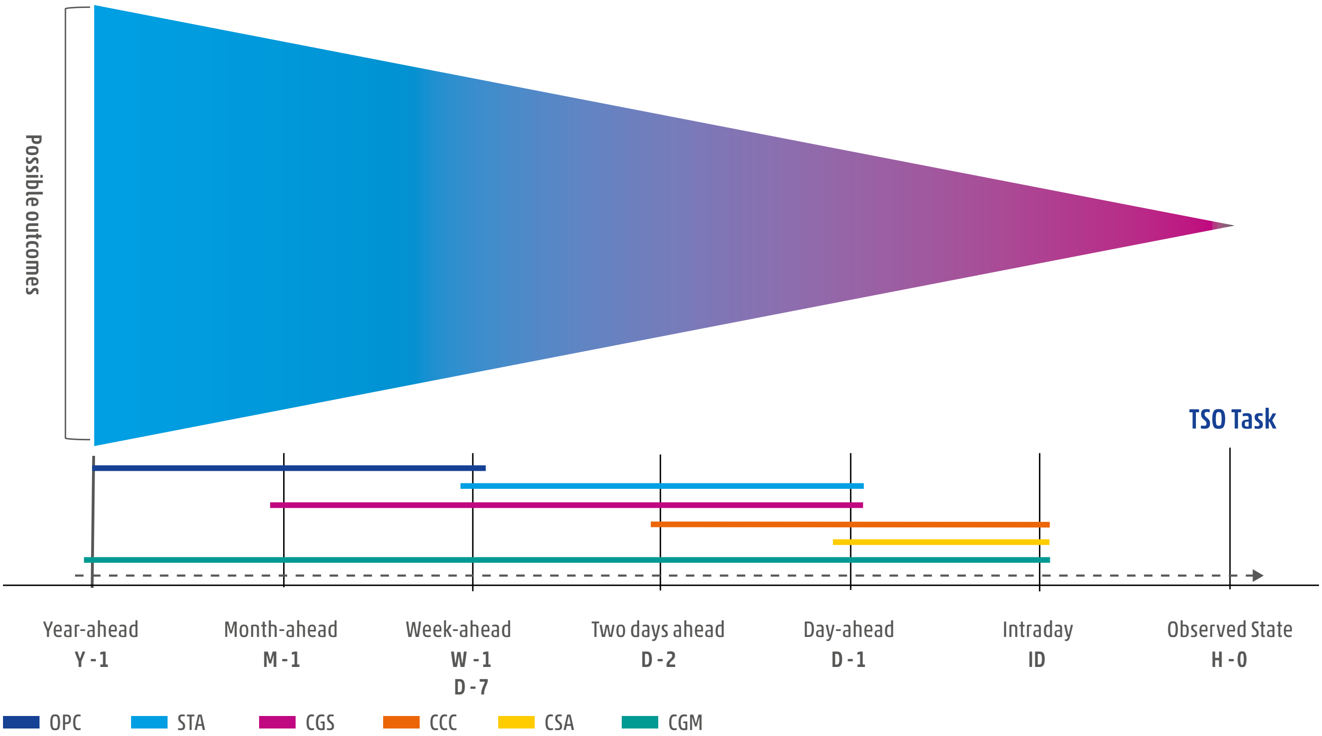
SCC delivers the following tasks mentioned in this report (the 4 out of 5 services from SOGL: OPC, STA, CGM and CSA but not CCC (Coordinated Capacity Calculations)) and the tasks CGS (Critical Grid Situations, decided by SOC in September 2017) and consistency assessment of defence and restoration plans (EU Reg 2019/943 art 37.1(d)). The Security Analysis provided by SCC is not a Coordinated Security Analysis according to EU Reg 2017/1485 but a Security Analysis which is used until the Coordinated Security Analysis goes live.

The RCC for the region affected by the Balkan Blackout is SCC. SCC thereby joins the task described in EU Reg 2019/943 art 37.1(i) (post-operation and post-disturbance analysis and reporting), which is chapter 4 in this report. The RCCs involved in the event were SCC, TSCNET, CORESO and SEleNe CC as they cover the regions where the event originated and propagated.

4.1.1 High Level Description on RCC Tasks

The tasks of RCCs have different time horizons, ranging from several years ahead to close to real-time operation. For the purpose of this investigation, we will focus on the tasks relevant for the specific hour of the event, which occurred on 21 June 2024 around 11.20 UTC. These tasks include outage planning coordination, short-term and very short-term operational security analysis.

4.1.2 Time Horizon of the Tasks and the Focus on the Specific Hour



The provided tasks from the RCCs have a few regional differences, but in general we can identify the following:

» **OPC:** As it is necessary to perform maintenance of the electricity grid, outages are a condition of the operation of the grid. Outages of grid elements and production units affect neighbouring countries and must be coordinated to ensure the secure operation of the grid. The OPC task coordinates the outages to optimise the availability of the Regional and European Power Grid.

- Time horizon: Y-1 to W-1.

» **STA:** RCCs investigates whether the reliable available expected production capacity can meet the expected consumption at any given time while also considering restrictions in the transmission grid. If there is insufficient reliable available production capacity to meet the consumption, measures need to be taken by TSOs to avoid an adequacy situation.

- Time horizon D-7 to D-1.

» **CSA:** The possibility to highlight and visualise possible operational security risks in advance gives the operators additional time during the preparation and planning phase to investigate possibly needed remedial actions, thus aiding operators in their decision-making in real time. This service provides operational support to the TSOs to identify operational security risks and recommends preventive remedial actions to the individual TSOs.

- Time horizon D-1 to ID.

» **CGM:** Based on IGMS, a CGM representing the power system is created, which can be used for performing further analysis through the tasks performed by RCCs.

- Time horizon Y-1 to ID.

» **CCC:** Electricity is freely traded across borders in the internal energy market. However, the limits of transmission capacity must be respected. The service calculates the secure power market capacities to maximise the transmission capacity offered to the market, while maintaining grid security.

- Time horizon Y-1 to M-1; and D-2 to ID.

» **CGS:** When the grid is experiencing extraordinary conditions that cannot be resolved through national countermeasures, the TSOs have the option to trigger a communication protocol to enhance collaboration with neighbouring TSOs/RCCs with the objective of mitigating the risk to the security of supply.

- Time horizon M-2 to D-2.

4.2 RCC Tasks Relevant for the Investigation

Task	RCC/RSC	Area	Timeframe	Result	References
OPC	SEleNe CC	SEleNe CC area (incl. GR)	Week ahead	OK	See chapter 4.2.1 for details
	SCC	SCC region	Week ahead	OK	
	TSCNET	TSCNET area (incl. HR)	Week ahead	OK	
STA	All RCCs (Main: SCC)	Pan-EU	Week ahead	OK	See chapter 4.2.2 for details
Security Analysis	TSCNET	TSCNET area (incl. HR)	Day ahead (23:22 CEST)	OK	See chapter 4.2.3 for details
			Intraday (11:25 CEST)	OK	
	SCC	SCC area (incl. BA, ME, AL)	Day ahead (20:27 CEST)	OK	
			Intraday (08:25 CEST)	OK	
	SEleNe CC	SEleNe CC area (incl. GR)	Day ahead (20:15 CEST)	OK	
CCC	TSCNET & Coreso	Core CCR (incl. HR-SI, HR-HU)	Day ahead	OK	See chapter 4.2.4 for details
E&R	SCC	SCC region	Every 5th year, done in 2019 and is ongoing in 2024	OK	See chapter 4.2.5 for details
	TSCNET	TSCNET area (incl. HR)		OK	

Table 9: Overview of the status from RCC tasks – For all processes, no issues were foreseen for the region.

4.2.1 Outage Planning Coordination (OPC)

4.2.1.1 Overview

The process consists of annual, monthly and weekly, where TSOs are obliged to report all planned outages of relevant elements defined by calculations based on the Relevant Assets for Outage Coordination (RAOC) methodology.

The regional OPC process is implemented by each RCC/RSC for its region, i.e. its TSOs. The W-1 OPC process covers a seven-day planning period beginning on Saturday and ending on the following Friday. TSOs are obliged to report preliminary planned disconnections on Wednesdays by 12:00 CEST. They receive a report from the OPC tool after the 1st Merge (on Wednesdays at 12:00 CEST) with detected possible tie-line inconsistencies with neighbours. TSOs are obliged to correct these tie-line inconsistencies by 16:00 CEST, when the 2nd Merge is triggered.

The results of the 2nd Merge are used by RCCs as input data for regional calculations.

After the security analysis performed by RCCs and analysis by the TSOs, the TSOs have the right to change the disconnection plan and submit an updated one until Thursday at 16:00 CEST, when the 3rd Merge is triggered. In addition to changing the disconnection plan, TSOs have the right to request the repetition of security analyses if they consider that between the 2nd and 3rd Merge they have reported some significant changes that have a major impact on the results.

The results of the 3rd Merge are presented at the regular weekly operational teleconference (WOPT) held for the SEE region every Friday at 09:00 CEST. The moderator of the meeting is SCC/Selene CC on the yearly rotational basis since both RCC are operating in the SEE region. Further details are described in 4.2.1.3 SEE MG WOPT. On WOPT, the final reconciliations of the disconnection plan for the next week are made, and TSOs are obliged to submit all changes to the OPC tool by 13:00 CEST when the last, final 4th Merge is triggered, which is used as the relevant disconnection plan for the next week.

Therefore, planned disconnections are considered to be only those that were reported to PE OPC tool before Friday 13:00 CEST. Disconnections reported after that moment are considered unplanned.

RCCs use week ahead (and year ahead) CGMs to assess all combinations of upcoming outage plans and possible N-x contingencies to evaluate grid security.

In the case of identified issues, remedial actions and/or cancelling of outage tasks are proposed.

4.2.1.2 W-1 OPI Results

OPI (Outage Planning Incompatibilities) Assessment[9] performed regularly two times per week after TLI (Tie line Inconsistencies) Errors Identification/Notification of affected TSOs.

The week ahead OPI assessment process uses the merged preliminary unavailability plan (.xml) and merged OPC Element List (.xml) from the PE OPC process, performs a regional security assessment on predefined scenarios (seasonal CGMs) and allows for the application of imported remedial actions on the CGM. The regional security assessment is performed by SEleNe CC in close cooperation with SEleNe CC TSOs.

SEleNe CC has performed week ahead OPI covering the period from 16/06 to 21/06. According to the results, on CW25, SEleNe CC initial and final OPI did not detect any contingencies for tie line Zemblak–Kardia. For the other lines related to the incident there are no findings as the coverage does not include elements outside the SEE CCR (GR, BG, RO). The TS closer to the incident is on 21 June 10:30 and the results can be found in Table 10. No overloading is observed in this timestamp.

Critical Outage identification			Critical Network Element identification			CNE After CO result		
Elements in outage	Base voltage (kV)	Area	Monitored element	Type	Base voltage	U	Loading I	Loading
						(kV)	(A)	%
Gutinas - Smardan OHL	380	RO	Barbosi - Filesti OHL	line	220	220.39	–669	**84**
lineGutinas - Smardan OHL	380	RO	Lacu Sarat - Filesti OHL	line	220	219.97	607	**76**
Brazi Vest transformer	380/220	RO	Bucuresti Sud - Fundeni c2	line	220	220.20	630	**72**
Brazi Vest transformer	380/220	RO	Bucuresti Sud - Fundeni c1	line	220	220.55	629	**72**

Table 10: SeleneCC OPI Results for CW25

OPI in SCC was performed for BD 18 June TS 07:30 as this date had the highest number of outages in the SEE region. Compared to 21 June, on Tuesday 18 June there was 46 outages planned and for Friday 21 June there were 43 outages planned. OPI performed for the 18 June did not detect any contingencies.

The results show that no contingencies are detected. In the 220 kV and 400 kV network, overloads greater than 100 % were detected for the following elements:

Critical Outage identification			Critical Network Element identification			CNE After CO result		
Elements in outage	Base voltage (kV)	Area	Monitored element	Type	Base voltage	U	Loading I	Loading
						(kV)	(A)	%
OHL 400 kV Gelibolu 2 - Bekirli Tes - I	400	TR	OHL 400kV GELİBOLU2 - BEKİRLİ TES - II	line	400	403.21	1062.0	**104.7**
OHL 400 kV Gelibolu 2 - Bekirli Tes - II	400	TR	OHL 400kV GELİBOLU2 - BEKİRLİ TES - I	line	400	403.21	1060.0	**104.6**
TIE 400 kV Trebinje - Lastva	400	ME	OHL 220kV Podgorica 1 - HE Perućica	line	220	226.14	102.80	**102.9**

Table 11: SCC OPI Results for CW25

TSCNET performs an OPI assessment for three timestamps per day one week before real-time. For any foreseeable congestion TSCNET assesses different available remedial action including the cancelation of outages. The results from this assessment are an early indicator for the grid security and are closer to real-time complemented by the day-ahead and intraday congestion forecasts.

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[9] The state in which a combination of the availability status of one or more relevant grid elements, relevant power generating modules, and/or relevant demand facilities and the best estimate of the forecasted electricity grid situation leads to a violation of operational security limits considering any remedial actions without costs at the TSO's disposal.

For 21.06.2024 12:30 the outage plans available until 13.06.2024 16:00 were considered. Based on this data, TSCNET foresaw some possible minor congestions in Switzerland and Germany but did not foresee any congestions in Croatia. As measures for reducing these congestions, TSCNET had considered topological measures in France, Italy, Belgium and Switzerland, as well as the cancelation of one outage in Switzerland.

None of the foreseen congestions and the proposed measures had a direct influence on the incident in the Balkan area and the grid situation for Croatia considered in the scenario can be considered as secure based on TSCNET's week-ahead OPI assessment.

4.2.1.3 SEE MG WOPT

All TSOs from the SEE region (AL, BA, BG, GR, HR, HU, KS, ME, NMK, RO, RS, TR) regularly participate in the pan-European OPC Process.

In the SEE region, the coordination of Week ahead and Year ahead disconnections is the task of the South East Europe Maintenance Group (SEE MG).

SEE MG is a dedicated regional group of EU and non-EU TSOs and RCCs whose obligation is to plan and coordinate outages in SEE.

For 2024, SEleNe CC has been assigned as a coordinator of SEE MG. Topics covered within role MG are:

1. Harmonisation of the yearly procedure for the annual maintenance plan in the SEE region;
2. Confirmation of planned outages and information exchange on a weekly basis;
3. Short term scheduling and information exchange on outage planning; and
4. Real time outages and information exchange.

Planned Outages for CW25 (2024-06-15 to 2024-06-21) are shown in the following Table:

Element	Start Date	Start Time	End Date	End Time	Daily / Permanently	Restitution Time [h]
TIE 400 kV Bekescsaba (MAVIR) – Nadab (TRANSELECTRICA) CKT 1	21.05.2024	07:00	12.07.2024	17:00	P	N
TIE 400 kV Arachthos (IPTO) – Galatina (TERNA) CKT 1	27.05.2024	08:00	23.06.2024	16:00	P	N
OHL 400 kV Bucuresti Sud (TRANSELECTRICA) – Pelicanu (TRANSELECTRICA) CKT 1*	28.05.2024	06:00	20.06.2024	17:00	P	24
OHL 400 kV Tirana 2 (OST) – Koman (OST) CKT 1	01.06.2024	00:00	30.09.2024	23:00	P	N
OHL 220 kV Kolacem (OST) – Tirana 2 (OST) CKT 1	01.06.2024	00:00	30.09.2024	23:00	P	N
TIE 400 kV Koman (OST) – Kosovo B (KOSTT) CKT 1	01.06.2024	00:00	30.09.2024	23:00	P	N
OHL 400 kV Cernavoda (TRANSELECTRICA) – Medgidia Sud (TRANSELECTRICA) CKT 1**	10.06.2024	06:00	21.06.2024	17:00	D	2
OHL 400 kV Bucuresti Sud (TRANSELECTRICA) – Slatina (TRANSELECTRICA) CKT 1	14.06.2024	05:00	20.06.2024	17:00	D	1
OHL 400 kV Paks (MAVIR) – Sandorfalva (MAVIR) CKT 1	15.06.2024	07:00	16.06.2024	17:00	D	2
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 2	15.06.2024	07:00	16.06.2024	17:00	D	1
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 3	15.06.2024	07:00	16.06.2024	17:00	D	1
OHL 400 kV KOZLODUY (ESO) – SOFIA ZAPAD (ESO) CKT 1	17.06.2024	07:00	21.06.2024	15:30	D	1
OHL 400 kV Obrenovac (EMS) – Kragujevac 2 (EMS) CKT 1	17.06.2024	07:00	23.06.2024	18:00	D	1
TR 400/220 kV MARITZA IZTOK 3 (ESO) – MARITZA IZTOK 3 (ESO) CKT 1	17.06.2024	07:00	28.06.2024	15:00	P	2
TIE 220 kV TE Sisak (HOPS) – Prijedor 2 (NOSBiH) CKT 1	17.06.2024	08:00	19.07.2024	17:00	D	0.5
OHL 400 kV Tuzla 4 (NOSBiH) – Ugljevik (NOSBiH) CKT 1	20.06.2024	08:00	21.06.2024	16:00	D	N

Table 12: Planned Outages for CW25 (2024-06-15 to 2024-06-21)), as it was available at Friday June 14th at 1 PM CEST

The map below shows the planned disconnections for CW25 (2024-06-15 to 2024-06-21)

Figure 47: Map of planned disconnections for CW25 (2024-06-15 to 2024-06-21)

It should be noted that because of the incident there are some planned outages that are practically changed as follows:

Element	Planned Status	Final Status
OHL 400 kV Tuzla 4 (NOSBiH) – Ugljevik (NOSBiH) CKT 1	OFF	ON
OHL 400 kV Tuzla 4 (NOSBiH) – Visegrad (NOSBiH)	ON	OFF
OHL 400 kV Melina (HR) – RHE Velebit (HR)	ON	OFF
REN	49.8	185

Table 13: Differences between planned and actual outages

4.2.2 Short Term Adequacy (STA)

All South-East Europe (SEE) TSOs and RCCs (EU and non-EU) participate in the Pan-European (also known as Cross-Regional) STA process.

All SEE TSOs are obliged to submit input data for the STA process. The process is triggered daily on the Pan-European level, which is executed automatically and monitored by the Main or Back-up RCC. Deterministic and probabilistic calculations of STA are performed daily.

If necessary, the Regional STA process is also triggered, which is a rare situation in SEE. A regional STA process is triggered if the results of deterministic calculation show inadequacy, for a time horizon on D+3 or less.

SCC was the Main Adequacy Assessment Agent (AAA) for the pan-EU process in the week when incident happened.

4.2.2.1 Input data

All input data (NTC files, Week Ahead Generation and Week Ahead Load files) relevant for all affected and neighbouring TSOs received on the STA tool on 20.06.2024 (the day before the incident) successfully passed validation and were considered during STA calculation.

CZC for affected and neighbouring TSOs for three timestamps

CZC values for all affected and neighbouring TSOs are presented in the next figures for timestamps 11:30, 12:30 and 13:30 CET which are relevant for the incident. Figures also display initial Remaining Capacities (RCs) for the bidding zones of the affected region. According to input data, all TSOs except HOPS and one bidding zone in Italy are initially adequate (when the bidding zone is green on the map than adequacy is satisfied, and vice versa a red colour indicates that the zone is initially inadequate and needs energy import). When a bidding zone is initially adequate, this means that zone can cover all its load with production in that bidding zone and there is no need for an import of energy. MEPSO had a long-term issue with the delivery of input data, and that region in the calculation is neglected. In that case, CZC capacities are available for the exchange of energy in calculations, but that region has neither load nor generation. Based on input data, the conclusion is that the adequacy situation in the region was good. CZC values for the import and export of energy presented on the maps indicates usual capability for energy exchange between bidding zones and, based on that, the situation for the analysed timestamps was usual and normal.

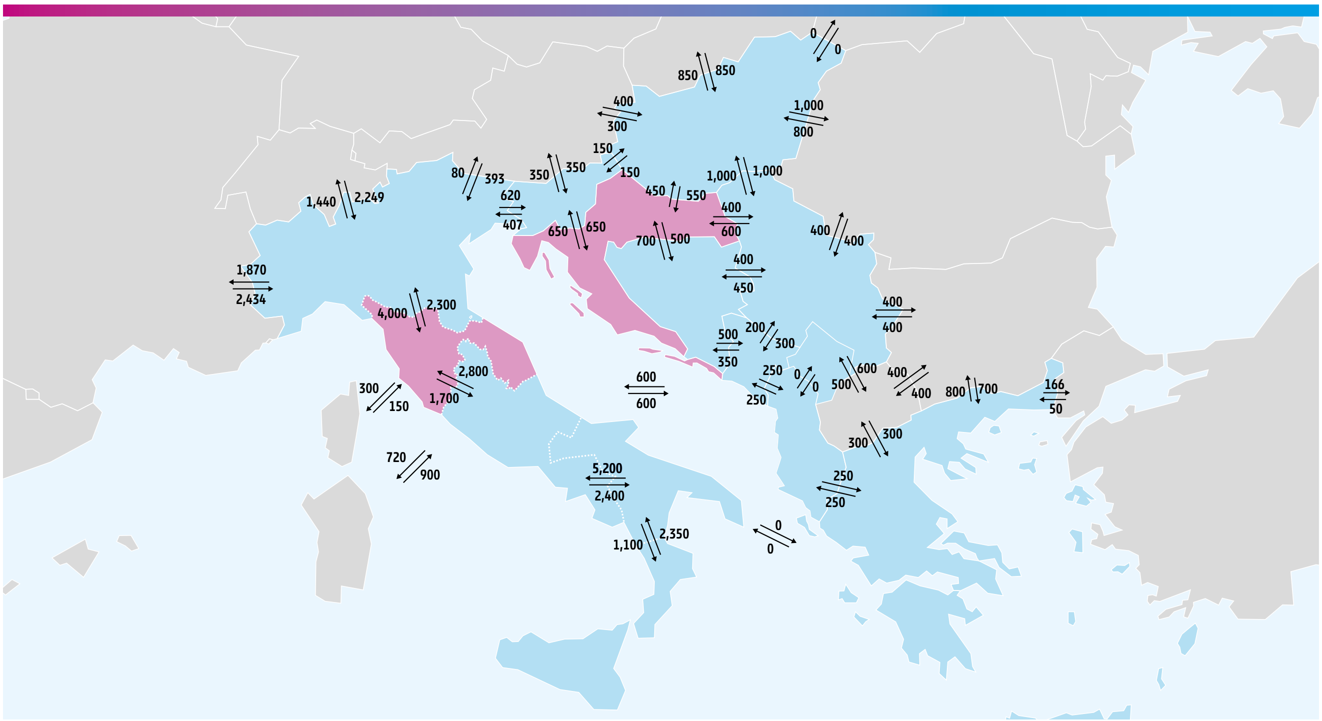

Figure 48: CZC values from the STA tool for all affected and neighbouring TSOs for 11:30

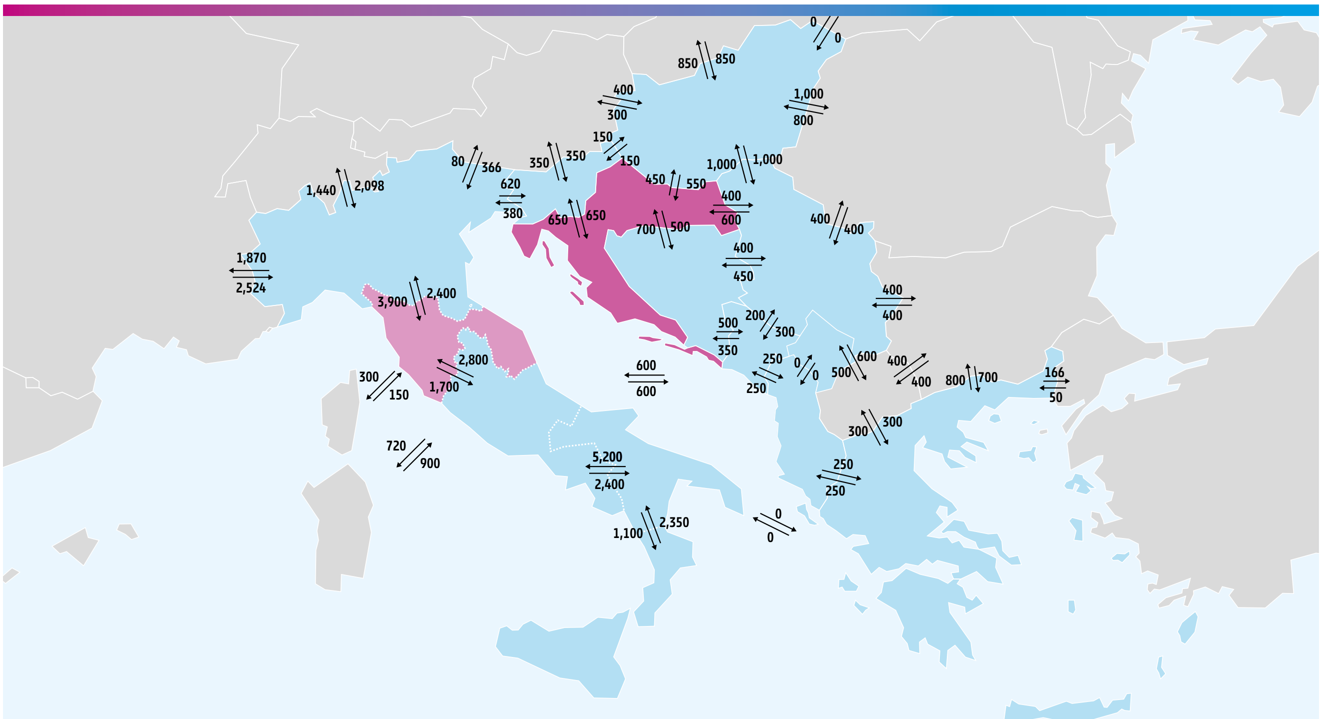

Figure 49: CZC values from the STA tool for all affected and neighbouring TSOs for 12:30

Figure 50: CZC values from the STA tool for all affected and neighbouring TSOs for 13:30

Initial Remaining Capacities

Initial RCs per bidding zone for timestamps 11:30, 12:30 and 13:30, before STA calculation, are presented in the figures below. As described in 1.3, the adequacy situation in the region was good, and in this step, based on the input data for the region, even before calculations it could be concluded that after calculations the region will also be adequate.

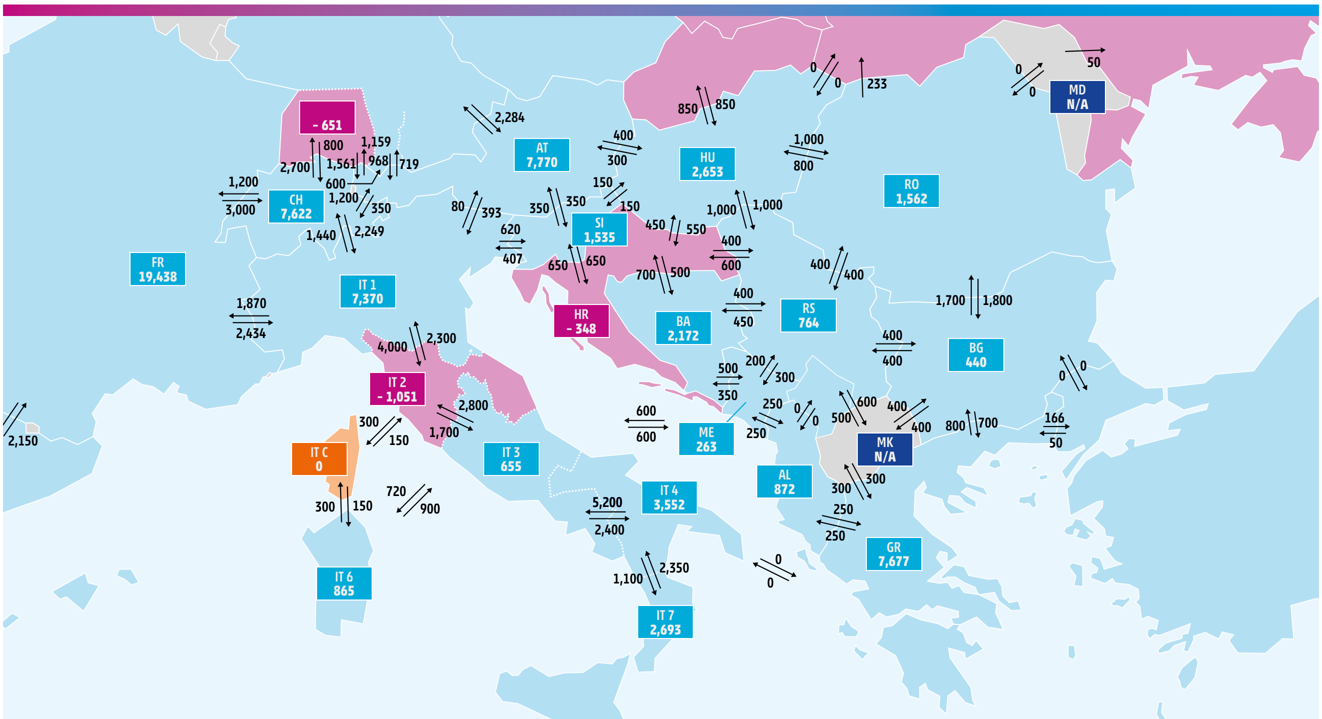

Figure 51: Initial RC values from the STA tool for all affected and neighbouring TSOs for 11:30

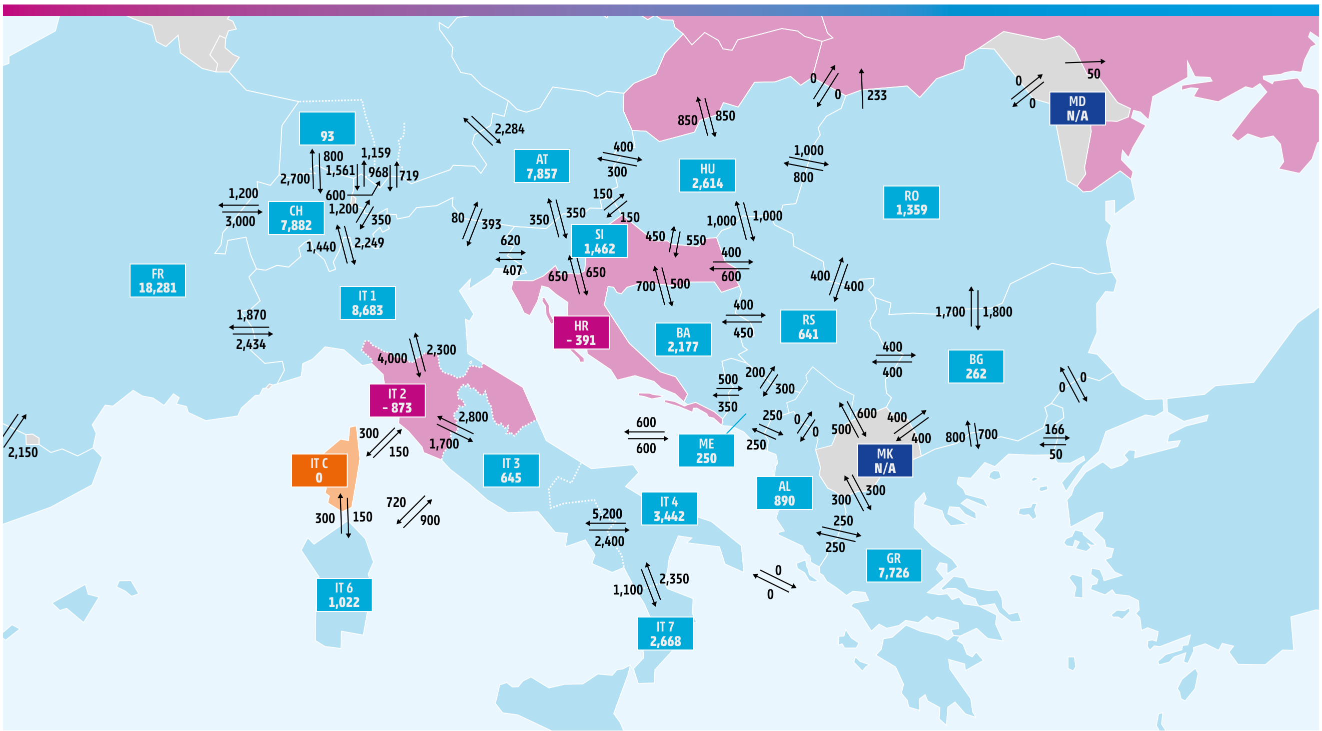

Figure 52: Initial RC values from the STA tool for all affected and neighbouring TSOs for 12:30

Figure 53: Initial RC values from the STA tool for all affected and neighbouring TSOs for 13:30

4.2.2.2 Cross-Regional Adequacy Results

STA calculation (1st run) has been done in time for approximately 30 minutes. This is normal calculation time usual in the everyday STA process.

SCC was the Main RSC for the STA process, so SCC's operator on duty was information about the STA results by email. The whole STA process went well without any detected failures of the system and reported issues on the ticketing system for the STA tool.

Both deterministic and probabilistic results for the period 21.06.2024 – 27.06.2024 did not show any adequacy issues in affected and neighbouring TSOs after the STA calculation.

Final Exchanges and Remaining Capacities

Final Exchanges and RCs per bidding zone for timestamps 11:30, 12:30 and 13:30, after STA calculation, are presented in the figures below. These figures present the final adequacy situation in the region. The framed value of RC for each bidding zone represents the amount of remaining capacity after calculation. If some bidding zone has zero RC after the calculation, the entire production of that bidding zone is exhausted, and this situation is not invalid. In this case, ME bidding zone load is fulfilled with full production in ME bidding zone combined with import from adjacent bidding zones. This is due to STA algorithm rules and priorities. The map also represents exchanges of power between bidding zones.

Based on the results, all TSOs and bidding zones which are important for the analysed incident on 21.06.2024 are adequate. The conclusion is that, based on these results, no problem could be detected. Even if some TSO was inadequate after assessment, no valid conclusion about the potential incident could be derived from that. The Pan-EU STA process is a process which deals with input data about production, load and exchanges, and power grid model is not considered. A regional STA process which will consider the power grid model is under development. The current regional STA process, which was not triggered on calculation day, also cannot predict issues related to power system security as the grid model is not considered.

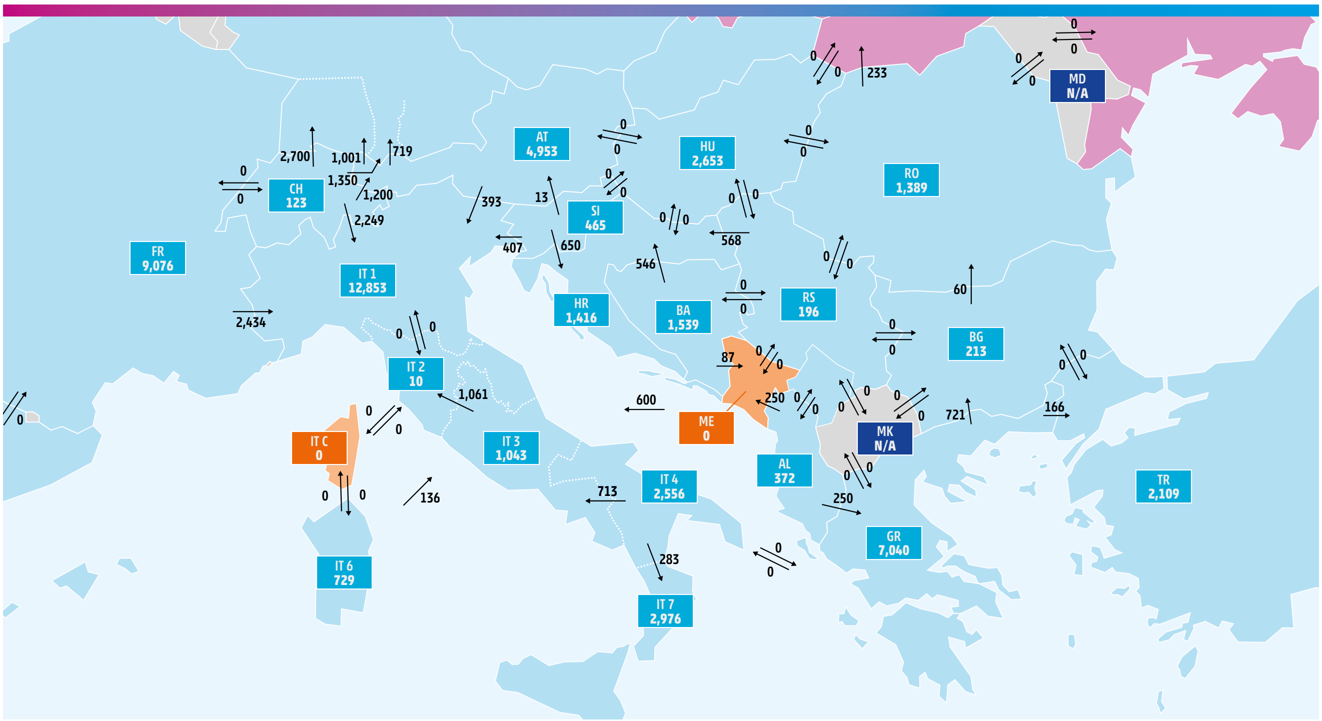

Figure 54: Final Exchanges and RCs from the STA tool for all affected and neighbouring TSOs for 11:30

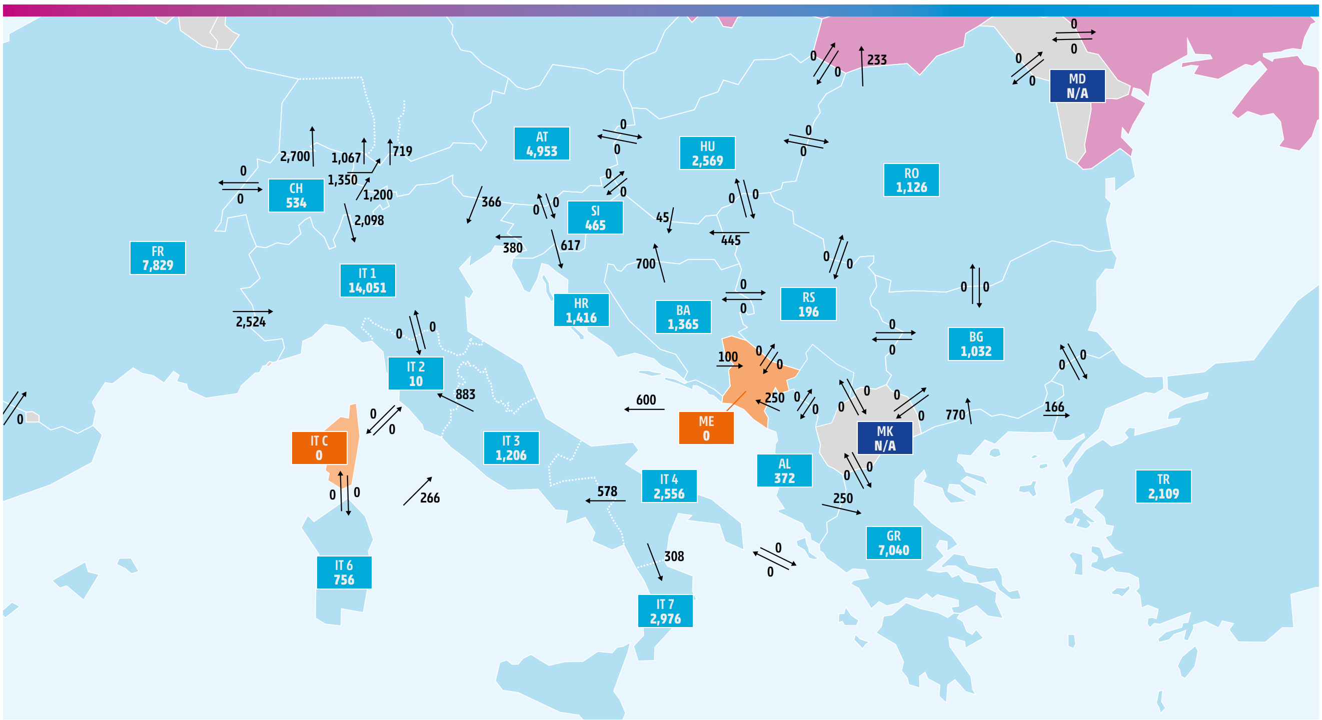

Figure 55: Final Exchanges and RCs from the STA tool for all affected and neighbouring TSOs for 12:30

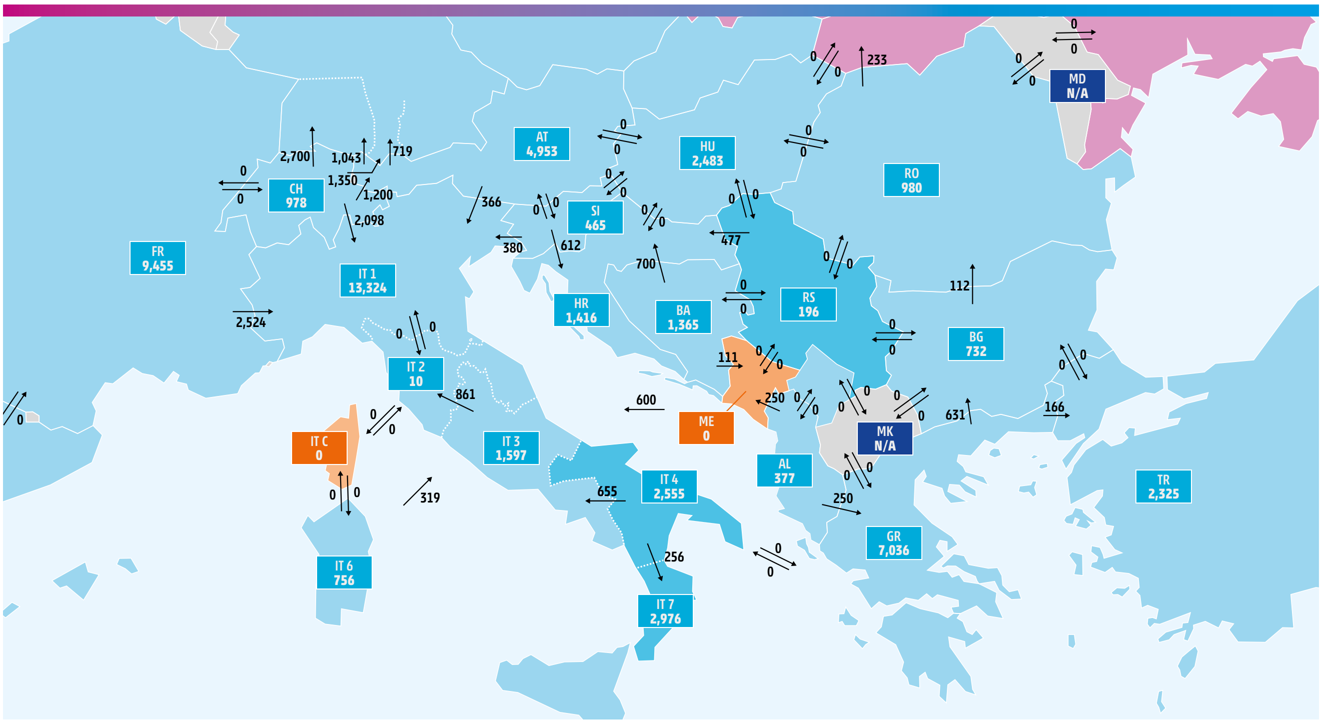

Figure 56: Final Exchanges and RCs from the STA tool for all affected and neighbouring TSOs for 13:30

4.2.3 Coordinated Security Analysis (CSA) and Common Grid Model (CGM)

4.2.3.1 Summary

SCC, SEleNe CC, TSCNET and Coreso have not yet fully implemented the CSA with all requirements according to Article 37(1)(b) of EU Regulation 2019/943. Instead, they perform a legacy Security Analysis for parts of the affected area. This relies on IGMs from the TSOs in the Union for the Co-ordination of Transmission of Electricity (UCTE) data exchange format. The CGMES based processes are not yet live. The Security Analysis consists of a DACF and additional Intraday Congestion Forecasts (IDCF) in some areas. For every day, 24 timestamps are considered, CGMs are generated, and N-X Security Analysis is performed. For the incident, the timestamp 12:30 is the best representation of the expected grid situation for the hour 12:00–13:00.

In the DACF and IDCF processes during the N-X calculation, the following lists are used:

- Contingency list – containing the contingencies selected by the TSOs based on CSAm Art. 7; and
- Monitoring list – containing all the elements that certain TSOs consider relevant to be monitored during security assessment in the DACF and IDCF processes, taking into account CSAm Art. 15(1).

These lists are not limited to elements and scenarios within the TSO's grid but may include neighbouring elements. Each TSO is responsible for maintaining its Contingency and Monitoring lists and for announcing in advance if some major changes are expected. The lists are then merged.

All elements from incident area were included in the SCC's regular security assessment process as Contingency and Monitoring elements. For TSCNET and SEleNe CC, they partially fall outside of their observability area.

The N-X Security Analysis assesses ordinary and exceptional contingencies but does not include the combination of multiple unrelated contingencies (N-2, N-3 etc.). These are considered "out-of-range" according to Art. 7 CSAm. Hence, none of the three RCCs assessed the tripping of OHL 400kV Ribarevine – Podgorica 2 and OHL-TIE 400 kV Zemblak – Kardia together. No relevant congestions were foreseen for the N situation and for the cases of one of these lines tripping. Overall, the grid was considered N-1 secure in the DACF and IDCF processes.

OHL-TIE 400 kV Zemblak – Kardia is a tie-line between Albania and Greece and, therefore, both TSOs provide information about it in their IGMs. For 21.06.2024, the TSOs provided different current limits. IPTO provided a limit of 1599 A and OST a limit of 1900 A. In such cases, the RCCs consider the lower limit for the whole line. Therefore, in this case 1599 A were used by all RCCs.

While some differences can be observed between the load flow results from different RCCs and between DACF and IDCF, the results can still be considered consistent. Minor differences are always to be expected as different load flow engines are being used which may have minor differences in their implementation. In addition, the RCCs used individually created UCTE CGMs. Updated IGMs, updated market schedules and model corrections can create further differences. These did not significantly affect the results for the relevant grid elements and can be considered negligible.

4.2.3.2 SCC DACF & IDCF

According to Agreements on the provision of operational services, which are concluded among SCC and its service users, CGMs and security analysis results for IDCF process were delivered by SCC to NOSBiH, CGES and OST on 21.06.2024. at 8:25 AM.

The IDCF process in SCC is performed 3 times per day for the upcoming 8 hours. The most recent N-X results relevant to this incident were calculated during the second IDCF process (performed for the period from 8:30 AM to 3:30 PM).

According to SCC's regular procedures, all the elements from the monitoring area that are (over)loaded above 90% of the defined limits either in the base case or after any contingency from the contingency area are listed.

Prior to the event, SCC did not have in its Contingency list the simultaneous outages of OHL 400 kV Ribarevine – Podgorica 2 and OHL-TIE 400 kV Zemblak – Kardia which happened in real time. Because of the physical distance of these two lines, SCC's TSOs did not include them in N-2 contingency.

The results shown below were extracted from SCC's regular reports for timestamp 12:30. As can be seen, nothing indicated a possible critical situation in the affected area. Only the overloading of TIE 150 kV Mourtos – Bistrica between IPTO and OST is noted for the outages of TIE 400 kV Zemblak – Kardia and for the outage of OHL 400 kV Zemblak – Elbasan 2. This overload in case of 400 kV failure is considered as manageable by OST in the operational hour as there is no effect on security of supply for this region of Albania. SEleNe CC DACF analysis based on IPTO's input lists simultaneously outage of Kardia-Zemlak and Bistrica-Mourtos is considered at the contingency analysis), as well as the overloading of TR 150/110 kV Bistrica for the outage of TIE 400 kV Zemblak – Kardia. In the CGES and NOSBiH results of IDCF security analysis for 12:30 no overloads were detected in the 220 kV and 400 kV grid in the case of any outage.

Time stamp	Contingency Name	Monitored Element Name	Loading_BC (%)	Loading after outage (%)
12:30	TIE 400 kV Kardia - Zemblak	TIE 150kV Mourtos - Bistrica (AL)	64.08	**130.41**
12:30	TIE 400 kV Kardia - Zemblak	TR 150/110kV Bistrica	61.25	**121.79**
12:30	TR 220/110 kV Tirana 2 (1)	TR 220/110kV Tirana 2 (2)	74.30	**111.84**
12:30	TR 220/110 kV Tirana 2 (2)	TR 220/110kV Tirana 2 (1)	74.30	**111.84**
12:30	TIE 400 kV Kardia - Zemblak	TIE 150kV Mourtos - Bistrica (GR)	51.49	**104.38**
12:30	OHL 400 kV Zemblak - Elbasan 2	TIE 150kV Mourtos - Bistrica (AL)	64.08	95.35

Table 14: SCC results for OSTof IDCF security analysis for 12:30[10]

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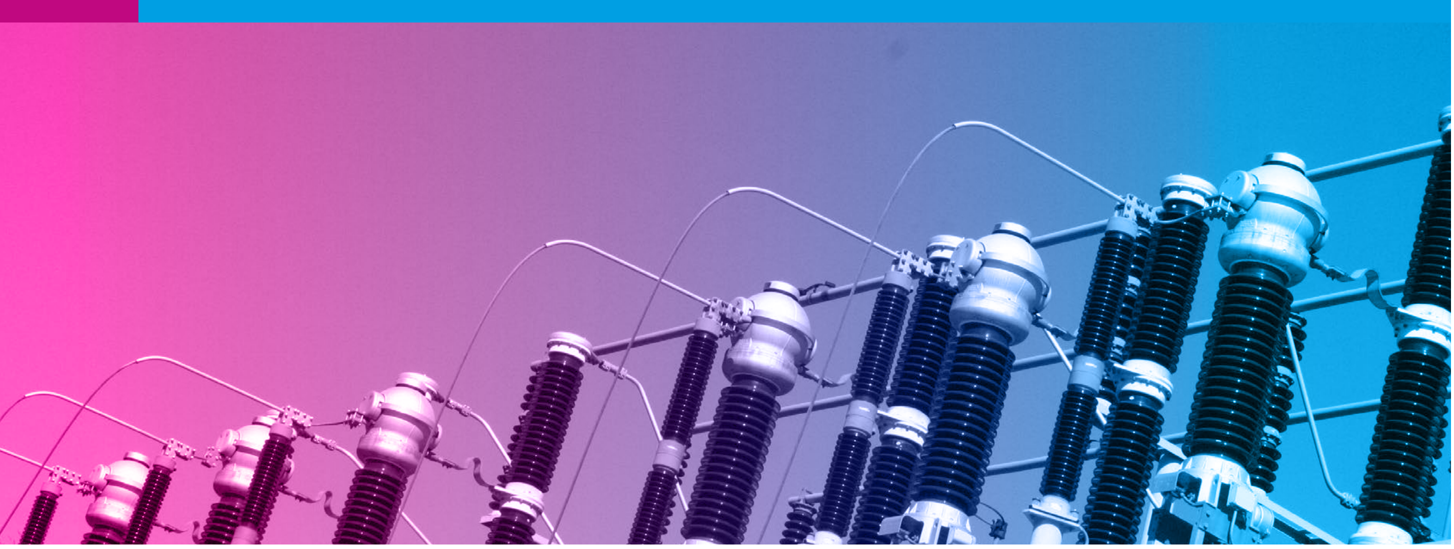
[10] Differences between Table 14 and 15 and similar tables in chapter 2 are due to different filtering of the results.



These results were consistent with the DACF results from the day before which were made available to the TSOs at 20:27 on the 20.06.2024.

Time stamp	Contingency Name	Monitored Element Name	Loading_BC (%)	Loading after outage (%)
12:30	TIE 400 kV Kardia - Zemlak	TIE 150 kV Mourtos - Bistrica (AL)	64.60	**133.55**
12:30	TIE 400 kV Kardia - Zemlak	TR 150/110 kV Bistrica	61.73	**124.88**
12:30	TR 220/110 kV Tirana 2 (1)	TR 220/110 kV Tirana 2 (2)	74.15	**111.62**
12:30	TR 220/110 kV Tirana 2 (2)	TR 220/110 kV Tirana 2 (1)	74.15	**111.62**
12:30	TIE 400 kV Kardia - Zemlak	TIE 150 kV Mourtos - Bistrica (GR)	51.91	**106.89**
12:30	OHL 400 kV Zemlak - Elbasan 2	TIE 150 kV Mourtos - Bistrica (AL)	64.60	97.42

Table 15: SCC results for OSTof DACF security analysis for 12:30

Element	Current (A)	Limit (A)	Loading (%)
Ribarevine - Podgorica 2	471.5	1920	24.6
Zemblak - Kardia	942.7	1599	59.0
Fierze - Prizren 2	127.3	720	17.7
Podgorica 1 - Mojkovac	161.8	720	22.5

Table 16: Load flow results from SCC DACF CGM for 12:30

4.2.3.3 SEleNe CC DACF

SEleNe CC provides a daily DACF process for SEleNe CC area. From the area of the incident in question, only the GR–AL tie lines are relevant.

The DACF process for SEleNe CC has been performed on 20.06.2024 at 20:15. The results did not suggest any violations for the GR–AL tie lines, which were relevant to this event. A slight overvoltage only appears in a few nodes at the Greek and Romanian system, irrelevant for this incident.

Element	Current (A)	Limit (A)	Loading (%)
Ribarevine - Podgorica 2	473	1920	24.0
Zemblak - Kardia	928	1599	58.0
Fierze - Prizren 2	130	720	18.1
Podgorica 1 - Mojkovac	164	720	23.0

Table 17: Load flow results from SEleNe CC DACF CGM

4.2.3.4 TSCNET DACF & IDCF

TSCNET provides a daily DACF and an hourly IDCF for the TSCNET area. From the area of the incident, this only includes Croatia, including its tie-lines.

The DACF process finished on 20.06.2024 at 23:22. Regarding the critical timestamp 12:30, almost all monitored elements were foreseen to be below the defined limits in the foreseen grid situation (N situation). Only for some 220 kV lines in France and for some transformers in Ukraine were overloads calculated which were considered unrealistic. For the incident, they were irrelevant.

For the contingency analysis, TSCNET simulates all contingency cases from the contingency lists provided by the TSOs. Also, for these scenarios (N-1 situations), there were no congestions foreseen in the area. Very slight N-1 congestions (<106 %) were foreseen for a French–Italian tie-line and an internal line in Austria. Both were fully within the expected limits and no consequent actions were taken by TSCNET.

The first elements that tripped during the incident were neither monitored nor part of the considered contingency cases. The provided CGM indicated the following flows:

Element	Current (A)	Limit (A)	Loading (%)
Ribarevine - Podgorica 2	481.4	1920	25.1
Zemblak - Kardia	947.0	1599	59.2
Fierze - Prizren 2	129.2	720	17.9
Podgorica 1 - Mojkovac	160.1	720	22.2

Table 18: Load flow results from the final TSCNET DACF CGM

The latest iteration of the hourly IDCF process before the incident finished at 11:25. Regarding the critical timestamp 12:30, almost all monitored elements were foreseen to be below the defined limits in the foreseen grid situation (N situation). Only for some lines in France and Italy and for some transformers in Ukraine were overloads calculated which were considered unrealistic or manageable. For France and Italy, primarily the results from Coreso would be considered. For the incident they were irrelevant. In addition, there were minor overloads detected on the Croatian transformers in Tumbri 380–110 kV (116 %) and in Ernestinovo 380–110 kV (104 %).

Also, for all configured contingency cases there were no violations of N-1 criterion foreseen in the area. Very slight N-1 violations (<109 %) were foreseen for internal lines in Austria and Italy. For the contingency analysis, TSCNET simulates all contingency cases from the contingency lists provided by the TSOs. Also, for these scenarios (N-1 situations), there were no congestions foreseen in the area.

The first elements that tripped during the incident were neither monitored nor part of the considered contingency cases. The provided CGM indicated the following flows:

Element	Current (A)	Limit (A)	Loading (%)
Ribarevine - Podgorica 2	494.2	1920	25.7
Zemblak - Kardia	966.1	1599	60.4
Fierze - Prizren 2	145.7	720	20.2
Podgorica 1 - Mojkovac	166.0	720	23.1

Table 19: Load flow results from the TSCNET IDCF CGM from 11:25

4.2.3.5 Coreso DACF & IDCF

The DACF and IDCF processes at Coreso did not foresee any constraints on the Italian–Montenegro border. For information, the 380 kV Divaca PST in Slovenia, at the border with Italy, was in outage.

Constraints in the operational security limits were detected on the FR–IT and IT–CH borders, but there was no impact on the Monita cable.

4.2.4 Coordinated Capacity Calculation (CCC) Processes

Currently, non-EU TSOs in the Balkans area do not belong to any EU CCR, despite the flows within them and within neighbouring EU TSOs having an influence on the CCC in both the Core and SEE CCRs. The capacity calculation is done with bilateral coordination among EU- and non-EU TSOs.

A disadvantage of the current approach is that the capacity calculation is not coordinated and performed sufficiently in advance. Day-ahead CCC in line with Regulation (UE) 2015/1222 went live in June 2022 in Core CCR and in July 2021 in SEE CCR. Unfortunately, CCC in SEE CCR will cover only two borders from the south-east area of CE, RO-BG and BG-GR. Capacity Allocation & Congestion Management (CACM) is not mandatory for non-EU TSOs and basic capacity calculations in SEE (which are still used for commercial purposes) are bilateral NTC calculations performed by neighbouring TSOs, using M-2 regional CGM harmonised among SEE TSOs. Therefore, a stronger and more detailed coordination at the level of RCCs (TSCNET, SCC and SELENE-CC) should be developed in the region as soon as possible. Preconditions for stronger and more detailed RCCs coordination are harmonised methodologies and business processes in SEE for CCC. The concept of CCC is based on "CCR regional modules" as well as coordination and cooperation on these matters with neighbouring CCRs (and RCCs). Currently, non-EU SEE TSOs do not belong to any CCR, and this issue must be solved (possible options are the creation of either so-called Shadow CCR 10 or WB6 CCR) to implement the "CCR regional modules" concept for the entirety of the Continental Europe Synchronous Area. Furthermore, a final solution for CCC in the south-east part of CE is the implementation of the flow-based approach after the application of market coupling within the whole area according to CACM regulation.

The possibility of developing a more sustainable solution for CCC and CSA for non-EU TSOs in the Balkans area and between these TSOs and neighbouring EU TSOs should be assessed to increase the system security and ensure a proper level of TSOs cooperation.

TSCNET and Coreso provide flow-based CCC for the Core Region, which includes the borders from Croatia to Slovenia and Hungary. For the day of the incident, the CCC process was successfully completed. According to the CCC results for the 21.06.2024, the load flow in the region was from north to south. The load flow was expected to be from Austria towards Slovenia and Hungary throughout the day. Similarly, the load flow was expected to be from Slovenia towards Croatia. At the time of the incident, Hungary was exporting energy to Croatia.

The most limiting element from the Core DACC point of view in the Croatia grid was 220 kV Pehlin – Divaca with "N-1 Melina – Divaca" contingency. Individual reductions have been applied in this element, including the hour when the incident started. In addition, it must be indicated that the minimum Remaining Available Margin (RAM) factor was 45.2 % instead of 70 % for this element.

There were no shadow prices in HR region for the whole day, but there were in neighbouring countries (Obersielach – Podlog with contingency "N-1 Maribor – Kainachtal 1" for almost all day).

Considering the elements that were out of service on the day of the event, there were limited options to manage the load flow. Measures taken, such as individual reductions and a lower minimum RAM factor value, can be cited as examples of steps taken to protect the system from overloads and congestion. Accordingly, no conclusion has been reached that the actions taken during the CCC process contributed to the development of the incident.

4.2.5 Consistency assessment of defence and restoration plans

The first check of the consistency assessment of defence and restoration plans was done in 2019. The final report was approved by SOC on 12.02 2020. There were no inconsistencies detected in 2019.

The consistency check shall be done every 5 years, and an iteration was triggered for 2024.

The consistency assessment by the RCCs was ongoing at the time of the incident and the assessment from 2019 is still relevant for 21 June, 2024.

5 COMMUNICATION OF COORDINATION CENTRES / SAM AND BETWEEN TSOs

As communication between the Coordination Centres and the TSOs is of utmost important in any term for a reliable and stable system operation, this chapter presents the different contacts at the time of the incident between the Coordination Centres on the one hand and the affected TSOs among each other on the other hand. The purpose of this chapter is thus to present the available data in this regard, while the data is further examined in the other chapters.

5.1 Communication of Coordination Centres SAM and between TSOs

» **21 Jun, 11:26 CET:**
CGES contacted TERNA to request a reduction in the setpoint on the HVDC Monita for voltage/reactive-power flows adjustment purposes. TERNA declined the request due to internal congestions on the North borders and proposed as a countermeasure the disconnection of the 70 MVAr – reactor in KS Kotor (TERNA). Due to the fact that voltages in SS Lastva and Podgorica 2 were above 400 kV at that moment, the measure was assessed as not appropriate. No further communication regarding this matter.

The incident triggered a series of communication exchanges among the affected TSOs, with the aim of coordinating restoration efforts and ensuring the safe and efficient operation of the grid. **The following timeline outlines the key communication events:**

» **21 Jun, 12:24 CET:**
TERNA informed CGES that HVDC cable Monita is out of operation.

» **21 Jun, 12:27 CET – 12:34 CET:**
During this period, CGES, NOSBiH, HOPS and OST engaged in an exchange of information regarding the incident and the system state in each country. The affected TSOs communicated relevant details of the incident to their neighbouring TSOs, including TERNA, IPTO, EMS, MAVIR and ELES. In addition, EMS and HOPS offered their support through the utilisation of 220 kV and 400 kV power lines.

» **21 Jun, 12:29 CET:**
OST informed IPTO that TIE 400 kV Zemblak (OST) – Kardia (IPTO) was disconnected and requested its reconnection.

» **21 Jun, 12:34 CET:**
OST called KOSTT – call related to switching on TIE 220 kV Fierze (OST) – Prizren (KOSTT).

» **21 Jun, 12:36 CET:**
OST contacted IPTO to communicate their readiness to switch on the TIE 400 kV Zemblak (OST) – Kardia (IPTO) and to request reconnection.

» **21 Jun, 12:48 CET:**
CGES updated NOSBiH concerning the operational status of the TIE 220 kV Piva (CGES) – Sarajevo 20 (NOSBiH), informing them not to exceed the power exchange limit of 100 MW.

» **21 Jun, 12:50 CET – 12:55 CET:**
A series of coordinated calls took place between HOPS and NOSBiH regarding the energisation of the TIE 220 kV Međurić (HOPS) – Prijedor (NOSBiH). These discussions were crucial for implementing a top-down restoration strategy aimed at gradually re-establishing power supply to the affected regions.

» **21 Jun, 12:56 CET – 13:08 CET:**
Several calls occurred between CGES and OST regarding the energisation of the TIE 400 kV Podgorica 2 (CGES) – Tirana (OST). These calls were focused on the critical step of switching on the power line as part of a top-down restoration approach to restore voltage in certain areas of Montenegro. During the discussions, OST established a power exchange limit of 100 MW for the line to ensure safe operations and prevent potential system overloads.

» **21 Jun, 13:06 CET:**
HOPS informed NOSBiH that maintenance operations on the TIE 220 kV Sisak (HOPS) – Prijedor (NOSBiH) had been completed. NOSBiH responded by indicating that the relevant work permits on their side remained open.

» **21 Jun, 13:16 CET:**
HOPS communicated to NOSBiH that they were prepared to switch on the TIE 400 kV Konjsko (HOPS) – Mostar 4 (NOSBiH). Discussions ensued regarding whether closing the 400 kV ring would be more advantageous if NOSBiH switched off the OHL 400 kV Sarajevo 10 – Mostar 4.

» **21 Jun, 13:24 CET – 13:28 CET:**
Several calls between HOPS and NOSBiH related to switching on TIE 400 kV Konjsko (HOPS) – Mostar 4 (NOSBiH).

» **21 Jun, 13:36 CET:**
Call between HOPS and NOSBiH related to switching on TIE 220 kV Mostar 4 (NOSBiH) – Zakučac (HOPS).

» **21 Jun, 13:46 CET:**
Conversations between HOPS and MAVIR took place concerning the energisation of the TIE 400 kV Ernestinovo (HOPS) – Pecs ckt2 (MAVIR).

» **21 Jun, 13:54 CET:**
Call between CGES and NOSBiH related to switching on TIE 220 kV Trebinje (NOSBiH) – Perućica (CGES).

» **21 Jun, 13:56 CET:**
Call between HOPS and NOSBiH related to switching on TIE 220 kV Trebinje (NOSBiH) – Plat (HOPS).

» **21 Jun, 13:56 CET – 14:19 CET:**
Several calls between EMS and NOSBiH related to switching on TIE 110 kV Janja – Lesnica.

» **21 Jun, 14:13 CET:**
Call between HOPS and NOSBiH related to switching on TIE 110 kV Opuzen – Neum.

» **21 Jun, 14:28 CET – 14:35 CET:**
Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Županja – Orašje.

- **21 Jun, 14:37 CET – 15:03 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Neum – Ston.
- **21 Jun, 14:44 CET – 14:50 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Grahovo – Knin.
- **21 Jun, 14:49 CET:**
  Call between CGES and NOSBiH regarding switching on TIE 220 kV Podgorica 1 (CGES) – Koplik (OST).
- **21 Jun, 14:56 CET – 15:01 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 220 kV Đakovo (HOPS) – Gradacac (NOSBiH) and TIE 220 kV Đakovo (HOPS) – Tuzla (NOSBiH).
- **21 Jun, 14:59 CET – 15:05 CET:**
  Several calls between CGES and NOSBiH regarding switching on TIE 400 kV Lastva (CGES) – Trebinje (NOSBiH).
- **21 Jun, 15:03 CET – 15:05 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Mazin (HOPS) – K. Vakuf (NOSBiH) and transformer 150 MVA in Đakovo (HOPS).
- **21 Jun, 15:07 CET – 15:16 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Livno – B. Blato.
- **21 Jun, 15:29 CET:**
  Call between HOPS and NOSBiH related to switching on TIE 110 kV Imotski – Grude.
- **21 Jun, 15:31 CET – 15:34 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 110 kV Capljina – Opuzen.
- **21 Jun, 15:36 CET:**
  Call between HOPS and NOSBiH related to switching on TIE 110 kV Vrgorac – Ljubuski.
- **21 Jun, 15:41 CET – 15:59 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 220 kV Prijedor (NOSBiH) – Sisak (HOPS).
- **21 Jun, 15:42 CET – 15:45 CET:**
  Several calls between HOPS and NOSBiH related to switching on TIE 220 kV Zakucac (HOPS) in SS Mostar 4 (NOSBiH).
- **21 Jun, 15:56 CET:**
  Call between CGES and NOSBiH related to switching on TIE 110 kV Nikšić – Bileća.

21 Jun, 16:00 CET:
Call between HOPS and NOSBiH related to switching on TIE 110 kV Komolac – Trebinje.

5.2 Communication between RCCs

During the incident situation, SCC operators on duty received total of three (3) calls from other RCCs but no official calls were received from SCC TSOs about the incident root cause and further situation.

In these calls, operators from Coreso and TSCNET tried to figure out more details about incident situation. Since there was no information from TSOs, all gathered information by SCC operators on duty were unofficial (media, other calls…). Based on operational processes that were performed for the incident timestamp, there was no indication about possible critical situation that would lead to the incident/blackout in affected region, which was shared during the phone calls that SCC operators had with other RCCs.

- **21 Jun, 13:23 CET:**
  Call between SCC and Coreso.
- **21 Jun, 13:35 CET:**
  Call between SCC and TSCNET.
- **21 Jun, 16:28 CET:**
  Call between SCC and Coreso.

5.3 Communication between affected TSO and Synchronous Area Monitor (SAM)

As defined for even month, Swissgrid was due as Synchronous Area Monitor (SAM) and thus took over the coordination following the blackout. This section presents a timeline of key interactions between Swissgrid and various TSOs.

» **21 Jun, 12:27 CET:**
Swissgrid received a phone call from Amprion and was informed about the frequency jump. Swissgrid also confirmed that it had noticed this jump. Amprion and Swissgrid further discussed the incident and the further coordination briefly as the frequency measurements of HOPS were marked as invalid on the EAS at this time. Regardless, the SAM was unable to clearly identify HOPS as the cause.

» **21 Jun, 12:29 CET:**
Swissgrid contacted ELES, the leader of SHB block, who reported a substantial load loss in HOPS, stating, "[…] many people without electricity. […]". CC South & North extended an offer of assistance, which ELES declined at that time, indicating that they would provide further updates as new information became available.

» **21 Jun, 12:38 CET:**
Swissgrid informed Amprion about the assistance offer from CC South & North and ELES's subsequent refusal.

» **21 Jun, 12:50 CET:**
The frequency remained at the upper 50 mHz limit. Swissgrid contacted ELES to ask again whether they needed help. ELES accepted. Swissgrid said that they could get in touch as soon as they needed negative power. ELES also provided information about the blackout situation in Bosnia-Herzegovina, Albania, Montenegro and Croatia. However, they did not yet have an overview of their ACE about all affected lines in the control block.

» **21 Jun, 13:01 CET:**
ELES contacted Swissgrid and provided another update on the blackout situation. They did not need any help for the time being. However, they wanted to know what the help would look like.

» **21 Jun, 13:18 CET:**
Amprion was informed again by Swissgrid. They discussed whether a possible LLFD procedure should be carried out as normal or whether adjustments should be made. Swissgrid suggested that all procedures should be carried out as planned, provided that no further input was received from the affected TSOs – including a possible LLFD.

» **21 Jun, 13:26 CET:**
Swissgrid contacted OST. OST declined the offer of assistance, asserting that it was unnecessary. They elaborated on the measures they had undertaken, including the activation of power plants and management of affected transmission lines. OST indicated their intent to restore a 400 kV and 220 kV line between Montenegro and Albania, clarifying that these lines were energised but had not yet been switched on operationally by Montenegro.

5.4 ENTSO-E Awareness System (EAS)

The EAS was activated in response to critical incidents, enabling a coordinated response among various TSOs within the ENTSO-E framework. Below are the detailed changes in system states for each affected TSO during the series of events.

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

5.5 Conclusion

The effective communication during the critical event and subsequent restoration process was paramount. The TSOs were informed of the disturbance, allowing for a swift response to the voltage collapse and blackouts across the affected regions. This timely communication facilitated coordinated efforts and ensured that the necessary preconditions and preparatory actions for the restoration process were efficiently implemented.

6 RESTORATION PROCESS

6.1 Preconditions and preparatory actions for restoration process

Thanks to the traffic lights changes in EAS, TSOs received information shortly after the disturbance that the large part of the transmission systems of Albania, Montenegro, Bosnia and Herzegovina as well as Croatia suffered a voltage collapse followed by a totally or partly blackout (as shown in Figure 57).

Figure 57: Blackout incident in the south-eastern part of CE on 21 June

During the blackout incident in the south-eastern part of CE on 21 June, HOPS had blackouts in the small part of area Osijek and almost completely area Dalmatia.

NOSBiH and OST (except small load supplied radially in South of Albania from Greece System) had blackouts in all systems and the fastest restoration process of power system was undertaken using the neighbour's interconnections.

CGES was separated into the north part which was energised and the south part which was not energised, and the restoration plan was to connect these two parts of the CGES system, taking care of internal power flow.

After the exchange of information related to incidents between affected TSOs, restoration plan of TSOs was started immediately.

Interconnections were used for the top-down method of the restoration process, taking care with active power on tie-lines according to the Agreement on transmission system operation between TSOs.

6.2 Restoration sequences

6.2.1 HOPS

Due to the blackout state in Bosnia and Herzegovina and because of maintenance on OHL 400 kV Melina – Velebit, the HOPS dispatcher started the restoration process of the Dalmatia area from 220 kV voltage level (top-down method). The sequence of reconnection of elements in the HOPS network is shown in Figure 58.

At 12:52 the first reconnection was OHL 220 kV Brinje – Pađene ①, at 12:53 switched on OHL 220 kV Pađene – Konjsko ② at 12:54 switched on OHL 220 kV Konjsko – Zakučac and then at 12:55 put in operation transformer 220/110 kV in substation (SS) Zakučac ③. The aim of this manipulation was to energise 220 kV busbar in HPP Zakučac and to energise busbar 220 kV SS Konjsko where is connected static VAR compensator (SVC).

Due to the high voltage in the 220 kV grid, the HOPS dispatcher at 13:02 switched on HPP Zakučac with power of 63 MW and at 13:05 switched on SVC in the busbar 220 kV SS Konjsko. These manipulations helped with the problem of high voltage caused by long underloaded lines (Ferranti effect), as is shown in Figure 59.

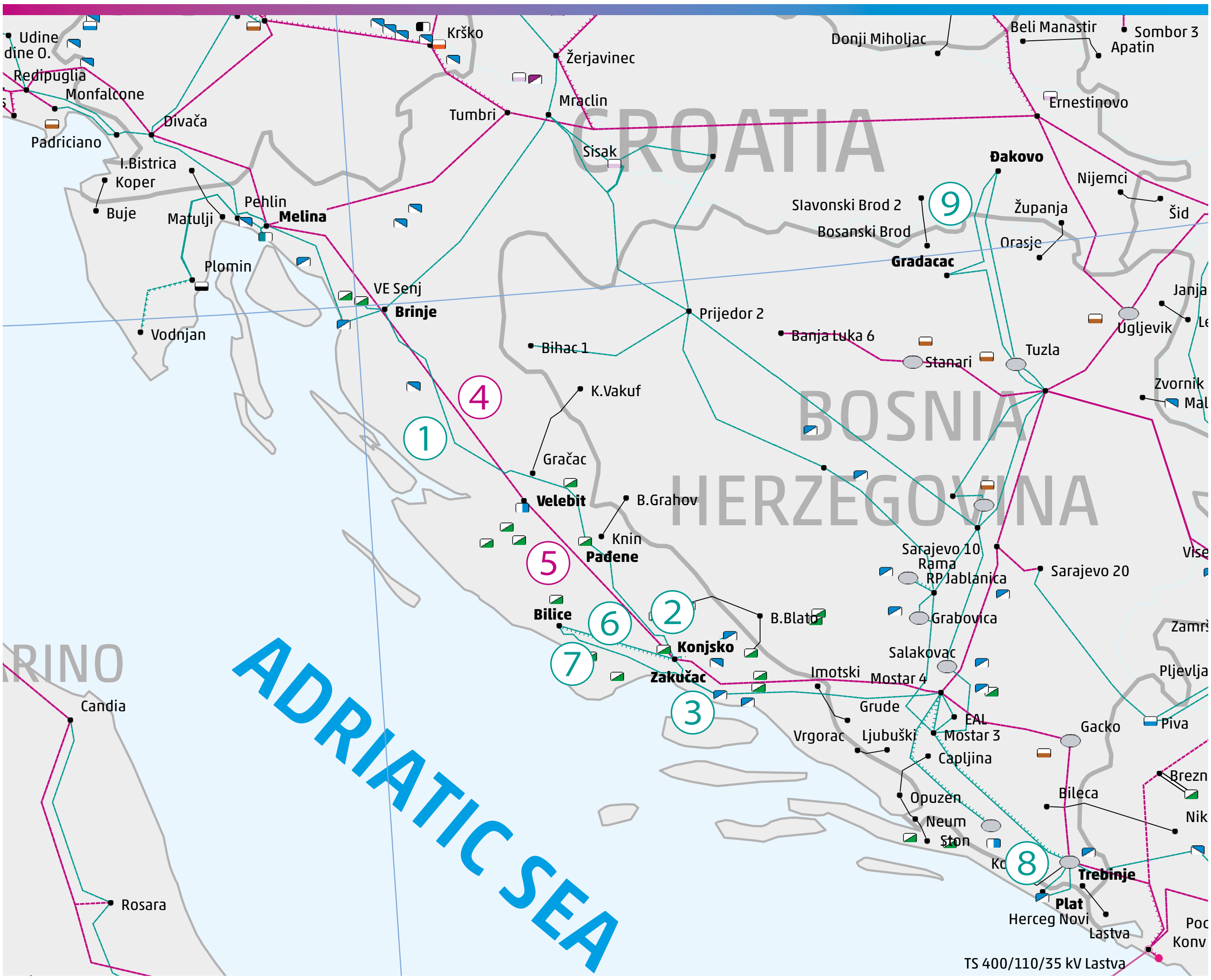


Figure 58: Step-by-step action during the restoration process in the HOPS grid

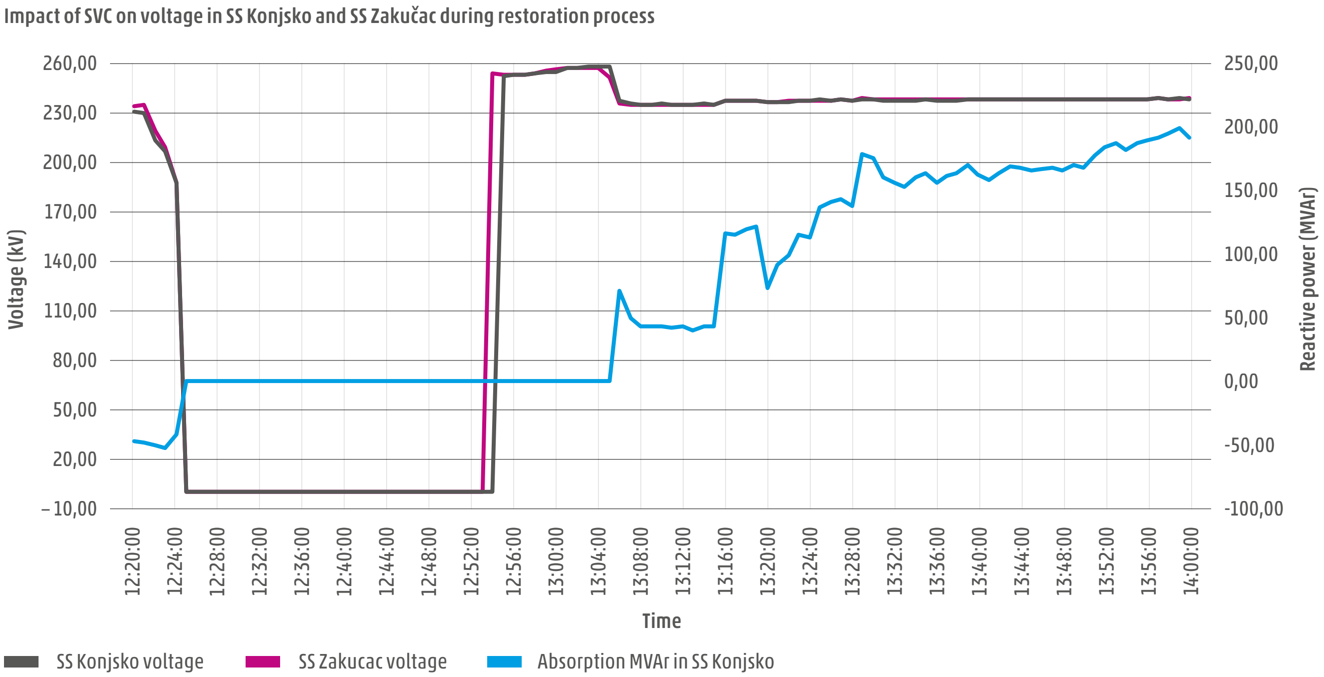


Figure 59: Impact of SVC on voltage in SS Konjsko and SS Zakučac during the restoration process

After the interruption of work on OHL 400 kV Melina – Velebit, the HOPS dispatcher started with the restoration of 400 kV voltage level.

At 13:09 switched on OHL 400 kV Melina – Velebit ④, at 13:11 switched on OHL 400 kV Velebit – Konjsko ⑤, at 13:14 and at 13:15 in SS Konjsko switched on both transformers 400/220 kV and at 13:19 switched on two transformers 220/110 kV in SS Konjsko. After these manipulations, the most important substation for this area was almost fully energised.

At 13:24 switched on OHL 220 kV Konjsko – Bilice 1 and OHL 220 kV Konjsko – Bilice 2 ⑥, OHL 220 kV Bilice – Zakučac ⑦ and at 13:51 switched on transformer 220/110 kV in SS Bilice.

At 14:04 switched on transformer 400/110 kV in SS Velebit.

Part of the HOPS grid around Dubrovnik starts being energised from NOSBiH grid. At 14:09 switched on TIE 220 kV Trebinje (BA) – Plat (HR) ⑧ and then transformer 220/110 kV in SS Plat at 14:14.

At 15:00 switched on TIE 220 kV Đakovo (HR) – Gradačac (BA) and subsequently TIE 220 kV Đakovo (HR) – TPP Tuzla (BA) are switched on ⑨. At 15:20 first transformer 220/110 kV in SS Đakovo is switched on and at 15:26 second transformer 220/110 kV is also switched on.

6.2.2 NOSBiH

After the exchange of information related to the incident with the neighbouring TSOs of Croatia (HOPS), Serbia (EMS) and Montenegro (CGES), the restoration plan was started immediately.

Interconnections with HOPS, EMS and CGES, which did not switch off, were used for restoration using a top-down method.

Before starting the restoration process, dispatchers in NOSBiH according to the Restoration plan switched off all circuit breakers in the SS.

Both 400 kV tie-lines from SS Ugljevik to Ernestinovo (HR) and S. Mitrovica 2 (RS) were in operations and NOSBiH dispatchers decided to start the restoration process from SS Ugljevik (as shown in Figure 60).

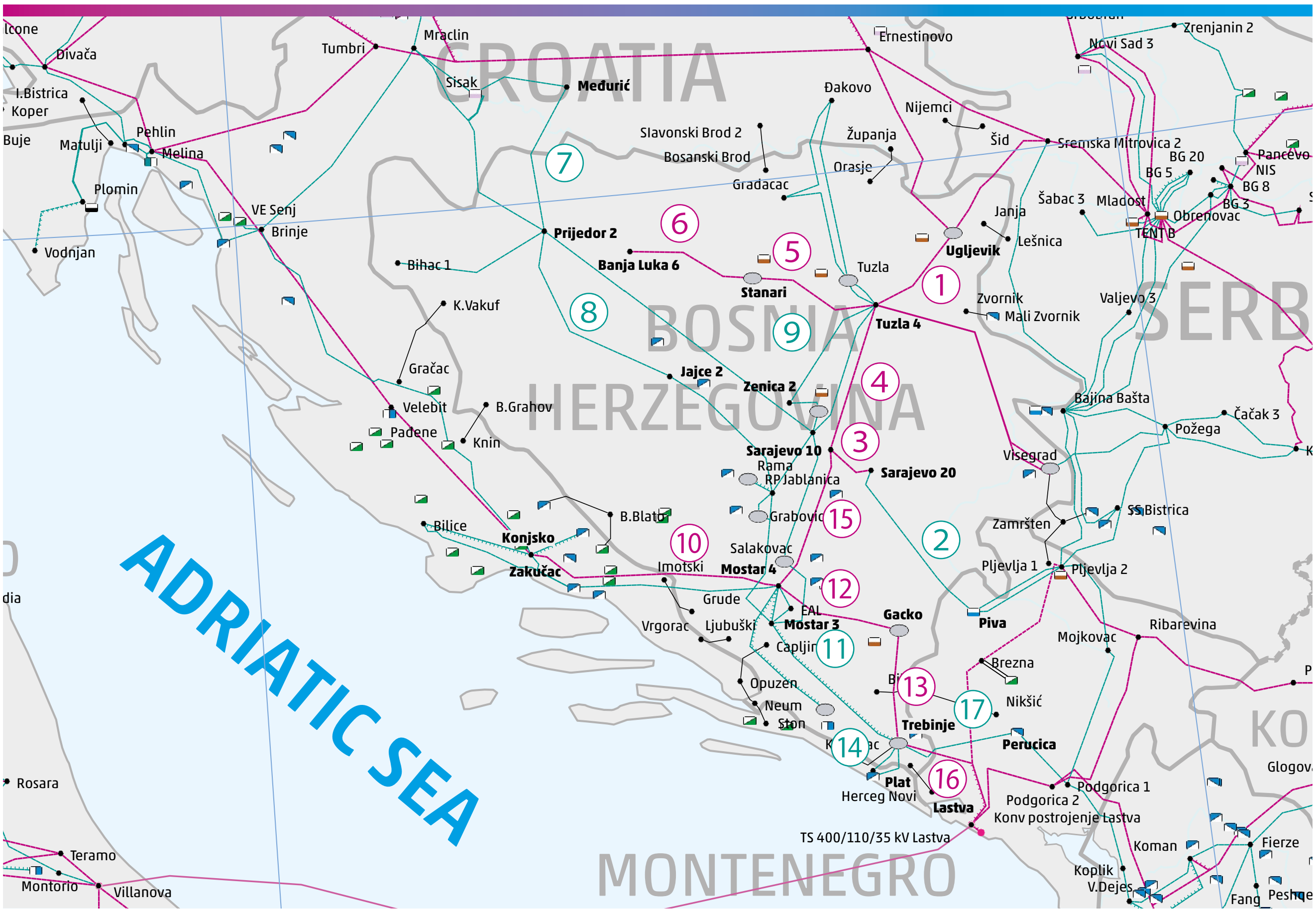


Figure 60: Step-by-step action during the restoration process in the NOSBiH grid

The start of restoration was at 12:33, when internal line OHL 400 kV Ugljevik – Tuzla 4 ① switched on and a 400 kV busbar was energised in SS Tuzla 4, which is one of most important for NOSBiH.

At 12:41 switched on TIE 220 kV Sarajevo 20 – Piva, ② reconnecting the system with the north part of CGES, immediately afterwards switched on OHL 400 kV Sarajevo 20 – Sarajevo 10 ③, energised 400 kV busbar in SS Sarajevo 10 and put in operation TR 400/110 kV in SS Sarajevo 10.

At 12:46 switched on OHL 400 kV Tuzla 4 – Sarajevo 10 ④ and immediately switched on OHL 400 kV Tuzla 4 – Stanari ⑤, at 13:05 switched on OHL 400 kV Stanari – Banja Luka 6 ⑥ and at 13:07 put in operation TR 400/110 kV in SS Banja Luka 6. From this moment on, three of the four most important 400 kV SS were energised.

At 12:55 switch on TIE 220 kV Međurić – Prijedor 2 ⑦, from SS Prijedor 2 at 13:00 started energising 220 kV SS Jajce 2 ⑧ and continue to 220 kV SS Jablanica where HPP Rama (installed capacity 170 MW) and HPP Grabovica (Installed capacity 114 MW) are connected.

After switching on TR 400/220 kV in SS Tuzla 4, at 13:28 switched on OHL 220 kV Tuzla 4 – Zenica 2 ⑨, at 13:42 switched on OHL 220 kV Zenica 2 – Kakanj V (TPP Kakanj installed capacity 215 MW) and at 13:43 connected ring of 220 kV grid with switched on OHL 220 kV SS Kakanj – Kakanj V.

Because of the high voltage caused by long underloaded lines in the power system, waiting for the presence of voltage from 400 kV SS Konjsko (HR) or 220 kV SS Zakučac (HR) to SS Mostar 4 was the fastest solution. TIE 400 kV Konjsko (HR) – Mostar 4 (BA) ⑩ is switched on at 13:47 and immediately followed by TR 400/220 kV in SS Mostar 4.The next step was energised 220 kV SS Mostar 3 from SS Mostar 4 and 220 kV Trebinje from Mostar 3 ⑪.

At 14:06 from SS 400 kV Mostar 4 was energised 400 kV SS Gacko ⑫, immediately after was energised 400 kV SS Trebinje ⑬ and at 14:07 switched on TR 400/220 kV in SS Trebinje.

Then at 14:09 switched on TIE 220 kV Trebinje (BA) – Plat (HR) ⑭.

At 15:05 switched on OHL 400 kV Sarajevo 10 – Mostar 4 ⑮ and immediately at 15:06 switched on TIE 400 kV Trebinje (BA) – Lastva (ME) ⑯ and at 15:08 switched on TIE 220 kV Trebinje (BA) – Perućica (ME) ⑰.

6.2.3 CGES

CGES was separated into the north part, which was energised, and the south part, which was not energised, and the restoration plan was to connect these two parts of CGES system, taking care of internal power flows.

Before starting the connection of lines, dispatchers in CGES according to the Restoration plan switched off all circuit breakers in SS in the south part of grid.

The sequence of reconnection of elements in the CGES network is shown in Figure 61. The fastest way to restore the south part of the power system of CGES was to synchronise the two separated parts.

The restoration process of the south part of the CGES grid started with the reconnection of OHL 220 kV Mojkovac – Podgorica 1 ① at 12:39 and immediately after that at 12:40 switched on OHL 220 kV Podgorica 1 – HPP Perućica ②. At 12:46 switched on TR 1 220/110 kV in SS Podgorica 1 and started reenergising consumers in the capital city of Montenegro, while the second transformer 220/110 kV in SS Podgorica 1 switched on at 13:23.

After that, at 13:01 switched on TIE 400 kV Tirana 2 (AL) – Podgorica 2 (ME) ③ and at 13:02 TR 2 400/110 kV in SS Podgorica 2. From this moment on, CGES was resynchronised with OST.

At 13:49 connected OHL 400 kV Podgorica 2 – Lastva ④ and both transformers in SS Lastva 400/110 kV.

At 13:49 switched on tie-lines 220 kV Trebinje in HPP Perućica to be resynchronised with the south part of NOSBiH grid, while at 15:08 HPP Perućica switched on in SS Trebinje ⑦.

At 13:58 switched on TR 1 400/110 kV in SS Podgorica 2.

At 14:01 switched on OHL 400 kV Ribarevine – Podgorica 2 and switched off after 1 minute.

At 14:51 switched on TIE 220 kV Podgorica 1 (ME) – Koplik (AL) ⑤.

At 15:05 switched on TIE 400 kV Lastva (ME) – Trebinje (BA) in SS Lastva ⑥ and at 15:16 Lastva – HVDC 1 and Lastva – HVDC 2 ⑧.

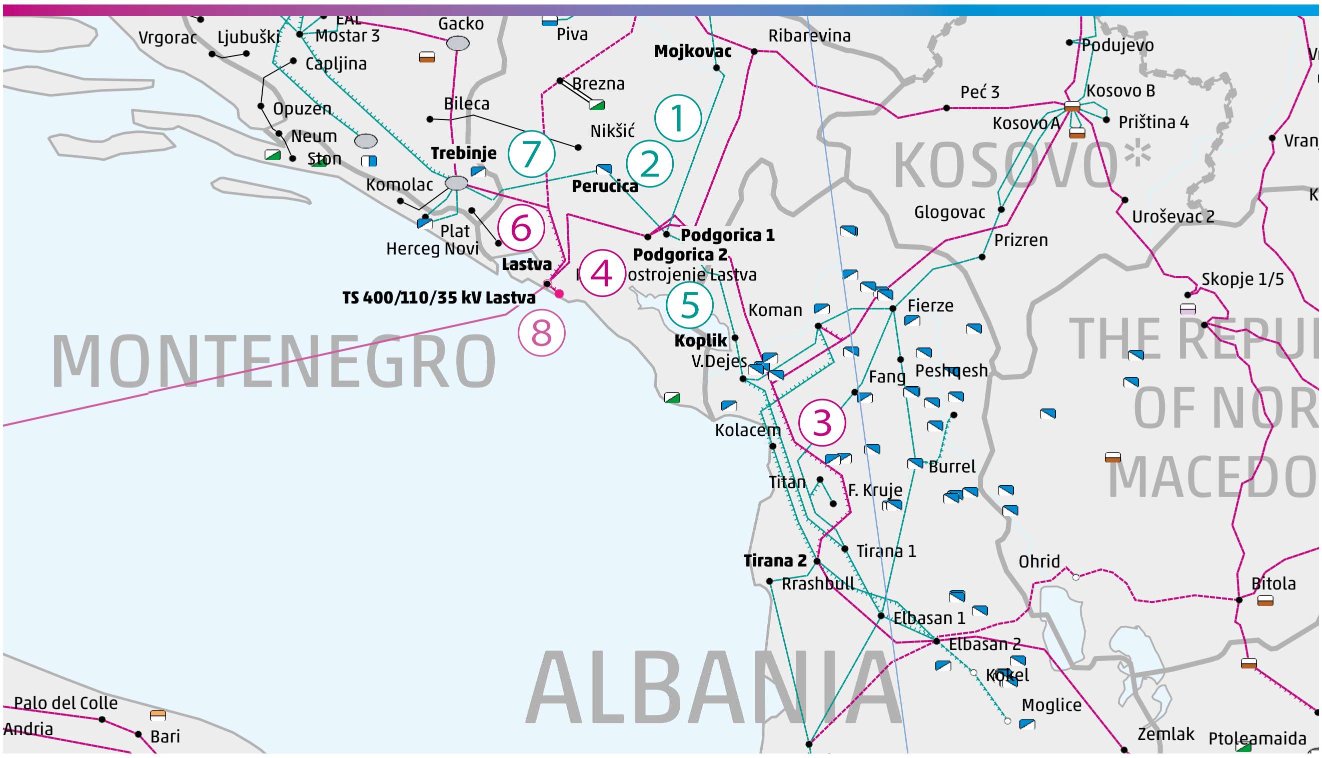


Figure 61: Step-by-step action during the restoration process in the CGES grid

6.2.4 OST

The sequence of reconnection of elements in the OST network is shown in Figure 62. Because circuit breakers in SS Zemblak, Elbasan 2 and Tirana 2 were switched on, immediately after switching on TIE 400 kV Kardia (GR) – Zemblak (AL) ① at 12:38, voltage was on 400 kV bus bar Zemblak, Elbasan 2 and Tirana 2.

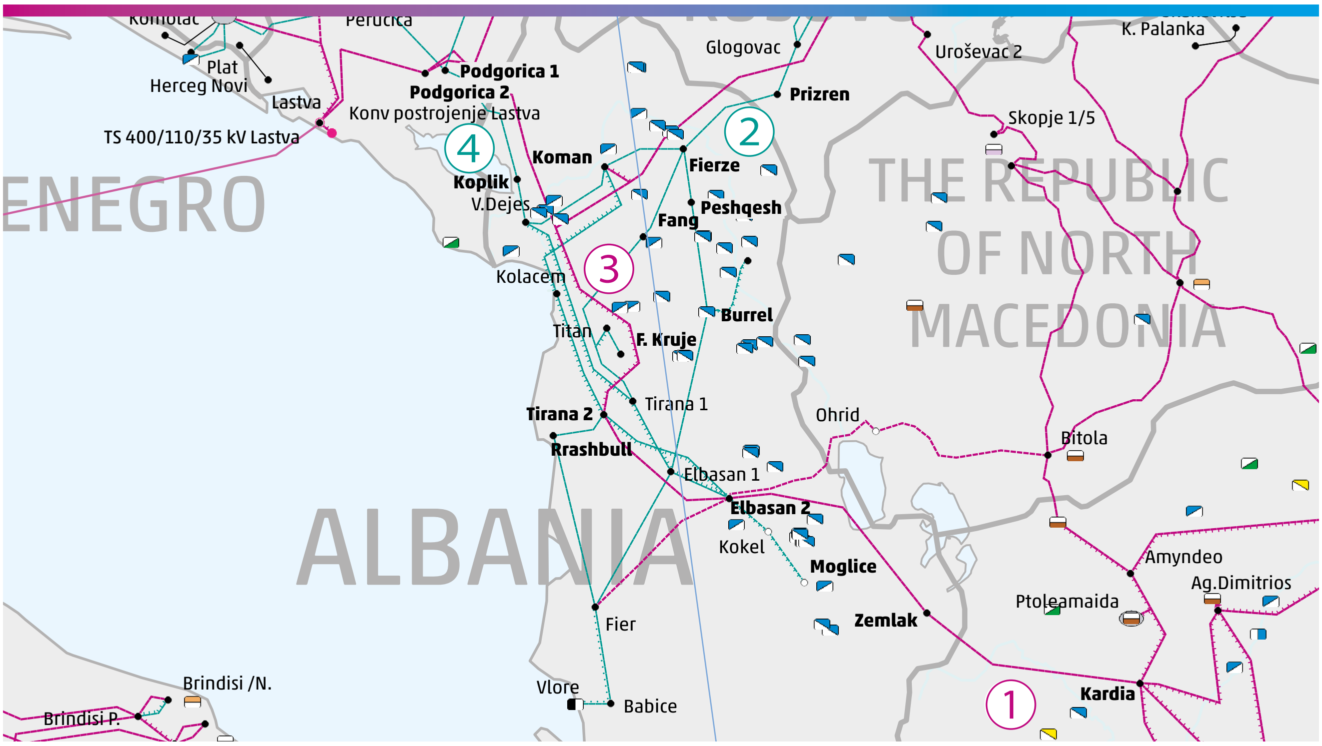


Figure 62: Step-by-step action during the restoration process in the OST grid

Circuit breakers on transformers 400/220 kV in Elbasan 2 and Tirana 2 were switched on and, because of that, busbars 220 kV in SS Elbasan 2 and Tirana 2 were energised immediately.

Circuit breakers 220 kV in SS Elbasan 2, SS Elbasan 1, SS Burelli, SS Peshquesh, SS Fier, SS Rashbull, SS Karvast, SS Moglice were switched on and energised immediately.

At 12:40 resynchronised with KOSTT via TIE 220 kV Pristina 2 – Fierza ②, bus bar at SS Koman and Fangu energised immediately.

At 12:59 resynchronised with CGES via TIE 400 kV Tirana 2 (AL) – Podgorica 2 (ME) ③ and at 13:06 via TIE 220 kV Koplik (AL) – Podgorica 1 (ME) ④.

6.3 Generation recovery actions

6.3.1 HOPS

WPP Senj in SS Brinje with total power 34 MW switched off at 12:24 and synchronised at 12:30.

HPP Dubrovnik G1 in SS Plat with total power 97 MW switched off at 12:21 and synchronised at 14:43.

Generation of HOPS

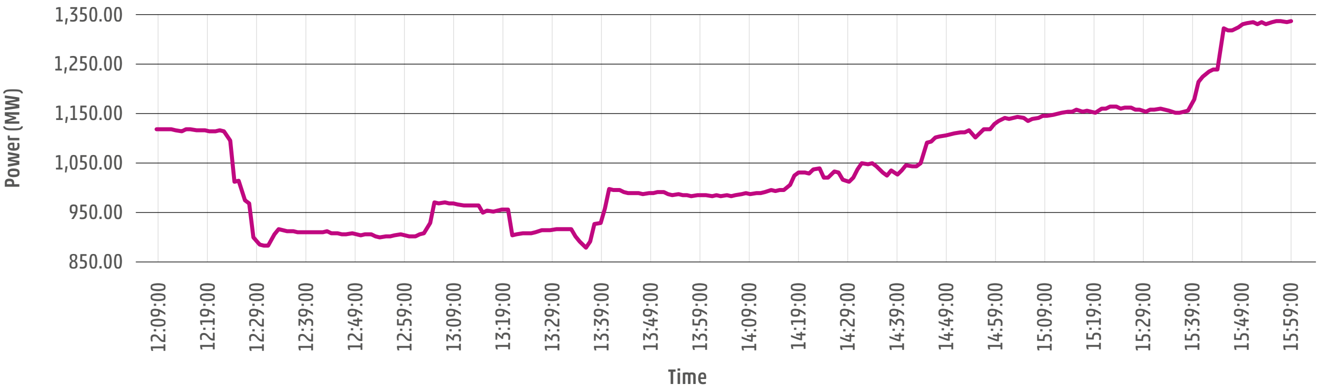


Figure 63: Generation of HOPS

6.3.2 NOSBiH

- HPP Dubrovnik G2 in SS HE Dubrovnik with total power 107 MW switched off at 12:21 and synchronised at 14:45.
- HPP Trebinje 1 in SS HE Trebinje 1 with total power 46 MW switched off at 12:21 and synchronised at 14:10.
- TPP Tuzla G4 in SS TE Tuzla with total power 169 MW switched off at 12:23 and synchronised at 20:30.
- TPP Tuzla G5 in SS TE Tuzla with total power 173 MW switched off at 12:24 and synchronised next day.
- TPP Stanari in SS TE Stanari with total power 260 MW switched off at 12:25 and synchronised next day.
- SPP Hodovo in SS SE Hodovo with total power 34 MW switched off at 12:24 and synchronised at 16:15.
- SPP Bileća in SS SE Bileća with total power 45 MW switched off at 12:24 and synchronised at 15:30.
- SPP Petnjik in SS SE Petnjik with total power 21 MW switched off at 12:24 and synchronised at 16:05.
- TPP Kakanj G5 in SS TE Kakanj with total power 81 MW switched off at 12:24 and synchronised at 21:00.
- TPP Kakanj G6 in SS TE Kakanj with total power 85 MW switched off at 12:24 and synchronised at 21:05.
- HPP Jablanica in SS HE Jablanica with total power 85 MW switched off at 12:24 and synchronised at 14:55.
- SPP Zvizdan in SS SE Zvizdan with total power 12 MW switched off at 12:24 and synchronised at 14:57.
- HPP Mostar in SS HE Mostar with total power 14 MW switched off at 12:21 and synchronised at 14:35.

Generation of NOSBiH

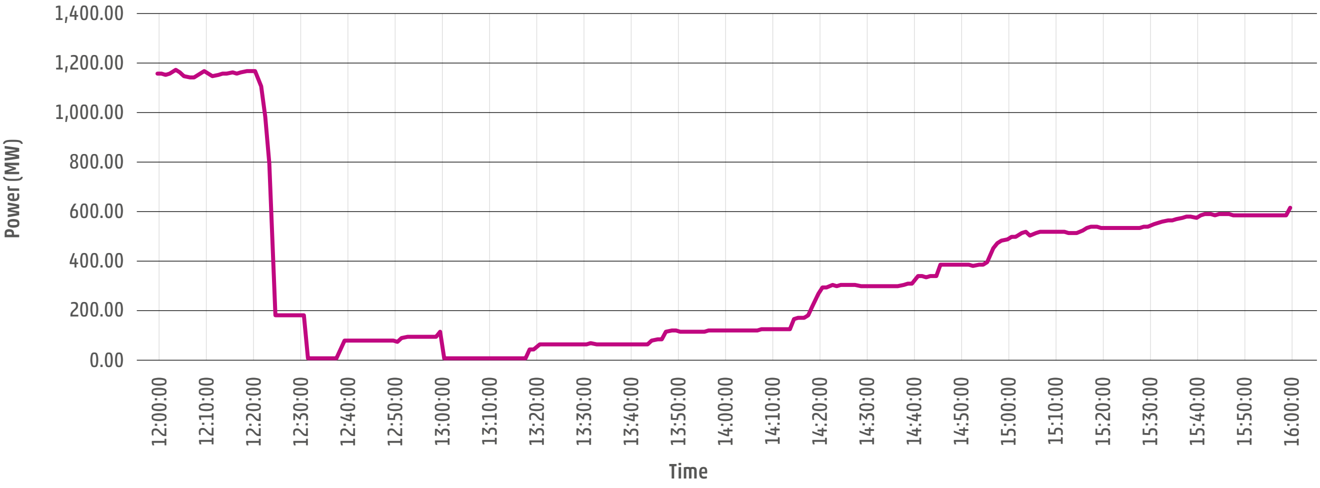


Figure 64: Generation of NOSBiH

6.3.3 CGES

- HPP Perućica in SS Perućica at 12:22 with total power around 110 MW switched off at 12:24 and synchronised at 13:41.
- HPP Piva in SS Piva with total power 99 MW switched off at 12:33 and synchronised at 15:15.

Generation of CGES

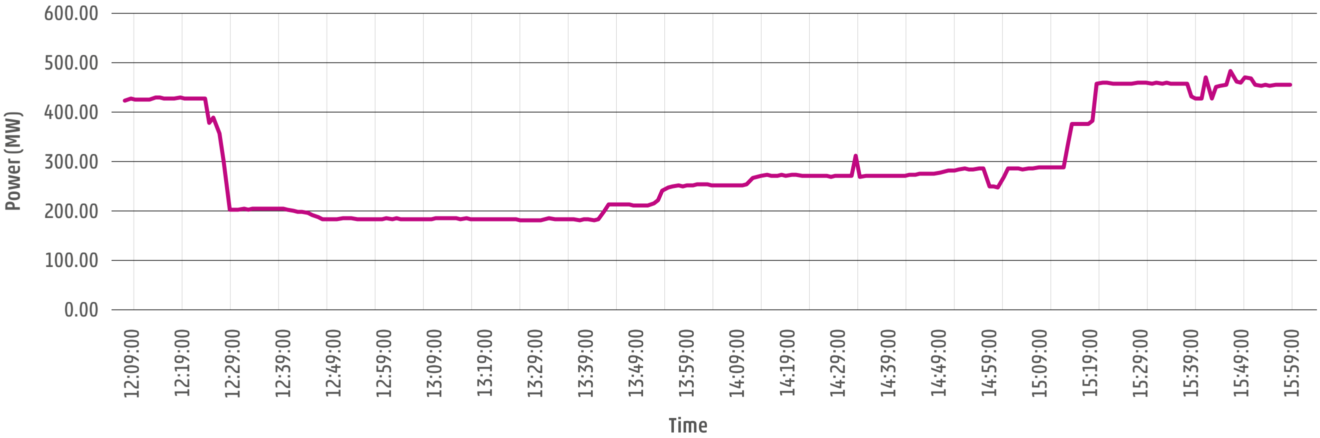


Figure 65: Generation of CGES

6.3.4 OST

- HPP Vau Dejes in SS Vau Dejes with total power 40 MW switched off at 12:24 and synchronised at 13:11.
- HPP Fierze in SS Fierze with total power 109 MW switched off at 12:24 and synchronised at 12:43.
- HPP Fang in SS Fang with total power 61 MW switched off at 12:24 and synchronised at 12:48.
- HPP Koman in SS Koman with total power 211 MW switched off at 12:24 and synchronised at 13:30.

Generation of OST

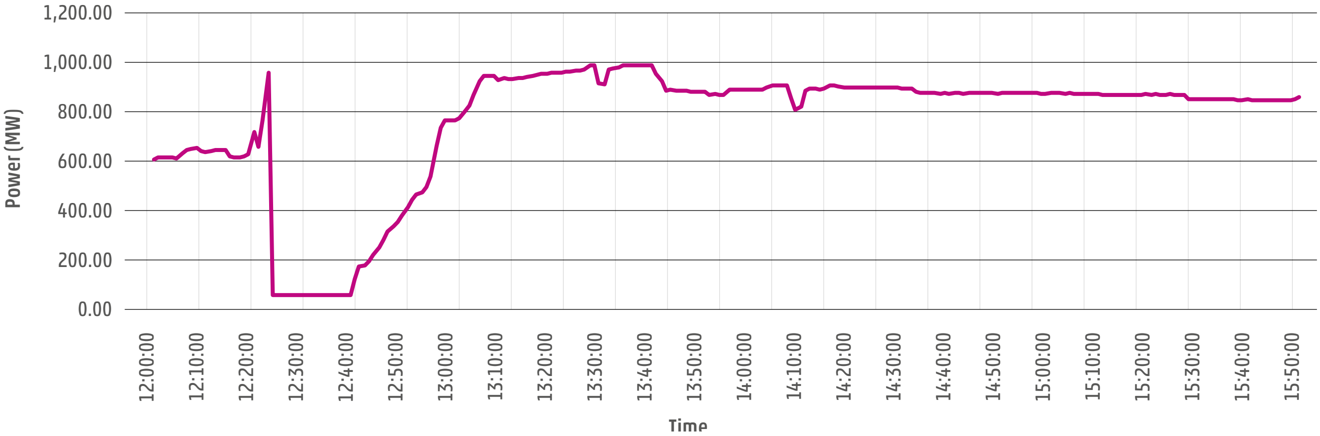


Figure 66: Generation of OST

6.4 Load recovery actions

6.4.1 HOPS

HOPS lost approximately 700 MW. The next figure presents the increase of consumption in the HOPS grid during the restoration process. The speed of returning consumption depended on DSOs and network centres.

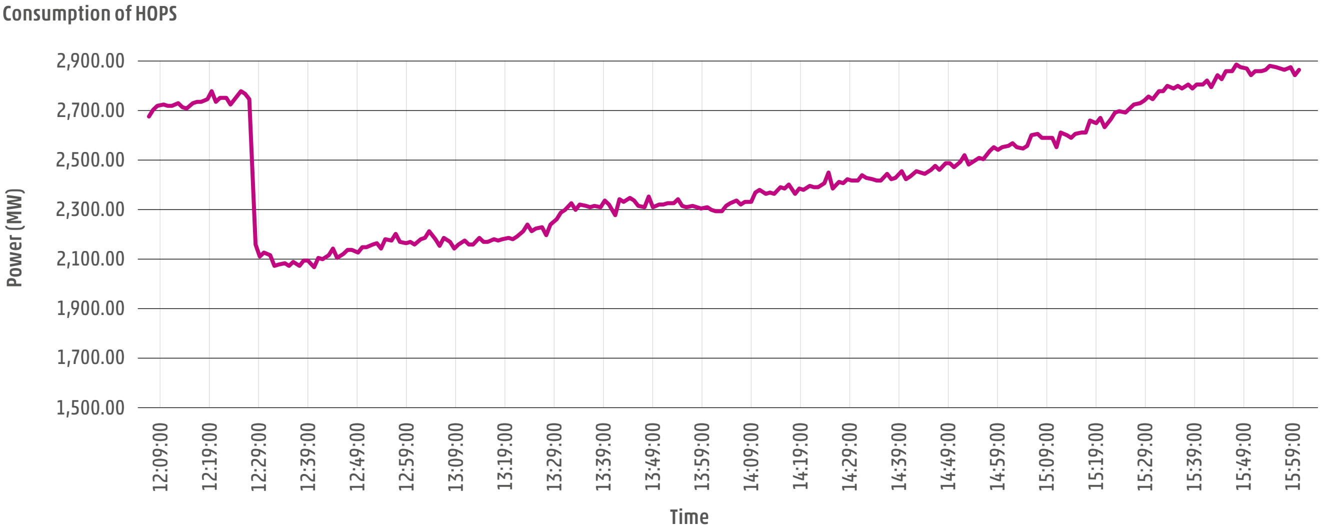


Figure 67: Consumption of HOPS

6.4.2 NOSBiH

NOSBiH lost all consumption. The next figure presents the increase of consumption in the NOSBiH grid during the restoration process. The speed of returning consumption depended on DSOs and network centres.

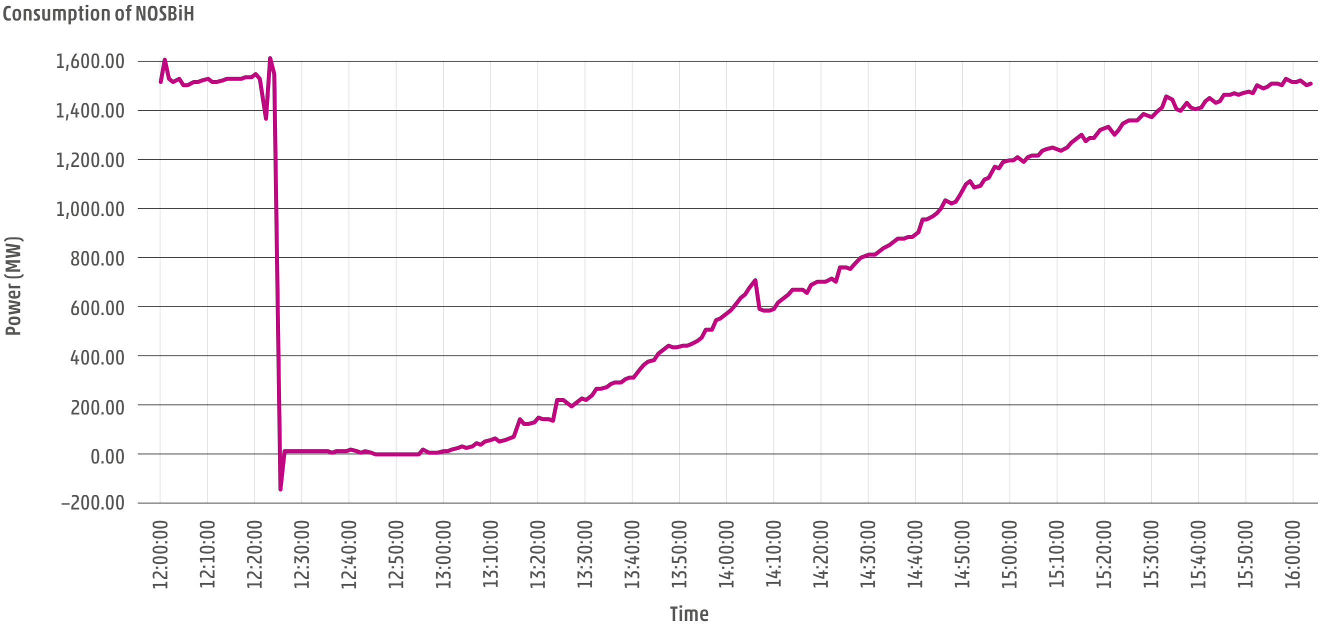


Figure 68: Consumption of NOSBiH

6.4.3 CGES

CGES lost approximately 70 % of consumption. The next figure presents the increase of consumption in the CGES grid during the restoration process. The speed of returning consumption depended on DSOs and network centres.

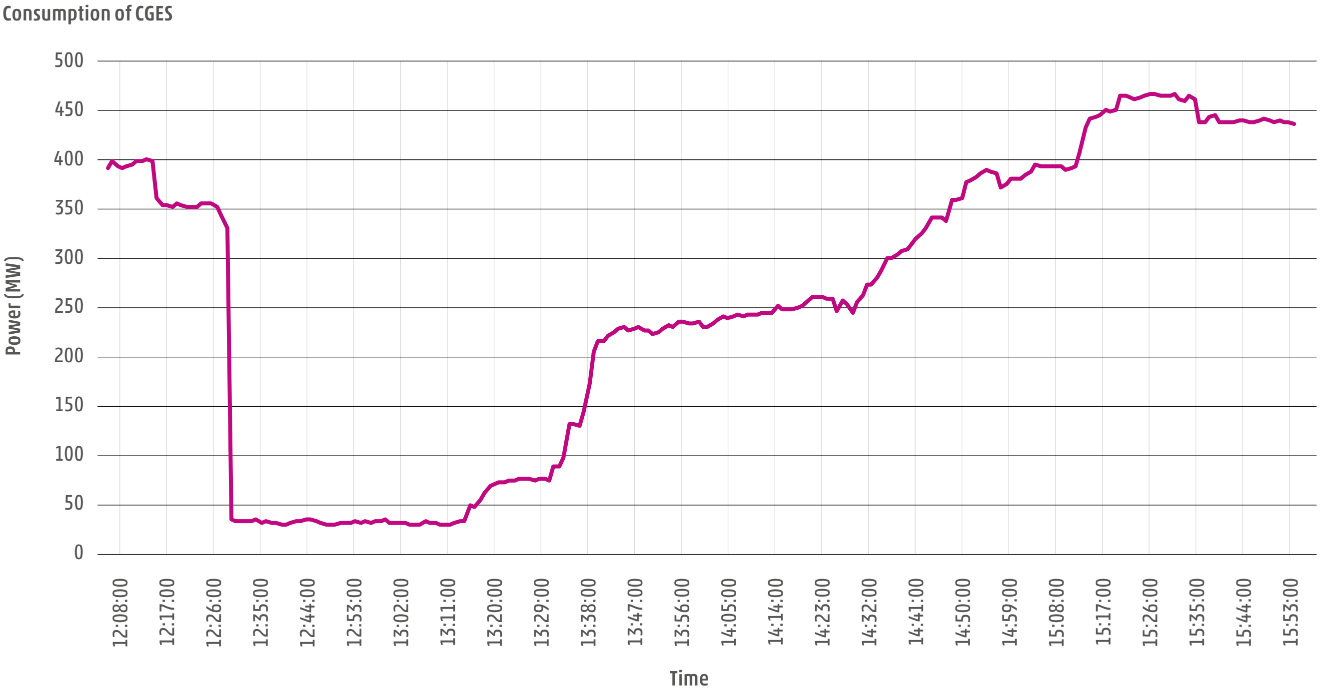


Figure 69: Consumption of CGES

6.4.4 OST

OST lost almost all consumption; only a small part of grid was radially connected to the IPTO grid. The next figure presents the increase of consumption in the OST grid during restoration process. The speed of returning consumption depended on DSOs and network centres.

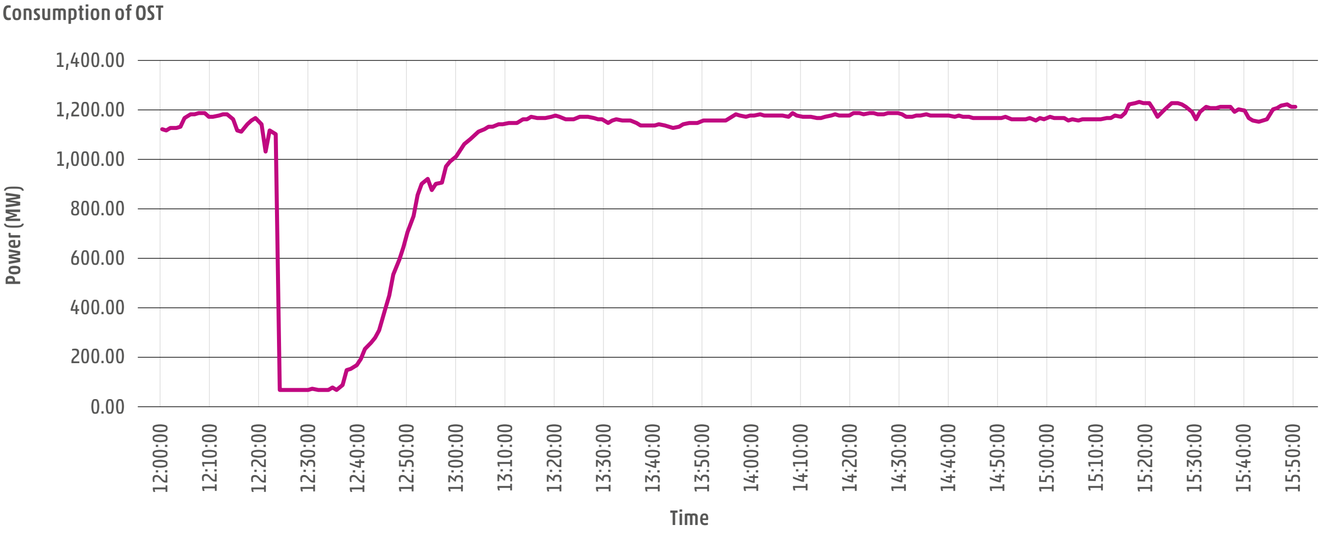


Figure 70: Consumption of OST

6.5 End of restoration and return to market

6.5.1 HOPS

The reconnection of TR 400/110 kV in TS Velebit at 14:04 can be considered the end of the restoration of the central part of the Dalmatia region because from this moment on, all important transformers for this region were switched on.

The reconnection of TR 220/110 kV in TS Plat at 14:14 can be considered the end of the restoration of the part around the city of Dubrovnik.

The reconnection of TR 220/110 kV in TS Đakovo at 15:20 can be considered the end of the restoration of the Osijek region, with a note that all substations 110/x that were in blackout had 110 kV voltage present before the reconnection of the mentioned transformers.

HOPS had no interruption of market operations.

6.5.2 NOSBiH

With the reconnection of TR 220/110 in TS Mostar 4 at 14:18, all important transformers for the consumption of Bosnia and Herzegovina were switched on. The speed of returning consumption depended on DSOs and network centres. The energy market in Bosnia and Herzegovina was open again at 16:00.

6.5.3 CGES

The end of the restoration of the CGES network can be seen as the moment of switching on of two TR 400/110 kV in TS Lastva at 13:49. All important transformers for the consumption of Montenegro were switched on. The speed of returning consumption depended on DSOs and network centres. CGES had no interruption of market operations.

6.5.4 OST

The switching on of two interconnections with Montenegro at 12:59 and 13:06 can be considered the end of the restoration, as most of the switches remained on, so the restoration of consumption was also fast, as can be seen in Figure 70.

6.6 Lessons learned

Both in the normal state of the system and in the emergency state of the system, it is necessary to ensure that the manipulations of switching off/on the elements are carried out according to the restoration plan and Agreement on transmission system operation between TSOs. Considering that we know that in such situations it is inevitable that mistakes happen, it is necessary to reduce them to a minimum.

In accordance with the prescribed procedures and rules for managing the transmission system, the voltage needs to be distributed as a priority to the more important load nodes, as well as production units, with the aim of resynchronising and providing the necessary electricity to cover consumption needs.

It should be noted that communication, team organisation and coordination of work with neighbouring operators are especially important. This significantly eases the newly created situation, and the common goal – to return the system to its normal state – is reached faster.

This event represented an invaluable experience for those who were "on the front line of defence" and also the already significant knowledge of the dispatchers was expanded even more by this situation.

7 CLASSIFICATION ON THE INCIDENT BASED ON THE ICS METHODOLOGY

The ICS Methodology has been developed in accordance with Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 and updated to fulfil the objectives and the security indicator requirements laid out in Article 15 of Commission Regulation (EU) 2017/1485 of 02 August 2017 establishing a guideline on electricity transmission system operation (SOGL). The definitions are extended further to provide a realistic view of the system states, within the meaning of Article 18 of the SOGL, during incidents.

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)		

Figure 71: Incident Classification Scale

Figure 71 shows the criteria from the methodology and the corresponding scale. In addition, they are ordered by priority. #1 marks the criterion with the highest priority and #27 marks the lowest priority. An incident can consist of multiple events and can meet multiple criteria. In this case, the highest criterion decides the scale of the incidents. In the event of a scale 2 or scale 3, an investigation of an Expert Panel is conducted. While only the highest priority criterion is relevant for deciding the scale, the other criteria are also assessed.

7.1 Scale of the incident

The highest criterion from ICS in this incident is the OB3 criterion. This criterion is met if there is a loss of more than 50 % of demand or if there is a total absence of voltage for at least three minutes. This is assessed per TSO's control area. The lost load on 21 June 2024 was:

- 1,102 MW for Albania (97 % of the demand before the incident)
- 1,500 MW for Bosnia-Herzegovina (100 % of the demand before the incident)
- 709 MW for Croatia (26 % of the demand before the incident)
- 338 MW for Montenegro (72 % of the demand before the incident)

This means that the OB3 criterion was met for Albania, Bosnia-Herzegovina and Montenegro. For Croatia, the lost load was below 50 % but above 10 % and therefore the L2 criterion was met. In total, the incident is therefore classified as scale 3.

Abovementioned four TSOs (OST, NOSBiH, CGES and HOPS) are considered to be affected by the incident of scale 2 or 3. Whenever a term "affected TSOs" is used throughout this report, it shall be explicitly understood that the statements refers to those TSOs only.

7.2 RCC Investigation Threshold

The RCC Post-Operation and Post-Disturbances Analysis and Reporting Methodology has been developed to define the RCC task in accordance with Article 37(1)(i) of the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity. This methodology foresees an RCC investigation in addition to the work of the Expert Panel if both of the following criteria are met:

a. as a result of actions taken by a TSO being in emergency, blackout or restoration system state, another TSO has moved from Normal or Alert System State to Emergency System State; and

b. the incident has been confirmed as at least a scale 2 incident as defined by the ICS Methodology.

Post-analysis confirmed that Albania, Bosnia and Montenegro were in emergency, blackout and restoration state during the incident and that Croatia was in an emergency state. Consequentially, the incident met the RCC Investigation Threshold and the RCC Investigation will be initiated. The conclusions of the RCC Investigation will be added as a dedicated chapter in the final report.

7.3 Scale of all events linked to the incident

Next to the OB3 and L2 criteria that were deciding for the scale of the incident, several other events are linked to the incident that meet other ICS criteria. A summary of all criteria is included in Table 20.

Chapter 3.1 lists all relevant disconnections during the incident. The first trip of Ribarevina (CGES) – Podgorica 2 (CGES) resulted in the N-1 criterion ceasing to be fulfilled (T1). The further trips resulted in violations of operational security limits (T2). The consequences were limited to OST, NOSBiH, HOPS and CGES. However, the disconnected elements included tie-lines with Terna, IPTO and KOSTT.

The G criterion assesses the lost generation during the incident. OST, HOPS and CGES experienced a loss of generation of≤600 MW which is below scale (BS). NOSBiH lost approximately 1,365 MW in their control area, which is a G0 criteria violation. The total lost generation was around 2.2 GW (G1).

The ON criterion assesses N and N-1 violations. After the tripping of Ribarevina (CGES) – Podgorica 2 (CGES) there have been violations of operational security limits in the case of Zemblak (OST) – Kardia (IPTO) tripping and the grid was no longer N-1 secure. This is in an ON1 criteria violation starting at 12:09. With the tripping of four elements at 12:21, there have been wide area deviations from operational security limits for OST, NOSBiH and HOPS resulting in the ON2 criteria violation.

The OV criterion assesses the violation of standards on voltage. The relevant threshold is <0,85 pu for >30 sec. The first voltage drop at 12:21 was for <30 sec and is therefore not in ICS criteria violation. The second drop and collapse began at 12:23:37 for CGES and 12:23:34 for HOPS and, as it impacted neighbouring TSOs, is considered OV2. For OST and NOSBiH, the elements were disconnected and dropped to 0kV in <30 sec. Therefore, for OST and NOSBiH, they are not considered OV criteria violation.

		OST	NOSBiH	HOPS	CGES	KOSTT	IPTO	Terna	Total
OB	3	X	X		X				X
L	2			X					
	1								
	0								
F	2	Not violated during this incident							
	1								
	0								
T	2	X	X	X	X	X	X	X	X
	1				X				
	0								
G	2								
	1								X
	0		X						
	BS	X		X	X				
ON	2	X	X	X					X
	1	X	X	X					
RS	2	Not violated during this incident							
	1								
	0								
OV	2			X	X				X
	1								
	0								
	BS								
RCC	2	Not violated during this incident							
	1								
	0								
LT	2	Not violated during this incident							
	1								
	0								

Table 20: ICS criteria violations by TSO. Each violated ICS criteria has an X in the cell. The criteria frequency degradation (F), separation from the grid (RS), reduction of reserve capacity (RRC) and loss of tools, means and facilities (LT) were not violated during the scale 3 incident on 21 June 2024.

8 NEXT STEPS

As described in chapter 7 regarding the classification of the incident based on the ICS methodology, the event on 21 June 2024 is classified as a Scale 3 incident under the ICS methodology.

The Expert Panel's final report will not only present an analysis of the incident but also make recommendations, if necessary, to help prevent similar occurrences in the future. The investigation will focus on several key aspects, including:

- a general and specific analysis of voltage collapse, particularly in this context;
- a technical examination of the incident;
- an investigation into the primary causes and other critical factors contributing to the event; and
- a conclusion, along with any recommended actions based on the findings of the investigation.

The Expert Panel consists of representatives from both impacted and non-impacted TSOs, alongside members from the RCC and ENTSO-E working groups, as well as representatives of ACER and NRAs. The panel began its work in July 2024, and a final report summarising their findings is expected to be published on the ENTSO-E website by beginning of 2025.

To expedite the investigation, TSOs have already conducted preliminary analyses, focusing on the following key questions:

- What were the root causes of the incident, and why was it not preventable?
- What other significant factors during the disturbance need to be considered?
- Which defence measures were effective in preventing further issues within the power system?

To answer these questions, both steady-state and dynamic simulations may be necessary. The investigation will also assess whether responsibilities outlined by European regulations and contracts – such as those in the SO GL, Emergency and Restoration Network Code (ER NC), or Synchronous Area Framework Agreement (SAFA) – were fully adhered to, or whether any failures contributed to the incident.

This preliminary analysis is expected to streamline the Expert Panel's work, enabling a timely evaluation of the event and the development of recommendations to avoid similar disruptions in the future.


SERW
L1

LIST OF ABBREVIATIONS

A	Ampere(s)
AAA	Adequacy Assessment Agent
ACE	Area Control Error
ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserves
AGC	Automatic Generation Control
CACM	Capacity Allocation and Congestion Management
CAO (SEE CAO)	Coordinated Auction Office in South - East Europe
CB	Circuit Breaker
CC	Coordination Centre
CCC	Coordinated Capacity Calculations
CE	Continental Europe
CEST	Central European Summer Time
CET	Central European Time
CGES	TSO of Montenegro
CGM	Common Grid Model
CGS	Critical Grid Situations
CSA	Coordinated Security Assessment
CZC	Cross-Zonal Capacity
DACF	Day-Ahead-Congestion-Forecast
DC	Direct Current
DFRs	Disturbance Fault Recordings
DIFF	Differential Protection
DIST	Distance Protection
EAS	ENTSO-E Awareness System
ECA&D	European Climate Assessment & Dataset
EF	Earth Fault
ELES	TSO of Slovenia
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ER NC	Emergency and Restoration Network Code
FCR	Frequency Containment Reserves
GW	Gigawatt
HOPS	TSO of Croatia
HPPs	Hydro Power Plants
HVDC	High Voltage Direct Current

ICS	Incident Classification Scale
IDCF	Intra-day Congestion Forecast
IGCC	International Grid Control Cooperation
IGM	Individual Grid Model
Inom	Nominal Current
IPTO	TSO of Greece
JSC	Joint Stock Company
KOSTT	TSO of Kosovo
kV	Kilovolt(s)
LCC (HVDC)	Line - Commutated Convertor
LFC	Load Frequency Controller
LFDD	Low Frequency Demand Disconnection
LVDD	Undervoltage Demand Disconnection
MAN	Manual
MEPSO	TSO of North Macedonia
mHz	Millihertz
MVA	Megavolt Ampere
MW	Megawatt
NC ER	Emergency and Restoration Regulation
NOSBiH	TSO of Bosnia and Herzegovina
NRA	National Regulatory Authority
NTC	Net Transfer Capacity
OC	Overcurrent
OHL	Overhead Line
OPC	Outage Planning Coordination
OPI	Outage Planning Incompatibilities
OST	TSO of Albania
PMU	Phasor Measurement Unit
pu	Per Unit
PV	Photovoltaic
RAM	Remaining Available Margin
RAOC	Relevant Assets for Outage Coordination
RCs	Remaining Capacities
RCC	Regional Coordination Centre
RG CE	Regional Group Continental Europe
ROCOF	Rate of Change of Frequency

RSC	Regional Security Coordinator
RT	Real Time
SA CE	Synchronous Area Continental Europe
SAFA	Synchronous Area Framework Agreement
SAM	Synchronous Area Monitor
SCADA	Supervisory control and data acquisition
SEE	South-East Europe
SEE MG	South-East Europe Maintenance Group
SO GL	System Operation Guideline
SOR	System Operation Region
SS	Substation
STA	Shot-Term Adequacy
SVC	Voltage source converter
TERNA	TSO of Italy
TPPs	Thermal power plants
TSO	Transmission System Operator
TTC	Total Transfer Capacity
UCTE	Union for the Co-ordination of Transmission of Electricity
UV	Undervoltage
VSC	Voltage Source Converter
WAM	Wide Area Monitoring
WOPT	Weekly Operational Teleconferences
WPPs	Wind Power Plants
XBID	Cross-Border Intraday

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Publisher

The Expert Panel on the Grid Incident
on 21 June 2024

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Design

DreiDreizehn GmbH, Berlin
www.313.de

Images

Cover: courtesy of EMS
p. 26/27, 31, 34, 55, 76: courtesy of CGES
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Publishing date

4 November 2024