

» Grid Incident in Czech Republic on 4 July 2025

ICS Investigation Expert Panel
Final Report

26 June 2026



Preamble

This final report has been prepared by the Expert Panel established to perform this technical investigation, in accordance with Article 15 of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SOGI) and the Incident Classification Scale (ICS) methodology. The final report provides a factual, technical, and objective account of the incident that occurred on 4 July 2025 in the Czech Republic, to transparently inform stakeholders and governance bodies.

Its purpose is to identify the causes of the incident and to recommend measures that strengthen the resilience of the European power system. The analyses, findings, and recommendations contained in this final report are based on data, documents, and other materials provided by the impacted Transmission System Operator (TSO), distributed system operator (DSO) and significant grid users (SGUs). While the Expert Panel has exercised due care and applied its best effort in reviewing and evaluating the information received, it does not independently verify, audit, or validate the completeness, accuracy, or reliability of the data sources. Importantly, the report is not intended to assign liability or responsibility to any party and should not be interpreted as doing so in any way. This report has been prepared and agreed upon by the Expert Panel.

Any analyses, findings, and recommendations set out in this report reflect the Expert Panel's technical assessment at the time of writing and are without prejudice to any investigation or enforcement action that may be taken by the competent authorities. The recommendations outlined in this report represent a comprehensive set of measures designed to enhance operational robustness, improve cross stakeholder information exchange, and contribute to maintaining a high level of security of supply across the European power system. Monitoring the implementation of the recommendations' provided in this report does not fall within the mandate or remit of the Expert Panel. While voluntary in nature, the recommendations are intended to prompt and support concrete action to help prevent the recurrence of similar events in the future. Any responsibility for the consideration, follow-up, and implementation of the recommendations lies with each addressee.

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1 MANAGEMENT SUMMARY

1.1 Introduction

On 4 July 2025, the power system in the Czech Republic experienced an incident – a loss of around 28 % of consumption in the ČEPS control area. The sequence of events leading to the loss lasted about 8 minutes, starting with the tripping of the V411 Hradec–Výškov 400 kV line at 11:51:08 and ending with the point of no return – the manual disconnection of V208. The lost consumption was restored by 17:35. The operation of the interconnected European grid continued as usual, and no other country was affected by the incident.

The incident occurred after unexpected reductions of generation in a part of the grid after the transient of an otherwise manageable N-1 event (a line trip). Over several minutes after the N-1 event, unexpected

reductions of generation related to the transient led to increasing overloads in the grid. Countermeasures in the form of manual load shedding, load decrease, or generation increase in the area with a generation deficit were unavailable in the necessary time (several minutes) and therefore not performed. The dispatchers manually disconnected an overloaded 220 kV line, expecting no further consequences on the grid, but the disconnection nevertheless led to the tripping of the two remaining connection points, the islanding of the affected area, and its immediate collapse due to the generation-load deficit (the automatic load frequency demand disconnection was unable to prevent the collapse due to the high rate of change of frequency (RoCoF)).

1.1.1 Expert Panel and structure of the Final report

The incident has been classified as a scale 2 pursuant to the Incident Classification Scale (ICS) methodology¹. Consequently, pursuant to the same legal framework, an Expert Panel was set up, which began investigating the incident with the aim of delivering a factual and a final report. The factual report was published on 19 December 2025.

In accordance with the ICS methodology, the Expert Panel comprises representatives from affected and non-affected TSOs, the Agency for the Cooperation of Energy Regulators (ACER), National Regulatory Authorities (NRAs), and convenors from relevant ENTSO-E bodies. The Panel is led by an expert from a TSO not directly affected by the incident: Donatas Matelionis from Litgrid (Lithuania). Overall, the Expert Panel comprises 18 experts – 10 from ACER and NRAs, and 8 from TSOs, and ENTSO-E bodies – from across Europe (the complete list of Expert Panel members is available on the final page of this report). Additional experts from ENTSO-E member TSOs participated and contributed via text suggestions, figures, analyses, and/or other input. These measures aim to ensure the neutrality of the final report.

In line with the Expert Panel's terms of reference, the contribution of the affected TSO involves providing input and suggestions for specific chapters in a transparent and constructive manner but not acting as the primary authors of the respective chapters where their TSO has been involved in any way in the relevant actions for the event. These measures aim to ensure the neutrality of the reports delivered by the Expert Panel.

This final report builds on the description of the event provided in the factual report, which outlined the events of that day, including the operational planning, the conditions before the incident, the evolution of the incident, and the subsequent restoration. This final report complements the provided information with a root cause tree in Chapter 2.3, analysis of the relevant factors in Chapter 7, and a set of recommendations in Chapter 9. Transmission system operator (TSO), distribution system operators (DSOs), and significant grid users (SGUs) in the Czech Republic, as well as the relevant regional coordination centres (RCCs), provided the relevant information in this report.

1 The ICS methodology was developed pursuant to Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009, which was repealed by Regulation (EU) 2019/943 and updated to fulfil the objectives under Article 15(5) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SO GL).
https://eepublicdownloads.entsoe.eu/clean-documents/SOC documents/Incident_Classification_Scale/IN_USE_FROM_JANUARY_2020_191204_Incident_Classification_Scale.pdf



1.1.2 Data collection

The ICS methodology provides that an Expert Panel established to investigate a scale 2 or 3 incident carries out its investigation based on data reported by the affected TSOs, as listed in Annexes 1 ("Common data for reporting"), 2 ("Specific data reported for depending on the ICS criterion") and 3 ("Additional data for the investigation of scale 2 and scale 3 incidents"). The methodology also indicates that the Expert Panel shall request additional data and information deemed necessary for the investigation, including data owned by third parties not represented in the Expert Panel (e.g., DSOs

and significant grid users (SGUs)), to be provided by the affected and other relevant TSOs. In accordance with this provision, the affected TSO delivered the required data under the ICS methodology. The Expert Panel also considered it necessary to request and collect specific data from a DSO and a power plant owner.

The Expert Panel reviewed this information and took it into account for the purposes of the final report, contributing to a more comprehensive assessment of system behaviour and operational conditions.

1.2 System state and market conditions before the incident

With the ongoing energy transition, ČEPS faces significant investments to modernise and maintain the grid. On 4 July 2025, ten 400 kV lines and one 220 kV line had scheduled outages due to modernisation and increase in parameters, and two 400 kV lines were unavailable due to maintenance and repairs.

During weekly operational planning, ČEPS verified operational security limits, including transient stability, by assessing critical clearing times (CCTs), and prepared remedial actions for three identified contingencies to keep the system N-1 secure. In the daily coordinated security analysis (the day-ahead congestion forecast (DACF) facilitated by TSCNET), preventive remedial actions were implemented in the model, including reconfigurations in the 400 kV substation Hradec Zápád and the 220 kV substation Čechy Střed. Additional contingencies were identified; however, preventive remedial actions were not needed for these contingencies, as the transitory admissible overloads of the affected elements were acceptable due to the possibility of implementing timely corrective measures in real-time in case the contingency actually occurred (curative remedial actions).

The contingencies identified in intraday (ID) and real-time operations before the incident were consistent with the contingencies identified in the operational planning phase. At 11:01, ČEPS dispatchers applied the reconfiguration at the Čechy Střed 220 kV substation. At 11:17, the DSO operator requested permission to couple the 110 kV Řeporyje and Výškov areas to perform scheduled switching in the distribution network, thus creating a parallel connection to the transmission system.

The ČEPS dispatcher authorised the coupling, and the two areas were coupled from 11:19 to 11:41.

The most critical element with a contingency identified before the incident was the 400/220 kV transformer at the Hradec substation in the event of the V411 line loss. The flow on the element would be 114.5 % of rated capacity (at 11:42). The contingency was solved by allowing a curative transitory admissible overloading of the transformer (120 % up to 3 h) and a curative reconfiguration at the Hradec Zápád 400 kV and Čechy Střed 220 kV substations, had the contingency occurred.

At 11:51, right before the incident, all other contingencies were modelled to result in a loading on monitored elements below 100 %, including the 220 kV V208 Čechy Střed–Milín line following the loss of line V411, which was at 98.2 %. The V411 line was transmitting about 1,200 MW, which corresponds to 76.8 % of capacity.

Production in the affected area comprised:

- » 292 MW by transmission-connected Ledvice unit 6 (660 MW installed capacity, lignite)
- » 282 MW by transmission-connected Počeradý units 2 and 6 (205 MW installed capacity each, lignite)
- » 141 MW by transmission-connected Chvaletice unit 4 (205 MW installed capacity, lignite)
- » 74 MW by distribution-connected Ledvice unit 4 (110 MW installed capacity, lignite)
- » 547 MW by distribution-connected power-generating modules (PGMs).



1.3 Evolution of system conditions during the event

At 11:51:08, line V411 tripped (in all phases) following an unsuccessful auto-reclosure in phase 2. The affected area remained connected to the rest of the system at three points: line V208, the busbar coupler at the Krasíkov 400 kV substation, and the 400/110 kV transformer at the Krasíkov substation. Within 5 seconds, the transmission-connected Ledvice (unit 6) and Počeradý (units 2 and 6) power plants and the distribution-connected Ledvice power plant (unit 4) switched to droop speed control mode after detecting a frequency deviation above 50.2 Hz.

Following the switch of unit 4 of Ledvice power plant to droop speed control mode and due to the 0 % setting of the droop, the unit started oscillating.

At 11:51:46, Ledvice unit 6 suffered a boiler outage due to a high steam temperature behind a high-pressure bypass station and began losing active power. According to the power plant the fault was in no way related to the droop speed control mode operation.

By 11:52, the system had lost 287 MW of active power infeed in the affected area (i.e. the future island). That consisted of:

- » 110 MW decrease identified at Ledvice unit 6
- » 17 MW at Počeradý units 2 and 6 (combined)
- » 25 to 50 MW at Ledvice unit 4; that was the range of active power output oscillations at the terminals of the unit
- » 135 MW at distribution-connected renewables

An additional 151 MW of frequency restoration control error (FRCE) in the direction of the loss of generation occurred. The cause of that error was not identified, or localised. The total shortage of power in the Czech system at 11:52 was 438 MW.

At 11:52, the situation in the transmission system worsened with some elements overloading:

220 kV line V208 at 126.1 % (912 A)

- » 400/220 kV transformer at the Hradec substation at 119.3 %
- » Busbar coupler at the Krasíkov 400 kV substation at 105.1 %

At 11:52:45, Ledvice unit 6 lost all remaining active power output. Subsequently, between 11:53 and 11:59, the situation further deteriorated with overloads increasing to:

- » 220 kV line V208 at 142.9 % (1,035 A)
- » 400/220 kV transformer at the Hradec substation at 121.6 %
- » Busbar coupler at the Krasíkov 400 kV substation at 115.5 %

At 11:59:44, the ČEPS operator switched off the overloaded line V208. At this point, the affected area remained connected to the rest of the system through a busbar coupler and the 400/110 kV transformer at the Krasíkov substation. The substation was in a non-basic configuration, due to high flows West-East, maintenance of line V453, and readiness to disconnect some lines to reduce voltages.

At 11:59:47, the overcurrent relay opened the Krasíkov busbar coupler. The relay was set to 2,880 A (144 %) with a 3 s delay. 73 ms after the opening of the Krasíkov busbar coupler, the distance protection at the 110 kV side of the 400/110 kV transformer at the Krasíkov substation tripped. The transformer was the last connection between the affected area and the rest of the system, thus creating an island after it was tripped.

Within 780 ms, the island collapsed due to a significant power deficit of about 1,800 MW, which could not have been compensated by low-frequency demand disconnection (LFDD). While the LFDD served its intended purpose, it is not intended to prevent a collapse of an islanded part of the grid with a substantial generation deficit. The highest RoCoF recorded was 3.5 Hz/s (over a 500-ms sliding interval). This resulted in the disconnection of Počeradý units 2 and 6 and Chvaletice unit 4 to house load operation, the tripping of pumped-storage Dlouhé Stráně unit 2 from pumping (311 MW), and the loss of the remaining distributed generation in the area. The total production loss (11:51–12:00) in the affected area was between 1,200 and 1,400 MW². The total loss of load was about 2,300 MW, or 28% of the ČEPS control area's consumption.

2 The loss of the production at the moment of disconnection of KSP in substation Krasíkov 11:59:47 was cca 800–900 MW.



1.4 Restoration process

The restoration process began immediately after the event. At 12:09, the system state in the ENTSO-E Awareness System (EAS) was changed to emergency. Given that most of the grid was unaffected, ČEPS dispatchers decided to apply a top-down strategy and energise the affected area from two sides: the 400 kV grid from the Krasíkov 400 kV substation and the 220 kV grid from the Čechy Střed 220 kV substation. In both substations, one busbar remained energised from the unaffected grid.

First, ČEPS dispatchers applied an open-all strategy in the affected transmission substations. At 12:19, dispatchers energised the first substation in the affected area – the Týnec 400 kV substation. ČEPS dispatchers continued energising substations, with priority given to those supplying the capital Prague (the Chodov 400 kV substation and the Malešice 220 kV substation). At 12:30, both 220/110 kV transformers at the Malešice substation were energised, allowing load pickup in Prague. At 13:01, the Chodov 400 kV substation was energised, with two 400/110 kV transformers energised shortly thereafter. At this point, all transformers supplying Prague before the incident were energised.

At substations where units operating in house-load operation were connected, the dispatchers synchronised them to the grid: at 12:46, Chvaletice unit 4 at the Týnec 400 kV substation; at 13:26, Počeradý unit 2; and at 13:45, unit 6 at the Výškov 400 kV substation.

By 14:09, all 400- and 220-kV substations were energised. At 14:20, ČEPS dispatchers ordered a halt in load pickup due to significant contingencies on line V208 (up to 180% N-1 violation in the worst case contingency) and ordered CCGT Počeradý 2 to start. Load pickup resumed following the synchronisation of Počeradý 2 at 15:18 (first gas turbine).

At 17:35, ČEPS dispatchers received information from DSOs that all the lost load was re-energised.

At 23:13, the V411 line was switched on following repairs.

During the incident, cross-border ID trading was stopped at all Czech borders for the period from 13:30 to 00:00. Between 12:00 and 00:00, market activities were suspended, and special imbalance settlement rules were applied. Day-ahead (DA) trading for 5 July 2025 was unaffected. ID trading for 5 July 2025 was allowed at 22:28, thus affecting continuous trading up to that point and ID auctions (IDAs) 1 and 2.

1.5 Regional coordination processes

All relevant operational planning processes coordinated by the RCCs were successfully executed on the business day of 4 July 2025. None of the RCC tasks identified a specific security risk for the Czech transmission system for the relevant hours on 4 July 2025, and the grid was considered N-1 secure. Short-term adequacy (STA) assessments showed no adequacy issues, outage planning was properly coordinated, and both DA and ID capacity calculation processes were completed without disruption.

ČEPS provided all required input models on time, and regional security analyses (DACF and intraday congestion forecast (IDCF)) confirmed that any detected congestion was within tolerable limits and resolvable through remedial actions. No unusual deviations between modelled and actual physical flows were observed, and despite the incident, all processes – including capacity calculations and contingency analyses – functioned as designed.



1.6 Analysis of relevant factors

The final report analysed three factors affecting the outcome of the event:

- 1 // Island operation (IO) capability and the threshold for transition to droop speed control mode
- 2 // Behaviour of distribution-connected generation
- 3 // Dispatcher's actions

1.6.1 Transition to Island Operation

Regarding the IO capability, the report describes the service and analyses the threshold for switching from active power control mode to droop speed control mode. The analyses conclude that moving the threshold from 200 to 500 mHz would endanger the stability of the units during the transition.

Therefore, the 200 mHz threshold was kept. Based on these analyses, the related recommendation R4 then focuses on the possibility of introducing an intentional time delay before transitioning to island operation control mode.

1.6.2 Behaviour of distribution-connected generation

Following the tripping of the line V411, 135 MW of distributed generation output was lost. Of that, 5 MW were disconnected by frequency relays triggered by local frequency deviation exceeding 200 mHz. The remaining 130 MW were disconnected by voltage protections. Of that 130 MW:

- » 95 MW was lost in modules connected before the application of the RfG with no requirement for fault-ride-through (FRT) capability
- » 35 MW was lost in modules that should have FRT capability

This indicates that the 95 MW corresponds to disconnections that can be anticipated upon transient conditions and might occur in the future and/or elsewhere in Europe, depending on the specific situation and specific connection requirements. However, it is to note that the measurement on 110 kV side of distribution transformer in the area (in fig. 6.4, 6.9 and 6.10) indicates that voltage in these points of the distribution grid during the transient following the V411 tripping did not exceed the voltage range for continued operation ($110 \text{ kV} \pm 10 \%$). The Expert panel issues a relevant recommendation R2 and R3 on the risks of widespread distributed generation disconnections.

The 35 MW, however, corresponds to disconnections that should not have occurred – per the connection requirements applicable to these modules, it would have been expected that they remain connected. The Expert panel issues relevant recommendations R2 and R3 on the risks of widespread distributed generation disconnections and on validated control and protection settings.

Additional analysis of a measurement on the 110 kV side of a transmission transformer in the affected area was conducted. It shows that despite the short-circuit in the transmission system, the voltage drop observed in the distribution system remained well within the limits of the FRT withstand capability requirements.



1.6.3 System defence and unavailability of measures to reduce the generation deficit

The applicable operational procedures and the actions of ČEPS control room operators (dispatchers) are described in Chapter 6.5. The dispatchers immediately began addressing the tripping of the V411 line, analysing the situation, and investigating the causes of the loss of generation and the overload of transmission system components.

The dispatchers evaluated measures to resolve the overload on the V208 line and verified their effectiveness. Increasing active power infeed in the transmission system was not fast enough due to the state of the units or the time needed to arrange redispatching of the pumped-storage unit Dlouhé stráně. Increasing active power infeed of distributed selected units requires the

arrangement of a redispatch and is not possible at all for the vast majority of units. Manual load shedding was again not fast enough as it would have required the declaration of the state of emergency (according to Czech law). A reconfiguration of the substation Krasikov, where the flow over the busbar coupler had been above 100 % since shortly after the V411 break was not performed, due to priority given to the line V208, which was the most overloaded element, as described in the following chapter.

The Expert Panel issues related recommendations R7 on reviewing system defence plan procedures and R8 on reviewing the automatic response to frequency deviations.

1.6.4 Manual disconnection of the overloaded line

As there were no measures to resolve the generation deficit available, the dispatchers further considered that the V208 line passes through a densely populated area of Prague, and its overloading poses a risk to the inhabitants. The dispatchers conducted an online load flow analysis and N-1 calculation of the impact of switching off V208, and concluded at that time that the results meant that the disconnection would have no further consequences on the grid. However, the disconnection resulted in a further overloading of the busbar coupler in Krasikov beyond its protection setting, its trip, and the collapse of the island.

The ex-post analysis by the Expert Panel shows that the regular N-1 reports at 11:55 (as shown in table 3.4 and 3.5) correctly showed that the V208 disconnection would result in the overloading of the busbar coupler in the 400 kV substation Krasíkov over the protection limit; however, this effect was not identified at the time.

The Expert Panel issues a related recommendation R6 on decision support for control room operators and R9 on storing the data of online N-1 calculations.

1.7 Incident classification based on ICS methodology

The highest-priority ICS criterion violated during this incident was a scale 2 incident on load (L2). This criterion is met if the load loss is between 10 % and 50 %.

In this incident, 2,300 MW of load was lost, which is 28 % of the demand before the incident (8,200 MW) in the ČEPS control area.



1.8 Root causes

The unsuccessful auto-reclosure of V411 in phase L2 was caused by a wire break. After further examination and analysis by an expert institute, it was found that the tensile coupling had an insufficiently tight connection at the aluminium part of the conductor. Ultimately, the rope at the coupling broke, and the conductor fell. The Expert Panel was unable to determine the exact reason due to which the repair procedure resulted in an insufficiently tight tensile coupling. The Expert Panel issues a related recommendation R1 on quality assurance for works on the transmission network.

Unit 6 of the Ledvice power plant lost all active power output due to a boiler outage caused by high steam temperature behind the high-pressure bypass stations. The high temperature was due to a stuck high-pressure turbine bypass valve, caused by a defective relay on the actuator motor for that valve. According to the power plant, the fault was in no way related to the droop speed control mode operation.

The reduction in active power output on the transmission-connected Počerady units 2 and 6 and the distribution-connected Ledvice unit 4 was caused by a change in the opening of their control valves during the transient

phenomena that followed the V411 fault and disconnection. The turbine controller in power control mode rapidly adjusted valve openings during the disturbance to maintain scheduled active power, and when switching to droop speed control, the reduced valve positions were adopted as new setpoints.

Additional generation was lost in renewable energy sources connected to the distribution system. That was mostly caused by voltage protection activations on PGMs commissioned before the application of the RfG, which did not require FRT capability. Some PGMs, which should have had the FRT capability enforced by the pre-RfG distribution connection code, also disconnected. Finally, a small number of PGMs were disconnected by their frequency protections when local frequency deviation exceeded 200 mHz.

In the end, the reason for 151 MW of control error (FRCE) in the direction of loss of generation, that occurred during the incident, was not determined. It is highly likely that this was caused by a loss of unidentified generation, but the Expert Panel lacks sufficient data to conclude this. The Expert Panel issues a related recommendation R5 on investigation data governance.

1.9 Recommendations

Based on the findings in the Final report, the Expert Panel has formulated seven new recommendations:

- » 1 // R1 – Strengthen verification and quality assurance for works on the transmission network, with particular focus on emergency repairs and works affecting the mechanical integrity of primary equipment.
- » 2 // R2 – Assess and mitigate the risk of distributed generation disconnection after transient events.
- » 3 // R4 – Review the transition to droop speed control mode (IO mode) logic and frequency protection delay, where applicable.
- » 4 // R6 – Enhance the decision support for control room operators with real-time assessment and visualisation tools to identify the cascading risk.
- » 5 // R7 – Review and operationalise the system defence plan procedures for preventing the escalation of the incident, and ensure they include all technically possible measures, and that the measures are executable in practice where relevant.
- » 6 // R8 – Review the thresholds and technologies providing automatic response to frequency deviations.
- » 7 // R9 – Storing the data of online N-1 calculations

And two recommendations from the previous investigation from the grid incident in Spain and Portugal on 28 April 2025 :

- » 1 // R3 – Validated control and protection settings for generation and storage units and generation and storage evacuation grid connected to the TSO and DSO.
- » 2 // R5 – Streamlined cross TSO/DSO/PGM investigation data governance.



2 SYSTEM STATE AND MARKET CONDITIONS BEFORE THE INCIDENT

2.1 Information about topology

2.2.1 Planned outages

The TSO has recently undertaken several investment initiatives that must be included in the ČEPS outage plan to meet the requirements for line modernisation and proper maintenance. The grid configuration, including necessary planned outages to make these investments possible, was verified against the N-1 safety criterion in the framework of long-term (annual, monthly) operational preparation for various operational scenarios (high transit flow, high/low production of coal sources, etc.). These long-term requirements are supplemented by routine maintenance or line repairs during weekly operational preparation.

In addition to the contingency analysis, ČEPS performs a dynamic stability assessment (DSA) in all phases of operational planning – yearly, monthly, weekly, and daily – and in real time. The DSA tool assesses transient stability by calculating the CCT for a zero-impedance three-phase fault on lines directly³ connected to a substation where a synchronous PGM is connected, as this is considered by ČEPS to represent the worst possible fault in terms of potential loss of synchronism. The offline version of the DSA tool, designed for operational planning, allows the selection of critical scenarios to reduce the computational time of dynamic simulations. The ability to preselect critical scenarios based on the criteria listed below is implemented in the offline version of the DSA tool. Once the user selects the critical scenarios option, the algorithm first generates only those scenarios that meet the specified criteria for criticality before the CCT calculations take place.

The calculation is performed if the first two conditions below are fulfilled simultaneously; the third condition is always considered independently:

- » The short-circuit power of the node is considered low
- » The loading of the PGM (ratio of scheduled active power to apparent power) is considered high
- » A pump storage PGM is in pumping mode

The CCT threshold for preparing remedial actions is set at 100 ms, which is about 120 % of the fault-clearing time.

A scenario like that of 4 July was calculated across all phases of operational planning for July. Based on the indicators described above, the calculation was performed for faults on lines V473, V474 and V475 (all connected to the Kočín 400 kV substation in the southern part of the Czech Republic), considering the impact on PGMs at the Temelín nuclear power plant (NPP) (also connected to the Kočín 400 kV substation). The necessary conditions were not met, thus no indicators were fulfilled and therefore no calculation was performed for a fault on lines V411 or V480, which are the closest to unit 6 of thermal power plant (TPP) Ledvice.

The online version of the DSA tool, used for real-time operation, calculates all scenarios⁴ without applying the critical scenario selection, every minute based on the real-time model in the control system. Before the V411 outage, the online DSA tool did not detect any violation in dynamic stability (CCT less than 100 ms) for TPP Ledvice unit 6.

³ This implies that for the Ledvice power plant, connected to the Chotějovice substation, only a fault on the Chotějovice–Výškov double-circuit line V479/V480 is calculated. This is the worst-case scenario. A fault elsewhere in the grid (in this case on V411 Hradec–Výškov) has a lesser impact on the power-generating module due to the extra impedance of the lines between the power-generating module and the fault.

⁴ See Table 3.2.2. in Chapter 3.1.5 (paragraph 11:50 DSA).





The dispatchers can also display the following trends in the online version of the DSA tool:

- › Simulated time profile of accelerating power of the generator (kinetic energy);
- › Simulated time profile of active power output;
- › Simulated time profile of terminal voltage.

These simulation results can be displayed for each scenario. Figure 2.1 provides an example of how simulated trends from the dispatcher control system can be displayed.

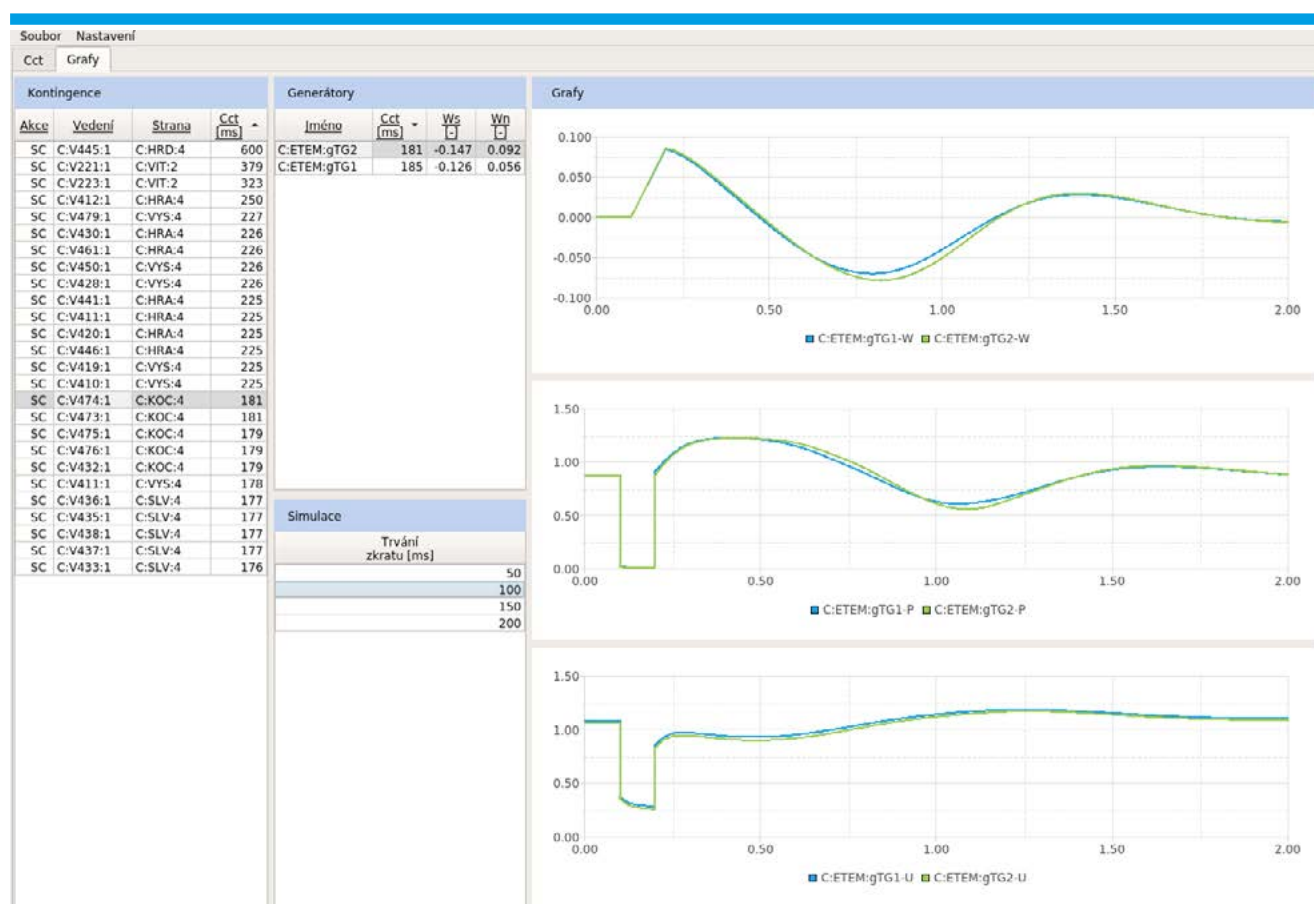


Figure 2.1: Example of visualisation in the online version of the DSA tool



2.1.2 Weekly operational planning for 4 July 2025

Figure 2.2 presents the 400 kV and 220 kV overhead lines that were switched off in the Czech power system on 4 July 2025.

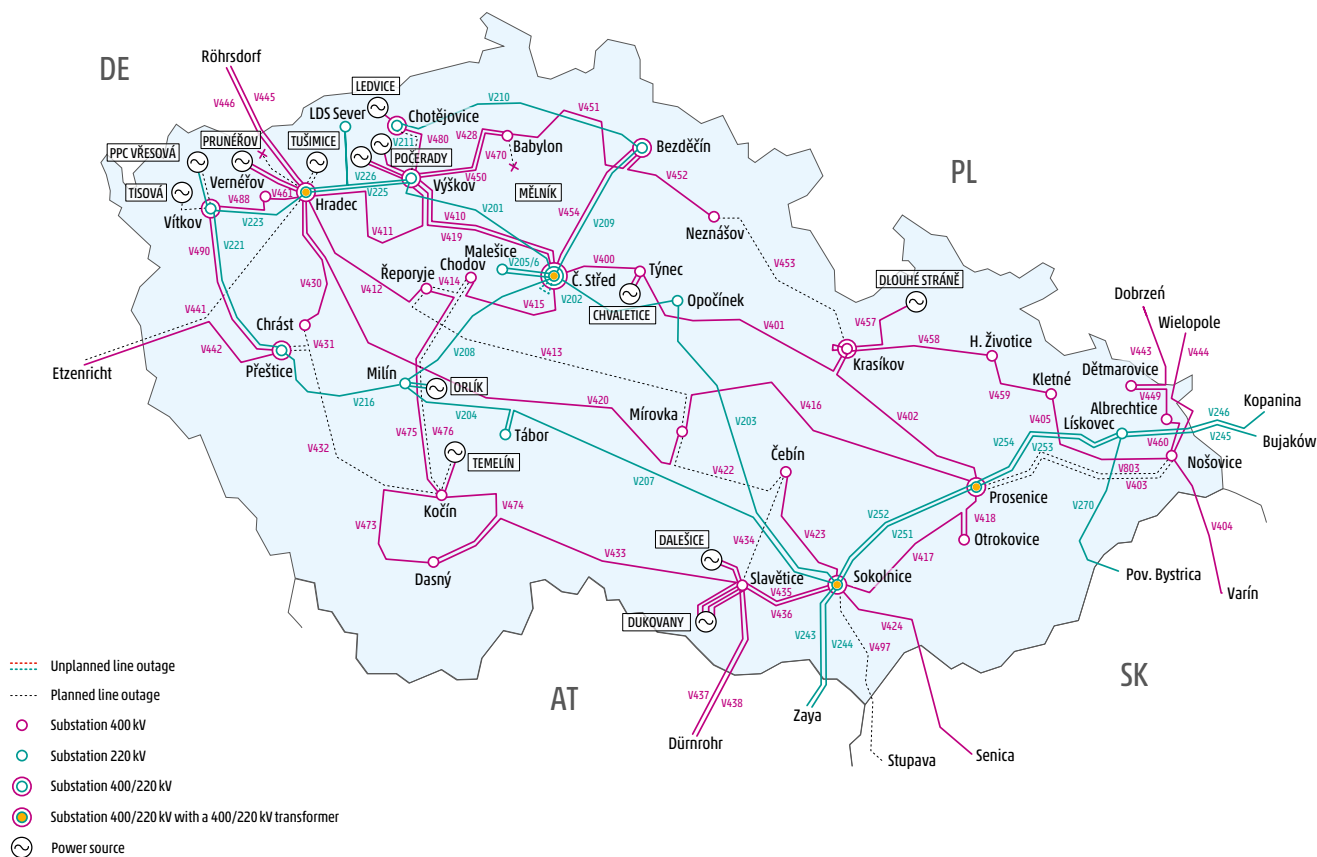


Figure 2.2: Situation of the Czech Republic transmission system on 4 July 2025, before the incident

400 kV lines

- » V431 Chrást–Přeštice without return-to-service time, 25.11.2024–03.10.2025 due to doubling of the line (V431/V831)
- » V453 Krasíkov–Neznášov without return-to-service time, 03.03.2025–29.08.2025 due to line modernisation
- » V413 Mírovka–Řeporyje without return-to-service time, 03.03.2025–27.11.2025, due to modernisation to higher transmission parameters
- » V403 and V803 Nošovice–Prosenice, with a return-to-service time of two days, 02.06.2025–15.08.2025, due to the finishing of the line doubling
- » V497 Sokolnice–Stupava without return-to-service time, 16.06.2025–04.07.2025 due to SEPS works in Slovakia
- » V434 Čebín–Slavětice without return-to-service time, 17.06.2025–31.07.2025 due to modernisation to higher transmission parameters
- » V432 Kočín–Přeštice without return-to-service time, 25.06.2025–29.08.2025 due to doubling of lines (V432/V429)
- » V422 Čebín–Mírovka without return-to-service time, 01.07.2025–14.11.2025 due to modernisation to higher transmission parameters



- » V414 Chodov–Řeporyje and V476 Chodov–Kočín, both without return-to-service time, 27.06.2025–21.07.2025, for replacement of the V414/476 pylons and protections in the Chodov substation
 - › The Chodov substation was in radial operation on line V415 (Chodov–Čechy Střed) due to the replacement of the V414 + V476 pylons. The disconnection of V414 + V476 was planned at the time of the shutdown of the Temelín NPP (B1), which was planned until 01.08.2025, so that the remaining outgoing lines from the Kočín substation would be able to transfer energy from the ETEM B2 to the transmission grid even if one of them failed. Therefore, the work could not be postponed until the V453 line was put into operation on 29.08.2025
- » V441 Etzenricht–Hradec without return-to-service time, 02.06.2025–15.09.2025 due to the repair of a damaged cable bushing on the ČEPS side

220 kV lines

V211 Chotějovice–Výškov without return-to-service time, 01.07.2025–24.07.2025 for switching of the conductors from the 220 kV to 400 kV substation and the redesignation to the new line V479.

Lines disconnected for voltage control

At 11:50, there were no lines disconnected for voltage control in the Czech Republic; only the connection to the Krasíkov 400 kV substation was prepared for a possible reconfiguration to reduce the voltage. The substation was prepared to switch off the V402 line or V458 line to reduce voltage if the EDST was not in operation.

Given the ongoing investment project⁵ and the west-to-east flow direction, the substation was optimally connected⁶. The current through the KSP in KRA4 at 11:51 was 307 A (16 % of load capacity).

Transformers

- » T401PRN (until 05.12.2025, without return-to-service time), reconstruction of the 220 kV substation
- » T402CST (until 14.08.2025, without return-to-service time), consumption switched to T201CST
- » T201VYS, termination of operation

Hradec substation

- » Operation of both HRA (Hradec west) and HRD (Hradec east) in basic connection⁷
- » Phase-shifting transformer T454HRD (on line V446) switched off due to defect
- » Phase-shifting transformer T453HRD (on line V446) switched off due to maintenance until 11.07.2025
- » Flow on line V446 controlled by the phase-shifting transformer T442ROH (confirmed by 50Hertz)
- » HRA4: KSP1 (busbar coupler) switched off due to maintenance until 25.07.2025

5 Disconnection of V453 Krasíkov–Neznášov due to line modernisation.

6 The connection of 400 kV substation Krasíkov is described in more detail in chapter 2.1.5.

7 The internal regulation of ČEPS specifies the basic connection of elements in all substations of the transmission system. The actual connection may vary depending on the current network situation.

Substation HRA (Hradec west)

– W1 busbar: V411, V441, V463, L401

– W2 busbar: V412, V461, T402, V464, V462, KSP1 W1-W2 switched on

Substation HRD (Hradec east)

– W1 busbar: V420, V445, V465, L402

– W2 busbar: V430, V446, V466 KSP2 W1-W2 switched on

Substations couplers SRW1 (ACB11) and SRW2 (ACB31) switched on, it means substations HRA and HRD connected.





Weekly operational planning

As the basic calculation model, the control system model (including the observability area) from 9:35 on 25 June 2025 was used. This model was updated in line with the expected parameters for 4 July 2025.

Parameters of the model used for 4 July 2025

Balance [MW]	Transit [MW]	PSE [MW]	SEPS [MW]	50Hertz [MW]	APG [MW]	TenneT [MW]
-588.5	2,983.1	-2,066.3	1,005.5	-1,505.3	1,788.7	188.9

Table 2.1: Cross-border flows in the week-ahead operational planning model for the ČEPS transmission grid for 4 July 2025

Balance: + = export / - = import
 Profile flows: + = from ČEPS / - = to ČEPS
 Dynamic thermal rating considered for a temperature of 33 °C

Flows through the lines:

- » V411: 842 MW (HRA → VYS)
- » V208: 22 MW (MIL → CST)

Power plant	Power [MW]	Power plant	Power [MW]	Power plant	Power [MW]
EDUK (Dukovany)	1980	ETU2 (Tušimice)	0	ETI2 (Tisová)	0
ETEM (Temelín)	1075	ECHV (Chvaletice)	0	EPVR (Vřesová)	0
ELED (B6) (Ledvice)	616	EPC2 (Počerady)	0	EORK (Orlík)	0
EPR2 (Pruněřov)	410	EDST (Dlouhé Stráně)	0		
EPOC (Počerady)	205	EDAL (Dalešice)	0		

Table 2.2: Active power output of the power plants in the week-ahead model of the ČEPS transmission grid for 4 July 2025 (gross)



Tables 2.3 to 2.5 present the predicted breaching of N-1 for 4 July 2025 and the appropriate measures to address it.

Overloaded element	Contingency	Measures
T402HRA (109 %)	V411	» Use the transformer overloadability » Change connection in the Hradec west and Hradec east substations » Transfer of consumption supplied from the 220 kV to the 400 kV grid » As a last resort, switch off the overloaded transformer

Table 2.3: Predicted breaching in the case of transit flow from Germany and low generation in the Czech Republic

Overloaded element	Contingency	Measures
V444 (99 %)	V443	» Preventive reconfiguration in the Nošovice substation, or discuss the possibility of PST regulation on the 50Hertz-PSE profile

Table 2.4: Predicted breaching of N-1 in case of high transit from Poland

Overloaded element	Contingency	Measures
T401VER (97 %) Lines 110 kV (108 %) VER-VYS	V411	» Preventively ask the distribution company to separate the Verněřov-Výškov area » Separation of the Verněřov-Výškov area can cause N-1 breaching on the T202CHT transformer after the T401VYS switch-off. In this case, ask distribution to reduce consumption in the Výškov area and switch off the T202CHT transformer

Table 2.5: Predicting breaching of N-1 in the VER-VYS interconnected area

When operating Hradec west and Hradec east in the basic connection, the recommended limit flow from 50Hertz is 1,500 MW (considering the nominal transmission limit of PST Rohrsdorf at 1,200 MVA, with an overloadability of 120 %).

Dynamic stability

Individual operating modes were checked for alignment with angular stability using the DSA⁸ application, which calculated the CCT for these network states on the outgoing lines from the transmission substations, where the power plants are connected. In all cases, the CCT results were well above the limit of 100 ms (the lowest CCT was 176 ms at the Temelín NPP).

Results of weekly operational planning

All proposed measures from the weekly operational planning led to resolving potential non-fulfilment of the N-1 criterion in the model, and there was no possible propagation of the fault to other elements, even with a transit flow of 1,500 MW in the direction from 50Hertz to ČEPS.

8 Dynamic Stability Assessment – internal ČEPS angular stability tool.



2.1.3 DACF

The DACF process for 4 July 2025 was completed on 3 July at 23:48, with the N-1 operational safety criteria being met. At the 11:30 time stamp (relevant to the time of the initial cause, V411 outage), the following preventive measures were implemented in the prediction model:

- » Reconfiguration in the Čechy Střed 220 kV substation due to the breaching of N-1 on V201
 - › Busbar W2: T201, V205, V206, V208, V202
 - › Busbar W3: T401, V209, V201, busbar coupler open
- » Reconfiguration in the Hradec Západ 400 kV substation due to the breaching of N-1 on V411/VER:T401 125 %
 - › Busbar W1: T402, V461 W2: V411, V412 and all from HRD4

Additional information on the DACF process:

- » Contingencies HRA:T402/CST: T401, CST:T401/HRA:T402, V411/HRA: T402: no measures are implemented in advance, because the time-limited overload capacity 120 %/3 h and 130 %/1 h can be used, and corrective measures⁹ after the outage can be applied during this time. This is verified by the relevant calculations (reconfiguration in HRD4 and CST2).
- » Contingencies V435/V436 and V436/V435 (only for time stamp 18:30): no measures are implemented in advance, because time-limited overload capacity of 120 %/1 h can be used and corrective measures after the outage can be applied during this time. This was verified in advance by the relevant calculations (reconfiguration in the Sokolnice 400 kV substation, SOK4).

DACF results

N-1 for 4 July 2025 is met. The highest N-1 value is for the time stamp at 11:30, with V203/V208 at 94.64 %, as shown in Table 2.6.

Contingency cases				Affected Branches				Hour																													
ename	sub1	sub2	type	ename	sub1	sub2	type	0:30	1:30	2:30	3:30	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30						
C:HRA:T402	CHRA_11	CHRA_22	transformer	C:CST:T401	CCST_11	CCST_22	transformer	98.11	91.21	92.03	93.99	93.76	93.99	102.77	102.59	100.86	86.17	86.1										99.15	105.06	105.36	129.25						
C:HRA:T402	CHRA_11	CHRA_22	transformer	C:CST:T401	CCST_11	CCST_23	transformer																		77.59	76.88	73.55										
C:CST:T401	CCST_11	CCST_22	transformer	C:HRA:T402	CHRA_11	CHRA_22	transformer	88.86	80.54	81.37	81.96	81.77	82.39	92.79	91.22	90.63	82.45						74.66	87.57	98.07	97.56	93.03	88.76	94.91	94.17	120.37						
V436:1	CSLV_1A	CSOK_12	line	V435:1	CSLV_11	CSOK_11	line							73.58										73.8	72.53	100.72	106.89	107.14	110.94	99.09	93.54						
V435:1	CSLV_11	CSOK_11	line	V436:1	CSLV_1A	CSOK_12	line							73.32										73.54	72.28	100.36	106.5	106.76	110.54	98.73	93.19						
V411:1	CVYSH_14	CHRA_14	line	C:HRA:T402	CHRA_11	CHRA_22	transformer										73.09						97.33	103.02	91.55	85.28	79.91				78.47						
V461:1	CVER_11	CHRA_13	line	C:VYS:T401	CVYSH_1B	CVYS_53	transformer	94.71	100.03	91.95	88.22	88.17	87.37	86.35	93.54	88.48															76.85						
C:CST:T401	CCST_11	CCST_22	transformer	V201:1	CVYS_21	CCST_23	line																					93.4	97.1	95.27	89.86						
V411:1	CVYSH_14	CHRA_14	line	C:VER:T401	CVER_11	CVER_57	transformer												70.09	74.71	73.42		86.48	96.27													
V208:1	CMIL_22	CCST_22	line	V203:1	COPO_21	CSOK_21	line												96.08	85.64	83.98	85.56	81.13	70.95	73.7	72.75											
V203:1	COPO_21	CSOK_21	line	V208:1	CMIL_22	CCST_22	line												94.64	84.46	82.32	84.09	79.53	70.13	74.21	73.74	71.32										
V223:1	CHRA_21	CVIT_22	line	V203:1	COPO_21	CSOK_21	line												89.62	84.41	79.68	81.3	79.26	72.95	77.06												
V420:1	CHRD_11	CHBM_14	line	KRA:4:nKSP	CKRA_11	CKRA_12	line																				89.51	79.01	88.17	84.2							
V433:1	CDAS_13	CSLV_18	line	V216:1	CPRE_21	CMIL_21	line																			78.94	89.06										
V411:1	CVYSH_14	CHRA_14	line	V201:1	CVYS_21	CCST_23	line															78.34	88.21														
V401:1	CTYN_11	CKRA_11	line	V202:1	COPO_22	CCST_22	line																					77.54	87.6	85.2	71.02						

Table 2.6: Day-ahead contingency report for the ČEPS transmission grid from AMICA generated on 3 July 2025 at 23:20, after the final run of the DACF process

9 Measures such as re-dispatching or reconfiguration that can be taken during the time the element may be overloaded.

2.1.4 IDCF

The description of the IDCF process for 4 July 2025 is based on the shift handover at approximately 6:45 and on the IDCF calculation at 11:15.

Based on the results presented in Table 2.7, corrective measures were implemented in the model for the 11:30 time stamp:

- » The same reconfiguration in the Čechy Střed 220 kV substation as in the DACF process was implemented:
 - Busbar W2: T201, V205, V206, V208, V202.
 - Busbar W3: T401, V209, V201 SP OFF.

The implementation of real-time reconfiguration at the Čechy Střed substation has been postponed until real-time calculations confirm the N-1 violation. This type of decision is used as a standard to avoid unnecessarily weakening the ČEPS transmission network.

Additional information on the IDCF process:

- » Reconfiguration in the Hradec Západ 400 kV substation was not implemented. The dispatcher shift decided to solve the non-fulfilmentviolation of N-1 V411/VER:T401 by changing the connection of the 110 kV grid at the moment of the indicated non-fulfilment of N-1 in the real-time calculation. This type of decision is used as a standard to avoid unnecessarily weakening the ČEPS transmission network or distribution network.
- » The measures for indicated contingencies T402 HRA/T401 CST, T401 CST/T402 HRA and V411/T402 HRA were not implemented in advance, because the time-limited overload capacity of 120 %/3 h and 130 %/1 h can be used and corrective measures after the outage could be applied during this time (verified in advance by the relevant calculations, reconfiguration in the Hradec east 400 kV and Čechy Střed 220 kV substations).
- » The measures for contingencies V435/V436 and V436/V435 for time stamp 18:30 were not implemented in advance, because the time-limited overload capacity of 120 %/1 h can be used and corrective measures after the outage can be applied during this time (reconfiguration in SOK4).

IDCF results

The indicated N-1 non-fulfilment from 11:30 to 13:30 concerned only the 400/110 kV transformers in Verněřov and the 400/220 kV transformers in Hradec. These N-1 non-fulfilments can be easily addressed by changing the 110 kV network connection or increasing the transformer's overloadability to 120 %/3 h or 130 %/1 h.

Co ntingency cases								Affected Branches								Hour																				
ename	sub1	sub2	type	ename	sub1	sub2	type	0:30	1:30	2:30	3:30	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30					
C:HRA:T402	CHRA_11	CHRA_22	trafo	C:CST:T401	CCST_11	CCST_22	transformer	105.39	95.75	98.28	97.54	96.65	96.63	105.18	99.77	101.97	87.23	80.37				13:30		15:30	16:30	17:30	18:30		19:30	20:30	21:30	22:30	23:30			
C:CST:T401	CCST_11	CCST_22	trafo	C:HRA:T402	CHRA_11	CHRA_22	transformer	96.22	85.22	87.48	86.88	85.81	86.00	93.50	89.83	93.64	84.15	80.90	74.86	73.09	70.3	76.5	77.29	82.78	111.08	114.28	86.21	91.93	97.14	96.04	121.69					
C:CST:T401	CCST_11	CCST_23	trafo	C:HRA:T402	CHRA_11	CHRA_22	transformer	96.22	85.22	87.48	86.88	85.81	86.00	93.50	89.83	93.64	84.15	80.90	74.86	73.09	70.3	76.5	77.29	82.78	111.08	114.28	86.21	91.93	97.14	96.04	121.69					
V411:1	CVYSH_14	CHRA_14	line	C:VER:T401	CVER_11	CVER_57	transformer											95.53	116.99	116.24	114.17	111.92	97.81	98.66	77.44											
V436:1	CSLV_1A	CSOK_12	line	V435:1	CSLV_1I	CSOK_11	line							75.01										76.3	76.29	100.35	109.49	107.41	113.14	101.24	94.03					
V435:1	CSLV_1I	CSOK_11	line	V436:1	CSLV_1A	CSOK_12	line							74.74										76.04	76.03	99.99	109.10	107.03	112.73	100.88	93.69					
V411:1	CVYSH_14	CHRA_14	line	C:HRA:T402	CHRA_11	CHRA_22	transformer										77.85	95.62	111.15	108.66	106.07	110.20	105.09	107.21	98.94	87.44	81.60				76.86					
V401:1	CTYN_11	CKRA_11	line	VIT:2:nSP:1	CVIT_21	CVIT_22	line																				110.87									
V203:1	COPO_21	CSOK_21	line	VIT:2:nSP:1	CVIT_21	CVIT_22	line																				110.12									
C:CST:T401	CCST_11	CCST_22	trafo	V201:1	CVYS_21	CCST_23	line									70.57									96.90	109.15		95.52	98.24	95.99	90.34					
V461:1	CVER_11	CHRA_13	line	C:VYS:T401	CVYSH_18	CVYS_53	transformer	93.56	102.56	92.96	82.84	82.54	85.59	91.78	96.49	83.52														71.2	79.25					
V208:1	CMIL_22	CCST_22	line	V203:1	COPO_21	CSOK_21	line												93.63	82.72	82.86	86.64	85.17	95.39			101.04									
V203:1	COPO_21	CSOK_21	line	V208:1	CMIL_22	CCST_22	line												91.71	81.02	80.71	84.55	83.67	93.86			100.96									
V411:1	CVYSH_14	CHRA_14	line	V201:1	CVYS_21	CCST_23	line											83.82	99.31	99.07	99.43	100.50	88.69	84.52	81.38	77.57										
V401:1	CTYN_11	CKRA_11	line	V216:1	CPRE_21	CMIL_21	line																				99.11									
V420:1	CHRD_11	CHBM_14	line	KRA:4:nKSP	CKRA_11	CKRA_12	line																				92.60	83.47	88.69	84.38						
V251:1	CXPRN_21	CSOK_21	line	V254:1	CLIS_22	CPRN_25	line																					82.84	91.57	73.54						
V252:1	CPRN_25	CSOK_22	line	V253:1	CLIS_21	CXPRN_21	line																					82.84	91.57	73.54						

Table 2.7: Intraday contingency report for the ČEPS transmission grid from AMICA for IDCF process generated on 4 July 2025 at 6:24 (shift change)

Contingency cases								Affected Branches								Hour																			
ename	sub1	sub2	type	ename	sub1	sub2	type	0:30	1:30	2:30	3:30	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30				
C:HRA:T402	CHRA_11	CHRA_22	trafo	C:CST:T401	CCST_11	CCST_22	transformer	105.39	95.75	98.28	97.54	96.65	96.63	103.18	101.88	104.99	91.86	90.77							112.11	120.52		101.3	105.47	104.61	129.11				
C:CST:T401	CCST_11	CCST_23	trafo	C:HRA:T402	CHRA_11	CHRA_22	transformer	96.22	85.22	87.48	86.88	85.81	86	93.5	91.89	97.86	88.85	91	82.56	81.08	77.37	79.62	83.47	83.3	108.17	112.39	84.66	91.19	95.8	93.7	120.33				
C:CST:T401	CCST_11	CCST_22	trafo	C:HRA:T402	CHRA_11	CHRA_22	transformer	96.22	85.22	87.48	86.88	85.81	86	93.5	91.89	97.86	88.85	91	82.56	81.08	77.37	79.62	83.47	83.3	108.17	112.39	84.66	91.19	95.8	93.7	120.33				
V411:1	CVYSH_14	CHRA_14	line	C:VER:T401	CVER_11	CVER_57	transformer										72.97	99.08	118.61	119.5	118.26	110.85	102.25	101.27	74.95										
V411:1	CVYSH_14	CHRA_14	line	C:HRA:T402	CHRA_11	CHRA_22	transformer										82.29	102.25	115.13	113.47	111.08	109.68	110.2	108.16	96.17	85.91	82.92			79.25					
V436:1	CSLV_1A	CSOK_12	line	V435:1	CSLV_1I	CSOK_11	line							75.01										76.39	75.54	100.84	108.79	106.81	112.05	100.33	92.44				
V435:1	CSLV_1I	CSOK_11	line	V436:1	CSLV_1A	CSOK_12	line							74.74										76.12	75.28	100.47	108.4	106.43	111.65	99.97	92.1				
V208:1	CMIL_22	CCST_22	line	V203:1	COPO_21	CSOK_21	line												110.63	102.01	98.22	91.95	91.56	95.64			98.13								
V203:1	COPO_21	CSOK_21	line	V208:1	CMIL_22	CCST_22	line												109.34	101.46	98.01	91.85	91.16	94.97			98.58								
V401:1	CTYN_11	CKRA_11	line	VIT:2:nSP:1	CVIT_21	CVIT_22	line																			109.03									
V203:1	COPO_21	CSOK_21	line	VIT:2:nSP:1	CVIT_21	CVIT_22	line																				108.73								
V223:1	CHRA_21	CVIT_22	line	V203:1	COPO_21	CSOK_21	line												83.42	80.04	74.97	73.59	76.68	77.09											
																			107.38	102.83	95.26	89.68	91.46	89.68											
C:CST:T401	CCST_11	CCST_22	trafo	V201:1	CVYS_21	CCST_23	line									71.44		74.38							91.43	104.71		93.07	96.93	94.25	89.43				
V461:1	CVER_11	CHRA_13	line	C:VYS:T401	CVYSH_18	CVYS_53	transformer	93.56	102.56	92.96	82.84	82.54	85.59	91.78	94.73	82.43														77.15					
V411:1	CVYSH_14	CHRA_14	line	V201:1	CVYS_21	CCST_23	line											85.92	96.55	97.68	99.25	95.37	88.08	83.57	76.46	74.28									
V401:1	CTYN_11	CKRA_11	line	V216:1	CPRE_21	CMIL_21	line																				97.02								
V221:1	CPRE_21	CVIT_21	line	C:SOK:T401	CSOK_12	CSOK_21	transformer																				90.66								
V420:1	CHRD_11	CHBM_14	line	KRA:4:nKSP	CKRA_11	CKRA_12	line																			90.48	83.23	87.98	82.87						

Table 2.8: Last relevant intraday contingency report for the ČEPS transmission grid from AMICA before the outage of V411, generated on 4 July 2025 at 10:24

As presented in Table 2.8, a deterioration of the N-1 V203/V208 at 109.34 % was indicated for time 11:30.

This non-fulfilment can be solved by the reconfiguration of the Čechy Střed 220 kV substation:

- » Busbar W2: T401, V205, V206, V208, V202.
- » Busbar W3: T201, V209, V201 SP OFF).

This reconfiguration was recalculated by the study in AMICA (as shown in Table 2.9) and led to a significant reduction in the non-fulfilment of V203/V208. N-1 on V411/208 was 92 %, which meets the N-1 criterion.

Contingency V411/T401VER will be solved by the disconnection of the 110 kV Verněřov–Výškov area.



Contingency cases						Affected Branches					Hour
name	ename	sub1	sub2	type	category	name	ename	sub1	sub2	type	11:30
CVYSH_1_CHRA_1_1:line	V411:1	CVYSH_11	CHRA_11	line	Single	CVER_1_CVER_5_2:trf	C:VER:T401	CVER_11	CVER_57	transformer	136.00
CVYSH_1_CHRA_1_1:line	V411:1	CVYSH_11	CHRA_11	line	Single	CHRA_1_CHRA_2_1:trf	C:HRA:T402	CHRA_11	CHRA_22	transformer	92.12
CCST_1_CCST_2_1:trf	C:CST:T401	CCST_11	CCST_22	transformer	Single	CMIL_2_CCST_2_1:line	V208:1	CMIL_22	CCST_22	line	91.73
BASECASE					Single	CBEZ_2_CBEZ_5_3:trf	C:BEZ:T201	CBEZ_21	CBEZ_51	transformer	78.88
XHR_R01_D8ROE_1_445:line	445	XHR_R011	D8ROE_11	line	Single	CHRD_21_XHR_R01_2:line	V446:1	CHRD_212	XHR_R012	line	78.6
CCST_1_CCST_2_1:trf	C:CST:T401	CCST_11	CCST_22	transformer	Single	CHRA_2_CVIT_2_1:line	V223:1	CHRA_21	CVIT_22	line	77.08
CCST_1_CCST_2_1:trf	C:CST:T401	CCST_11	CCST_22	transformer	Single	CVIT_2_CVIT_2_2:line	VIT:2:nSP:1	CVIT_21	CVIT_22	line	76.9
CKOC_1_CETEM_1_2:line	V052:1	CKOC_11	CETEM_12	line	Single	CHRD_1_CHRA_1_1:line	HRD:4:nSRW2	CHRD_12	CHRA_14	line	76.49
D8ROE_1_D8ROE_1_442:trf	442	D8ROE_11	D8ROE_18	transformer	Single	CHRD_21_XHR_R01_1:line	V445:1	CHRD_211	XHR_R011	line	76.46
CKLT_1_CNOS_1_1:line	V405:1	CKLT_11	CNOS_11	line	Single	CVYSH_1_CHRA_1_1:line	V411:1	CVYSH_14	CHRA_14	line	76.42
CHRA_2_CVIT_2_1:line	V223:1	CHRA_21	CVIT_21	line	Single	CCST_1_CCST_2_1:trf	C:CST:T401	CCST_11	CCST_23	transformer	75.89
D8ROE_1_D8ROE_1_442:trf	442	D8ROE_11	D8ROE_18	transformer	Single	CHRD_21_CHRD_21_2:trf	C:HRD:T452	CHRD_213	CHRD_215	transformer	75.83
D8ROE_1_D8ROE_1_442:trf	442	D8ROE_11	D8ROE_18	transformer	Single	CHRD_21_CHRD_21_1:trf	C:HRD:T451	CHRD_213	CHRD_215	transformer	75.83

Table 2.9: Study report for the ČEPS transmission grid from AMICA - proposal of the measure for N-1 V203 on V208

Results of study report: The proposed reconfiguration demonstrably solved N-1 V203/V208.



Situation in real time before the incident

Tables 2.10 and 2.11 present the 10:30 N-1 reports from the ČEPS control system.

Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	114.8	574.2	74.2	355.2	0.0	71.0	+219.0	+43.8	C:HRA:T402
C:CST:T401	97.5	487.4	0.0	355.2	0.0	71.0	+132.3	+26.5	C:HRA:T402
C:HRA:T402	96.8	484.2	0.0	220.5	0.0	44.1	+263.7	+52.7	C:CST:T401
C:V445:1	94.4	1359.1	0.0	833.9	0.0	57.9	+525.2	+36.5	D8:ROH:T442
C:CHD:T401	91.0	318.4	0.0	169.1	0.0	48.3	+149.3	+42.7	C:CHD:T403
C:CHD:T403	90.9	318.2	0.0	149.0	0.0	42.6	+169.2	+48.3	C:CHD:T401
C:V446:1	85.9	1954.5	0.0	1252.2	0.0	55.0	+702.3	+30.9	C:V445:1
C:V433:1	79.1	395.6	0.0	355.2	0.0	71.0	+40.4	+8.1	C:HRA:T402

Table 2.10: N-1 report from the ČEPS control system¹⁰ at 10:30 – per relevant contingency

Zařízení	N-1% ▲	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	114.8	C:HRA:4:...	C:HRA:2:...	500.0	574.2	74.2	355.2	0.0	71.0	+219.0	+43.8	C:V411:1
C:VER:T401	111.8	C:VER:4:...	C:VER:1:...	350.0	391.4	41.4	161.0	0.0	46.0	+230.5	+65.8	C:V411:1
C:CST:T401	96.8	C:CST:4:...	C:CST:2:...	500.0	484.2	0.0	220.5	0.0	44.1	+263.7	+52.7	C:HRA:T402
C:V201:1	96.3	C:VYS:2:W1	C:CST:2:...	796.0	766.4	0.0	363.7	0.0	45.7	+402.7	+50.6	C:V411:1
D8:ROH:T442	94.4	D8:ROH:4:...	D8:ROH:4:...	1440.0	1359.1	0.0	833.9	0.0	57.9	+525.2	+36.5	C:V445:1
C:CHD:T403	91.0	C:CHD:4:...	C:CHD:1:...	350.0	318.4	0.0	169.1	0.0	48.3	+149.3	+42.7	C:CHD:T401
C:CHD:T401	90.9	C:CHD:4:...	C:CHD:1:...	350.0	318.2	0.0	149.0	0.0	42.6	+169.2	+48.3	C:CHD:T403
C:V445:1	85.9	C:HRD:4:...	D8:ROH:4:...	2276.0	1954.5	0.0	1252.2	0.0	55.0	+702.3	+30.9	C:V446:1
C:V446:1	84.6	C:HRA:4:...	D8:ROH:4:...	2276.0	1926.5	0.0	1180.4	0.0	51.9	+746.1	+32.8	C:V445:1
C:HRD:T451	80.2	C:HRA:4:...	C:HRD:4:...	850.0	681.3	0.0	438.7	0.0	51.6	+242.6	+28.5	C:V446:1
C:HRD:T452	80.2	C:HRA:4:...	C:HRD:4:...	850.0	681.3	0.0	438.7	0.0	51.6	+242.6	+28.5	C:V446:1
C:HRD:4:Y1_465_K...	77.3	C:HRA:4:...	C:HRA:4:...	2882.0	2227.5	0.0	1530.6	0.0	53.1	+696.9	+24.2	C:V446:1

Table 2.11: N-1 report from the ČEPS control system¹¹ at 10:30 – per relevant monitored element

Results of N-1 at 10:30:

- » Both the C:HRA:T402 and C:VER:T401 transformers are overloadable.
- » The solution for the case of N-1 non-fulfilment on the C:VER:T401 transformer was, in cooperation with the distribution company, the splitting of the interconnected 110 kV Verněřov-Výškov area.
- » The solution for the case of N-1 non-fulfilment on the C:HRA:T402 transformer is to coordinate with the distribution company to relieve consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » It is not yet necessary to proceed with the application of reconfiguration in Čechy Střed substation. The highest relevant N-1 value for V411/V201 is 96.3 %.

- 10 Kontingence contingency, element whose shutdown is simulated.
N-1 flow through the monitored element (lines in A, transformers in MVA) in case of contingency, <80, ≥80 and <100, ≥100 %.
N-1 % flow through the monitored element as % of limit in case of contingency.
Přes N-1 flow through the monitored element above the nominal power (lines in A, transformers in MVA).
Limit nominal limit of the monitored element (lines in A, transformers in MVA).
N-0 flow through the monitored element without contingency (lines in A, transformers in MVA).
Přes N-0 flow through the monitored element without contingency above nominal power (lines in A, transformers in MVA).
N-0 % flow in normal case without contingency, as % of limit.
Rozdíl difference of the flow on the monitored element in N-0 and N-1 (lines in A, transformers in MVA).
Rozdíl % difference of the flow on the monitored element in N-0 and N-1 in %.
- 11 Zařízení monitored element, element through which the flow is detected.
Uzel 1, Uzel 2 nodes through which the device is connected to the network.
Limit nominal power (lines in A, transformers in MVA)
The rest is the same as in the previous table



Tables 2.12 and 2.13 present the 11:01 N-1 report from the ČEPS control system before the decision to implement the reconfiguration at the Čechy Střed 220 kV substation and the splitting of the 110 kV Výškov–Verněřov area.

Kontingence	N-1%	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	121.3	606.5	106.5	372.9	0.0	74.6	+233.6	+46.7	C:HRA:T402
C:CST:T401	103.0	515.0	15.0	372.9	0.0	74.6	+142.1	+28.4	C:HRA:T402
C:HRA:T402	102.9	514.3	14.3	238.0	0.0	47.6	+276.3	+55.3	C:CST:T401
C:V445:1	96.3	1386.6	0.0	849.8	0.0	59.0	+536.8	+37.3	D8:ROH:T442
C:CHD:T401	89.2	312.1	0.0	165.6	0.0	47.3	+146.5	+41.8	C:CHD:T403
C:CHD:T403	89.1	311.9	0.0	146.2	0.0	41.8	+165.7	+47.3	C:CHD:T401
C:V446:1	87.3	1987.8	0.0	1271.5	0.0	55.9	+716.3	+31.5	C:V445:1
C:V433:1	82.6	412.8	0.0	372.9	0.0	74.6	+39.9	+8.0	C:HRA:T402
D8:V572:1	82.4	1187.2	0.0	866.2	0.0	60.2	+321.0	+22.3	D8:ROH:T441
C:V420:1	80.4	402.0	0.0	372.9	0.0	74.6	+29.1	+5.8	C:HRA:T402
C:V410:1	80.0	400.0	0.0	372.9	0.0	74.6	+27.1	+5.4	C:HRA:T402
C:V419:1	80.0	400.0	0.0	372.9	0.0	74.6	+27.1	+5.4	C:HRA:T402

Table 2.12: N-1 report from ČEPS control system at 11:01 – per relevant contingency

Zařízení	N-1%	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	121.3	C:HRA:4:...	C:HRA:2:...	500.0	606.5	106.5	372.9	0.0	74.6	+233.6	+46.7	C:V411:1
C:VER:T401	121.2	C:VER:4:...	C:VER:1:...	350.0	424.2	74.2	178.1	0.0	50.9	+246.1	+70.3	C:V411:1
C:CST:T401	102.9	C:CST:4:...	C:CST:2:...	500.0	514.3	14.3	238.0	0.0	47.6	+276.3	+55.3	C:HRA:T402
C:V201:1	100.6	C:VYS:2:W1	C:CST:2:...	796.0	800.7	4.7	370.0	0.0	46.5	+430.7	+54.1	C:V411:1
D8:ROH:T442	96.3	D8:ROH:4:...	D8:ROH:4:...	1440.0	1386.6	0.0	849.8	0.0	59.0	+536.8	+37.3	C:V445:1
C:CHD:T403	89.2	C:CHD:4:...	C:CHD:1:...	350.0	312.1	0.0	165.6	0.0	47.3	+146.5	+41.8	C:CHD:T401
C:CHD:T401	89.1	C:CHD:4:...	C:CHD:1:...	350.0	311.9	0.0	146.2	0.0	41.8	+165.7	+47.3	C:CHD:T403
C:V445:1	87.3	C:HRD:4:...	D8:ROH:4:...	2276.0	1987.8	0.0	1271.5	0.0	55.9	+716.3	+31.5	C:V446:1
C:V446:1	86.1	C:HRA:4:...	D8:ROH:4:...	2276.0	1960.1	0.0	1199.9	0.0	52.7	+760.2	+33.4	C:V445:1
D8:ROH:T441	82.4	D8:ROH:4:...	D8:ROH:4:...	1440.0	1187.2	0.0	866.2	0.0	60.2	+321.0	+22.3	D8:V572:1
C:HRD:T451	81.6	C:HRA:4:...	C:HRD:4:...	850.0	693.5	0.0	446.1	0.0	52.5	+247.4	+29.1	C:V446:1
C:HRD:T452	81.6	C:HRA:4:...	C:HRD:4:...	850.0	693.5	0.0	446.1	0.0	52.5	+247.4	+29.1	C:V446:1
C:HRD:4:ACT84:1	78.4	C:HRD:4:...	C:HRD:4:...	2530.0	1983.8	0.0	1264.9	0.0	50.0	+718.9	+28.4	C:V446:1

Table 2.13: N-1 report from ČEPS control system at 11:01 – per relevant monitored element

Results of N-1 at 11:01:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to reduce consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » Based on the non-fulfilment of N-1 on the VER:T401 transformer, it was decided to split the Výškov–Verněřov 110 kV area.
- » Based on the non-fulfilment of N-1 on line V201, it was decided to execute the reconfiguration in the Čechy Střed 220 kV substation.

- » Several options were considered, and it was finally decided to implement the following reconfiguration (different to reconfigurations modelled in DACF and IDCF):

- » Busbar W2 – V201, V202.
- » Busbar W3 – V205, V206, V208, V209, T401, SP OFF.

At 11:04, the ČEPS operator issued the order to ČEZd to disconnect the Verněřov–Výškov interconnected area.

At 11:12, the disconnection of the Verněřov–Výškov 110 kV area was executed, and the reconfiguration at the Čechy Střed 220 kV substation was implemented.



Tables 2.14 and 2.15 present the 11:13 N-1 report from the ČEPS control system, after the reconfiguration at the Čechy Střed 220 kV substation.

Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	112.1	560.3	60.3	339.8	0.0	68.0	+220.6	+44.1	C:HRA:T402
C:V445:1	98.4	1416.3	0.0	867.5	0.0	60.2	+548.8	+38.1	D8:ROH:T442
C:CST:T401	96.1	480.4	0.0	339.8	0.0	68.0	+140.6	+28.1	C:HRA:T402
C:CHD:T401	89.9	314.5	0.0	167.0	0.0	47.7	+147.5	+42.1	C:CHD:T403
C:CHD:T403	89.8	314.3	0.0	147.2	0.0	42.1	+167.1	+47.7	C:CHD:T401
C:V446:1	88.9	2022.7	0.0	1292.1	0.0	56.8	+730.6	+32.1	C:V445:1
C:V052:1	87.6	2523.8	0.0	1993.4	0.0	69.2	+530.4	+18.4	C:HRD:4:nSRW2:1
C:V405:1	85.8	1935.2	0.0	1684.4	0.0	74.7	+250.9	+11.1	C:V411:1
C:V420:1	84.8	1912.7	0.0	1684.4	0.0	74.7	+228.3	+10.1	C:V411:1
C:HRA:T402	84.8	1912.4	0.0	1684.4	0.0	74.7	+228.1	+10.1	C:V411:1
C:V433:1	83.7	1888.3	0.0	1684.4	0.0	74.7	+203.9	+9.0	C:V411:1
C:V223:1	83.5	1883.2	0.0	1684.4	0.0	74.7	+198.8	+8.8	C:V411:1
C:V480:1	83.1	1873.8	0.0	1684.4	0.0	74.7	+189.5	+8.4	C:V411:1
C:V459:1	81.0	1827.1	0.0	1684.4	0.0	74.7	+142.7	+6.3	C:V411:1
D8:V572:1	80.9	1164.3	0.0	852.0	0.0	59.2	+312.3	+21.7	D8:ROH:T441
C:REP:T404	79.4	277.7	0.0	175.8	0.0	50.2	+101.9	+29.1	C:REP:T403

Table 2.14: N-1 report from ČEPS control system at 11:13 – per relevant contingency

Zařízení	N-1% ▲	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	112.1	C:HRA:4:...	C:HRA:2:...	500.0	560.3	60.3	339.8	0.0	68.0	+220.6	+44.1	C:V411:1
D8:ROH:T442	98.4	D8:ROH:4:...	D8:ROH:4:...	1440.0	1416.3	0.0	867.5	0.0	60.2	+548.8	+38.1	C:V445:1
C:V208:1	94.1	C:MIL:2:W...	C:CST:2:W3	749.0	704.5	0.0	87.7	0.0	11.7	+616.8	+82.4	C:V411:1
C:CHD:T403	89.9	C:CHD:4:...	C:CHD:1:...	350.0	314.5	0.0	167.0	0.0	47.7	+147.5	+42.1	C:CHD:T401
C:CHD:T401	89.8	C:CHD:4:...	C:CHD:1:...	350.0	314.3	0.0	147.2	0.0	42.1	+167.1	+47.7	C:CHD:T403
C:V223:1	89.7	C:HRA:2:...	C:VIT:2:W...	1165.0	1044.9	0.0	569.6	0.0	48.9	+475.3	+40.8	C:V411:1
C:VIT:2:nSP:1	89.6	C:VIT:2:W...	C:VIT:2:W...	1165.0	1044.0	0.0	565.5	0.0	48.5	+478.5	+41.1	C:V411:1
C:V445:1	88.9	C:HRD:4:...	D8:ROH:4:...	2276.0	2022.7	0.0	1292.1	0.0	56.8	+730.6	+32.1	C:V446:1
C:V446:1	87.7	C:HRA:4:...	D8:ROH:4:...	2276.0	1995.3	0.0	1221.0	0.0	53.6	+774.3	+34.0	C:V445:1
C:HRD:4:nSRW2:1	87.6	C:HRA:4:...	C:HRA:4:...	2882.0	2523.8	0.0	1993.4	0.0	69.2	+530.4	+18.4	C:V052:1
C:V411:1	85.8	C:VYS:4:...	C:HRA:4:...	2256.0	1935.2	0.0	1684.4	0.0	74.7	+250.9	+11.1	C:V405:1
C:HRD:T452	83.2	C:HRA:4:...	C:HRD:4:...	850.0	707.0	0.0	454.6	0.0	53.5	+252.4	+29.7	C:V446:1
C:HRD:T451	83.2	C:HRA:4:...	C:HRD:4:...	850.0	707.0	0.0	454.6	0.0	53.5	+252.4	+29.7	C:V446:1
C:CST:T401	82.5	C:CST:4:...	C:CST:2:W3	500.0	412.3	0.0	259.0	0.0	51.8	+153.3	+30.7	C:V223:1
C:KRA:4:nKSP:1	81.8	C:KRA:4:...	C:KRA:4:...	2000.0	1637.0	0.0	298.1	0.0	14.9	+1338.9	+66.9	C:V411:1
D8:ROH:T441	80.9	D8:ROH:4:...	D8:ROH:4:...	1440.0	1164.3	0.0	852.0	0.0	59.2	+312.3	+21.7	D8:V572:1
C:HRD:4:ACT84:1	79.8	C:HRD:4:...	C:HRD:4:...	2530.0	2019.5	0.0	1286.7	0.0	50.9	+732.8	+29.0	C:V446:1

Table 2.15: N-1 report from ČEPS control system at 11:13 – per relevant monitored element

Results of N-1 at 11:13:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to reduce consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » After the aforementioned reconfigurations were executed, the ČEPS grid was N-1 secure.

At 11:14, the ČEZd operator requested permission from the ČEPS operator to couple the Řeporyje and Týnec 110 kV areas. The ČEPS dispatcher authorised the coupling.

At 11:17, the ČEZd operator asked the ČEPS operator for permission to couple the Řeporyje and Výškov 110 kV areas to change the configuration of the MV and HV networks at several locations. The ČEPS operator authorised coupling. The Řeporyje and Výškov areas were coupled from 11:19 to 11:41.



Tables 2.16 and 2.17 present the N-1 report from the ČEPS control system at 11:20, after the connection of the Řeporyje and Výškov 110 kV areas.

Kontingence	N-1%	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	103.0	514.8	14.8	339.9	0.0	68.0	+175.0	+35.0	C:HRA:T402
C:V445:1	99.7	1435.1	0.0	878.9	0.0	61.0	+556.2	+38.6	D8:ROH:T442
C:CST:T401	96.3	481.5	0.0	339.9	0.0	68.0	+141.6	+28.3	C:HRA:T402
C:V446:1	90.0	2049.4	0.0	1308.2	0.0	57.5	+741.1	+32.6	C:V445:1
C:CHD:T401	89.7	313.8	0.0	166.5	0.0	47.6	+147.2	+42.1	C:CHD:T403
C:CHD:T403	89.6	313.6	0.0	146.9	0.0	42.0	+166.6	+47.6	C:CHD:T401
C:V052:1	86.6	2494.9	0.0	1959.5	0.0	68.0	+535.4	+18.6	C:HRD:4:nSR...
D8:V572:1	83.8	1207.3	0.0	879.4	0.0	61.1	+327.9	+22.8	D8:ROH:T441
C:REP:T404	83.1	290.8	0.0	192.7	0.0	55.1	+98.1	+28.0	C:REP:T403
C:V223:1	83.0	414.9	0.0	260.8	0.0	52.2	+154.1	+30.8	C:CST:T401
C:V405:1	82.6	1862.8	0.0	1620.1	0.0	71.8	+242.7	+10.8	C:V411:1
C:HRA:T402	81.8	1846.2	0.0	1620.1	0.0	71.8	+226.1	+10.0	C:V411:1
C:V420:1	81.8	1845.9	0.0	1620.1	0.0	71.8	+225.8	+10.0	C:V411:1
C:REP:T403	80.1	280.4	0.0	178.3	0.0	50.9	+102.1	+29.2	C:REP:T404
C:V480:1	78.6	1772.8	0.0	1620.1	0.0	71.8	+152.7	+6.8	C:V411:1

Table 2.16: N-1 report from the ČEPS control system at 11:20 – per relevant contingency

Zařízení	N-1%	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	103.0	C:HRA:4:...	C:HRA:2:...	500.0	514.8	14.8	339.9	0.0	68.0	+175.0	+35.0	C:V411:1
D8:ROH:T442	99.7	D8:ROH:4:...	D8:ROH:4:...	1440.0	1435.1	0.0	878.9	0.0	61.0	+556.2	+38.6	C:V445:1
C:V445:1	90.0	C:HRD:4:...	D8:ROH:4:...	2276.0	2049.4	0.0	1308.2	0.0	57.5	+741.1	+32.6	C:V446:1
C:V208:1	89.9	C:MIL:2:W...	C:CST:2:W3	749.0	673.6	0.0	89.4	0.0	11.9	+584.1	+78.0	C:CST:T401
C:CHD:T403	89.7	C:CHD:4:...	C:CHD:1:...	350.0	313.8	0.0	166.5	0.0	47.6	+147.2	+42.1	C:CHD:T401
C:CHD:T401	89.6	C:CHD:4:...	C:CHD:1:...	350.0	313.6	0.0	146.9	0.0	42.0	+166.6	+47.6	C:CHD:T403
C:V446:1	88.8	C:HRA:4:...	D8:ROH:4:...	2276.0	2022.1	0.0	1237.2	0.0	54.4	+784.8	+34.5	C:V445:1
C:HRD:4:nSRW2:1	86.6	C:HRA:4:...	C:HRA:4:...	2882.0	2494.9	0.0	1959.5	0.0	68.0	+535.4	+18.6	C:V052:1
C:REP:T403	84.2	C:REP:4:...	C:REP:1:...	350.0	294.8	0.0	192.7	0.0	55.1	+102.1	+29.2	C:V411:1
C:HRD:T452	84.2	C:HRA:4:...	C:HRD:4:...	850.0	715.9	0.0	460.1	0.0	54.1	+255.8	+30.1	C:V446:1
C:HRD:T451	84.2	C:HRA:4:...	C:HRD:4:...	850.0	715.9	0.0	460.1	0.0	54.1	+255.8	+30.1	C:V446:1
D8:ROH:T441	83.8	D8:ROH:4:...	D8:ROH:4:...	1440.0	1207.3	0.0	879.4	0.0	61.1	+327.9	+22.8	D8:V572:1
C:CST:T401	83.0	C:CST:4:...	C:CST:2:W3	500.0	414.9	0.0	260.8	0.0	52.2	+154.1	+30.8	C:V223:1
C:V411:1	82.6	C:VYS:4:...	C:HRA:4:...	2256.0	1862.8	0.0	1620.1	0.0	71.8	+242.7	+10.8	C:V405:1
C:V223:1	81.1	C:HRA:2:...	C:VIT:2:W...	1165.0	944.8	0.0	571.3	0.0	49.0	+373.5	+32.1	C:CST:T401
C:VIT:2:nSP:1	81.0	C:VIT:2:W...	C:VIT:2:W...	1165.0	943.1	0.0	566.9	0.0	48.7	+376.2	+32.3	C:CST:T401
C:HRD:4:ACT84:1	80.9	C:HRD:4:...	C:HRD:4:...	2530.0	2046.4	0.0	1303.0	0.0	51.5	+743.4	+29.4	C:V446:1
C:HRD:4:ACT94:1	80.9	C:HRA:4:...	C:HRA:4:...	2530.0	2046.0	0.0	1302.6	0.0	51.5	+743.4	+29.4	C:V446:1
C:REP:T404	80.1	C:REP:4:...	C:REP:1:...	350.0	280.4	0.0	178.3	0.0	50.9	+102.1	+29.2	C:REP:T403
C:HRD:4:Y1_465_K...	79.8	C:HRA:4:...	C:HRA:4:...	2882.0	2300.6	0.0	1568.8	0.0	54.4	+731.8	+25.4	C:V446:1

Table 2.17: N-1 report from the ČEPS control system at 11:20 – per relevant monitored element

Results of N-1 at 11:20:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to reduce consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the transformer C:CHT:T202.
- » The connection of the Řeporyje–Výškov 110 kV areas led to a significant reduction of N-1 V411/V208.



Tables 2.18 and 2.19 present the N-1 report from the ČEPS control system at 11:42, after the disconnection of the Výškov-Řeporyje 110 kV areas.

Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	114.5	572.6	72.6	346.5	0.0	69.3	+226.1	+45.2	C:HRA:T402
C:V445:1	98.8	1422.3	0.0	850.5	0.0	59.1	+571.8	+39.7	D8:ROH:T442
C:CST:T401	98.0	490.0	0.0	346.5	0.0	69.3	+143.5	+28.7	C:HRA:T402
C:V446:1	92.9	2066.7	0.0	1347.8	0.0	60.6	+718.9	+32.3	C:V445:1
C:CHD:T401	90.7	317.5	0.0	168.6	0.0	48.2	+148.9	+42.5	C:CHD:T403
C:CHD:T403	90.7	317.3	0.0	148.6	0.0	42.5	+168.7	+48.2	C:CHD:T401
C:V405:1	89.3	1977.8	0.0	1723.9	0.0	77.9	+253.9	+11.5	C:V411:1
C:V052:1	88.7	2515.4	0.0	1985.4	0.0	70.0	+530.0	+18.7	C:HRD:4:nSR...
C:HRA:T402	88.4	1957.5	0.0	1723.9	0.0	77.9	+233.6	+10.6	C:V411:1
C:V420:1	87.7	1942.0	0.0	1723.9	0.0	77.9	+218.1	+9.9	C:V411:1
C:V223:1	87.1	1927.5	0.0	1723.9	0.0	77.9	+203.6	+9.2	C:V411:1
C:V433:1	86.9	1924.3	0.0	1723.9	0.0	77.9	+200.4	+9.0	C:V411:1
C:V459:1	84.8	1877.1	0.0	1723.9	0.0	77.9	+153.2	+6.9	C:V411:1
D8:V572:1	82.9	1194.3	0.0	871.2	0.0	60.5	+323.1	+22.4	D8:ROH:T441
C:V417:1	82.5	1826.0	0.0	1723.9	0.0	77.9	+102.1	+4.6	C:V411:1
C:V458:1	82.5	1825.9	0.0	1723.9	0.0	77.9	+102.0	+4.6	C:V411:1
C:V480:1	82.5	1825.7	0.0	1723.9	0.0	77.9	+101.8	+4.6	C:V411:1
C:V443:1	81.9	1812.2	0.0	1723.9	0.0	77.9	+88.3	+4.0	C:V411:1
C:V402:1	81.2	1798.1	0.0	1723.9	0.0	77.9	+74.2	+3.3	C:V411:1
C:V412:1	80.9	1791.6	0.0	1723.9	0.0	77.9	+67.7	+3.1	C:V411:1
C:V444:1	80.9	1791.2	0.0	1723.9	0.0	77.9	+67.3	+3.0	C:V411:1
C:V221:1	80.9	1790.5	0.0	1723.9	0.0	77.9	+66.6	+3.0	C:V411:1
C:V460:1	80.8	1788.9	0.0	1723.9	0.0	77.9	+65.0	+2.9	C:V411:1
C:V449:1	80.8	1788.8	0.0	1723.9	0.0	77.9	+64.9	+2.9	C:V411:1
D2:V465B:1	80.3	1777.1	0.0	1723.9	0.0	77.9	+53.2	+2.4	C:V411:1
Z:V456:1	80.1	1772.5	0.0	1723.9	0.0	77.9	+48.6	+2.2	C:V411:1
C:V475:1	79.5	2256.8	0.0	1985.4	0.0	70.0	+271.4	+9.6	C:HRD:4:nSR...

Table 2.18: N-1 report from the ČEPS control system at 11:42 – per relevant contingency

Zařízení	N-1% ▲	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	114.5	C:HRA:4:...	C:HRA:2:...	500.0	572.6	72.6	346.5	0.0	69.3	+226.1	+45.2	C:V411:1
C:V208:1	99.5	C:MIL:2:W...	C:CST:2:W3	724.0	720.6	0.0	87.7	0.0	12.1	+632.9	+87.4	C:V411:1
D8:ROH:T442	98.8	D8:ROH:4:...	D8:ROH:4:...	1440.0	1422.3	0.0	850.5	0.0	59.1	+571.8	+39.7	C:V445:1
C:V445:1	92.9	C:HRD:4:...	D8:ROH:4:...	2225.0	2066.7	0.0	1347.8	0.0	60.6	+718.9	+32.3	C:V446:1
C:V223:1	91.9	C:HRA:2:...	C:VIT:2:W...	1165.0	1070.1	0.0	581.4	0.0	49.9	+488.6	+41.9	C:V411:1
C:VIT:2:nSP:1	91.7	C:VIT:2:W...	C:VIT:2:W...	1165.0	1068.5	0.0	576.6	0.0	49.5	+491.9	+42.2	C:V411:1
C:CHD:T403	90.7	C:CHD:4:...	C:CHD:1:...	350.0	317.5	0.0	168.6	0.0	48.2	+148.9	+42.5	C:CHD:T401
C:CHD:T401	90.7	C:CHD:4:...	C:CHD:1:...	350.0	317.3	0.0	148.6	0.0	42.5	+168.7	+48.2	C:CHD:T403
C:V446:1	90.1	C:HRA:4:...	D8:ROH:4:...	2225.0	2005.5	0.0	1198.0	0.0	53.8	+807.5	+36.3	C:V445:1
C:V411:1	89.3	C:VYS:4:...	C:HRA:4:...	2214.0	1977.8	0.0	1723.9	0.0	77.9	+253.9	+11.5	C:V405:1
C:HRD:4:nSRW2:1	88.7	C:HRA:4:...	C:HRA:4:...	2837.0	2515.4	0.0	1985.4	0.0	70.0	+530.0	+18.7	C:V052:1
C:KRA:4:nKSP:1	85.4	C:KRA:4:...	C:KRA:4:...	2000.0	1708.8	0.0	333.1	0.0	16.7	+1375.7	+68.8	C:V411:1
C:HRD:T451	84.9	C:HRA:4:...	C:HRD:4:...	850.0	721.4	0.0	473.6	0.0	55.7	+247.8	+29.2	C:V446:1
C:HRD:T452	84.9	C:HRA:4:...	C:HRD:4:...	850.0	721.4	0.0	473.6	0.0	55.7	+247.8	+29.2	C:V446:1
C:CST:T401	84.0	C:CST:4:...	C:CST:2:W3	500.0	419.9	0.0	262.8	0.0	52.6	+157.1	+31.4	C:V223:1
D8:ROH:T441	82.9	D8:ROH:4:...	D8:ROH:4:...	1440.0	1194.3	0.0	871.2	0.0	60.5	+323.1	+22.4	D8:V572:1
C:HRD:4:ACT84:1	81.6	C:HRD:4:...	C:HRD:4:...	2530.0	2063.5	0.0	1342.3	0.0	53.1	+721.1	+28.5	C:V446:1
C:HRD:4:ACT94:1	81.5	C:HRA:4:...	C:HRA:4:...	2530.0	2062.8	0.0	1341.7	0.0	53.0	+721.1	+28.5	C:V446:1
C:HRD:4:Y1 465 K...	80.7	C:HRA:4:...	C:HRA:4:...	2837.0	2289.7	0.0	1581.3	0.0	55.7	+708.4	+25.0	C:V446:1
C:HRD:4:ACB18:1	78.8	C:HRA:4:...	C:HRA:4:...	2530.0	1994.3	0.0	1188.7	0.0	47.0	+805.7	+31.8	C:V445:1

Table 2.19: N-1 report from the ČEPS control system at 11:42 – per relevant monitored element

Results of N-1 at 11:42:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to relieve consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » N-1 V411/V208 increased; nevertheless, the ČEPS grid is N-1 secure.



Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	107.0	534.9	34.9	325.6	0.0	65.1	+209.3	+41.9	C:HRA:T402
C:V445:1	93.2	1341.5	0.0	812.7	0.0	56.4	+528.9	+36.7	D8:ROH:T442
C:CHD:T401	91.9	321.8	0.0	171.0	0.0	48.9	+150.8	+43.1	C:CHD:T403
C:CHD:T403	91.9	321.5	0.0	150.4	0.0	43.0	+171.1	+48.9	C:CHD:T401
C:CST:T401	91.4	457.1	0.0	325.6	0.0	65.1	+131.5	+26.3	C:HRA:T402
C:V446:1	87.6	1948.2	0.0	1287.4	0.0	57.9	+660.7	+29.7	C:V445:1
C:V052:1	87.2	2474.1	0.0	1903.5	0.0	67.1	+570.6	+20.1	C:HRD:4:nSR...
C:V405:1	85.6	1894.7	0.0	1642.5	0.0	74.2	+252.2	+11.4	C:V411:1
C:V420:1	83.7	1852.1	0.0	1642.5	0.0	74.2	+209.6	+9.5	C:V411:1
C:HRA:T402	83.6	1851.4	0.0	1642.5	0.0	74.2	+208.9	+9.4	C:V411:1
C:V433:1	82.9	1835.3	0.0	1642.5	0.0	74.2	+192.8	+8.7	C:V411:1
D8:V572:1	82.9	1193.5	0.0	875.5	0.0	60.8	+318.0	+22.1	D8:ROH:T441
C:V223:1	82.5	1826.8	0.0	1642.5	0.0	74.2	+184.3	+8.3	C:V411:1
C:V459:1	80.9	1790.4	0.0	1642.5	0.0	74.2	+147.8	+6.7	C:V411:1
C:V480:1	80.5	1782.5	0.0	1642.5	0.0	74.2	+140.0	+6.3	C:V411:1
C:V458:1	78.6	1740.4	0.0	1642.5	0.0	74.2	+97.9	+4.4	C:V411:1

Table 2.20: N-1 report in SCOPT¹² (extended OA with IDCF offline model) at 11:50 – per relevant contingency

Zařízení	N-1% ▲	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	107.0	C:HRA:4:...	C:HRA:2:...	500.0	534.9	34.9	325.6	0.0	65.1	+209.3	+41.9	C:V411:1
C:V208:1	95.1	C:MIL:2:W2	C:CST:2:W3	724.0	688.3	0.0	65.0	0.0	9.0	+623.4	+86.1	C:V411:1
D8:ROH:T442	93.2	D8:ROH:4:...	D8:ROH:4:...	1440.0	1341.5	0.0	812.7	0.0	56.4	+528.9	+36.7	C:V445:1
C:CHD:T403	91.9	C:CHD:4:...	C:CHD:1:...	350.0	321.8	0.0	171.0	0.0	48.9	+150.8	+43.1	C:CHD:T401
C:CHD:T401	91.9	C:CHD:4:...	C:CHD:1:...	350.0	321.5	0.0	150.4	0.0	43.0	+171.1	+48.9	C:CHD:T403
C:V445:1	87.6	C:HRD:4:...	D8:ROH:4:...	2225.0	1948.2	0.0	1287.4	0.0	57.9	+660.7	+29.7	C:V446:1
C:HRD:4:nSRW2:1	87.2	C:HRD:4:...	C:HRA:4:...	2837.0	2474.1	0.0	1903.5	0.0	67.1	+570.6	+20.1	C:V052:1
C:V223:1	87.1	C:HRA:2:...	C:VIT:2:W2	1165.0	1014.4	0.0	549.3	0.0	47.2	+465.1	+39.9	C:V411:1
C:VIT:2:nSP:1	87.0	C:VIT:2:W1	C:VIT:2:W2	1165.0	1013.2	0.0	545.7	0.0	46.8	+467.5	+40.1	C:V411:1
C:V411:1	85.6	C:VYS:4:...	C:HRA:4:...	2214.0	1894.7	0.0	1642.5	0.0	74.2	+252.2	+11.4	C:V405:1
C:V446:1	84.9	C:HRD:4:...	D8:ROH:4:...	2225.0	1888.2	0.0	1142.5	0.0	51.3	+745.7	+33.5	C:V445:1
D8:ROH:T441	82.9	D8:ROH:4:...	D8:ROH:4:...	1440.0	1193.5	0.0	875.5	0.0	60.8	+318.0	+22.1	D8:V572:1
C:KRA:4:nKSP:1	80.4	C:KRA:4:W1	C:KRA:4:W2	2000.0	1608.2	0.0	300.8	0.0	15.0	+1307.4	+65.4	C:V411:1
C:HRD:T452	80.2	C:HRD:4:...	C:HRD:4:...	850.0	681.7	0.0	453.6	0.0	53.4	+228.1	+26.8	C:V446:1
C:HRD:T451	80.2	C:HRD:4:...	C:HRD:4:...	850.0	681.7	0.0	453.6	0.0	53.4	+228.1	+26.8	C:V446:1
C:CST:T401	78.0	C:CST:4:W1	C:CST:2:W3	500.0	390.0	0.0	240.3	0.0	48.1	+149.8	+30.0	C:V223:1

Table 2.21: N-1 report in SCOPT (extended OA with IDCF offline model) at 11:50 – per relevant monitored element

Results of N-1 and cascade in SCOPT at 11:50:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to reduce consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » The calculation results using the SCOPT model do not contain any N-1 non-fulfilment and do not indicate any risk of cascade:
 - » Line loaded above 110 %
 - » Transformer loaded above 125 %
 - » Busbar coupler loaded above the tripping current set on the overcurrent protection

12 SCOPT is a ČEPS tool used to calculate N-1, cascade and automatically propose measures in case of non-compliance with N-1. The calculation takes place once every 15 minutes at 5, 20, 35 and 50 minutes in each hour.



11:50 DSA

The online version of the DSA tool, used for real-time operation, calculates all scenarios without applying critical scenario selection every minute based on the real-time model in the control system. Before the V411 outage, the online DSA tool did not detect any violation in dynamic stability (CCT less than 100 ms) at TPP Ledvice unit 6.

Table 2.22 presents the results of the online DSA for the state at 11:50. Each calculation case corresponds to a specific synchronous generator in operation, with a three-phase zero-impedance short circuit applied directly to the line on the side of the respective substation.

Power plant	Generator	CCT (ms)	Line	Substation
EDAL	HG2	129	V438	SLV4
EDAL	HG2	129	V437	SLV4
EDAL	HG2	130	V435	SLV4
EDAL	HG2	130	V436	SLV4
EDAL	HG2	131	V433	SLV4
EDAL	HG4	175	V436	SLV4
EDAL	HG4	175	V435	SLV4
EDAL	HG4	175	V433	SLV4
EDAL	HG4	175	V438	SLV4
EDAL	HG4	175	V437	SLV4
EDAL	HG3	175	V433	SLV4
EDAL	HG3	175	V438	SLV4
EDAL	HG3	175	V437	SLV4
EDAL	HG3	175	V436	SLV4
EDAL	HG3	175	V435	SLV4
EDST	HG2	178	V458	KRA4
EDST	HG2	178	V402	KRA4
ETEM	TG2	178	V475	KOC4
EDUK	TG42	179	V437	SLV4
EDUK	TG42	179	V438	SLV4
EDUK	TG41	179	V437	SLV4
EDUK	TG41	179	V438	SLV4
EDUK	TG22	179	V437	SLV4
EDUK	TG22	179	V438	SLV4
EDUK	TG31	179	V438	SLV4
EDUK	TG31	179	V437	SLV4
EDUK	TG32	179	V438	SLV4
EDUK	TG32	179	V437	SLV4
EDUK	TG12	179	V437	SLV4
EDUK	TG12	179	V438	SLV4
EDUK	TG11	179	V437	SLV4
EDUK	TG11	179	V438	SLV4
EDUK	TG21	179	V438	SLV4
EDUK	TG21	179	V437	SLV4
EDUK	TG31	179	V433	SLV4
EDUK	TG42	180	V435	SLV4
EDUK	TG42	180	V433	SLV4
EDUK	TG42	180	V436	SLV4
EDUK	TG41	180	V435	SLV4
EDUK	TG12	180	V433	SLV4
EDUK	TG41	180	V433	SLV4
EDUK	TG41	180	V436	SLV4
EDUK	TG11	180	V433	SLV4
EDUK	TG31	180	V435	SLV4
EDUK	TG31	180	V436	SLV4

Power plant	Generator	CCT (ms)	Line	Substation
EDUK	TG12	180	V435	SLV4
EDUK	TG12	180	V436	SLV4
EDUK	TG32	180	V435	SLV4
EDUK	TG11	180	V435	SLV4
EDUK	TG32	180	V433	SLV4
EDUK	TG32	180	V436	SLV4
EDUK	TG11	180	V436	SLV4
EDUK	TG21	180	V435	SLV4
EDUK	TG21	180	V436	SLV4
EDUK	TG21	180	V433	SLV4
EDUK	TG22	180	V435	SLV4
EDUK	TG22	180	V436	SLV4
EDUK	TG22	180	V433	SLV4
EDST	HG2	181	V401	KRA4
ETEM	TG2	187	V473	KOC4
ETEM	TG2	188	V474	KOC4
ELED	TG6	251	V480	CHT4
EPR2	TG23	285	V446	HRA4
EPR2	TG23	286	V412	HRA4
EPR2	TG23	287	V430	HRA4
EPR2	TG23	287	V461	HRA4
EPR2	TG23	288	V411	HRA4
EPR2	TG23	288	V420	HRA4
EPR2	TG25	331	V411	HRA4
ECHV	TG4	331	V400	TYN4
EPOC	TG6	332	V480	VYS4
EPR2	TG25	332	V412	HRA4
EPR2	TG25	332	V430	HRA4
EPOC	TG2	332	V480	VYS4
EPR2	TG25	332	V420	HRA4
EPR2	TG25	332	V461	HRA4
EPR2	TG25	332	V446	HRA4
EPOC	TG2	332	V411	VYS4
EPOC	TG6	333	V428	VYS4
EPOC	TG6	333	V450	VYS4
EPOC	TG6	333	V419	VYS4
EPOC	TG6	333	V410	VYS4
EPOC	TG2	333	V450	VYS4
EPOC	TG2	333	V428	VYS4
EPOC	TG6	333	V411	VYS4
EPOC	TG2	333	V419	VYS4
EPOC	TG2	333	V410	VYS4
ECHV	TG4	379	V401	TYN4
EPR2	TG25	600	V445	HRD4
EPR2	TG23	600	V445	HRD4

Table 2.22: Results of the online DSA for the state at 11:50



Tables 2.23 and 2.24 present the N-1 report from the ČEPS control system at 11:51, 25 s before the outage of line V411.

Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V411:1	110.6	553.2	53.2	331.2	0.0	66.2	+222.0	+44.4	C:HRA:T402
C:V445:1	95.9	1380.9	0.0	824.8	0.0	57.3	+556.1	+38.6	D8:ROH:T442
C:CST:T401	93.1	465.7	0.0	331.2	0.0	66.2	+134.6	+26.9	C:HRA:T402
C:CHD:T401	90.3	315.9	0.0	167.7	0.0	47.9	+148.2	+42.3	C:CHD:T403
C:CHD:T403	90.2	315.7	0.0	147.9	0.0	42.2	+167.8	+48.0	C:CHD:T401
C:V446:1	90.0	2003.4	0.0	1308.8	0.0	58.8	+694.6	+31.2	C:V445:1
C:V052:1	88.4	2507.3	0.0	1977.4	0.0	69.7	+529.9	+18.7	C:HRD:4:nSR...
C:V405:1	87.4	1935.8	0.0	1699.7	0.0	76.8	+236.1	+10.7	C:V411:1
C:V420:1	86.9	1923.1	0.0	1699.7	0.0	76.8	+223.4	+10.1	C:V411:1
C:HRA:T402	86.8	1921.4	0.0	1699.7	0.0	76.8	+221.7	+10.0	C:V411:1
C:V433:1	86.1	1906.9	0.0	1699.7	0.0	76.8	+207.2	+9.4	C:V411:1
C:V223:1	85.5	1893.9	0.0	1699.7	0.0	76.8	+194.2	+8.8	C:V411:1
C:V459:1	82.8	1832.2	0.0	1699.7	0.0	76.8	+132.5	+6.0	C:V411:1
D8:V572:1	82.1	1181.8	0.0	863.6	0.0	60.0	+318.2	+22.1	D8:ROH:T441
C:V480:1	81.9	1812.8	0.0	1699.7	0.0	76.8	+113.1	+5.1	C:V411:1
C:V417:1	81.1	1796.5	0.0	1699.7	0.0	76.8	+96.8	+4.4	C:V411:1
C:V458:1	80.6	1783.7	0.0	1699.7	0.0	76.8	+84.0	+3.8	C:V411:1
C:V443:1	80.5	1783.3	0.0	1699.7	0.0	76.8	+83.6	+3.8	C:V411:1
C:V402:1	80.0	1772.1	0.0	1699.7	0.0	76.8	+72.4	+3.3	C:V411:1
C:V412:1	80.0	1771.2	0.0	1699.7	0.0	76.8	+71.6	+3.2	C:V411:1
C:V221:1	79.8	1766.8	0.0	1699.7	0.0	76.8	+67.1	+3.0	C:V411:1

Table 2.23: N-1 report from ČEPS control system at 11:51 – per relevant contingency

Zařízení	N-1% ▲	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
C:HRA:T402	110.6	C:HRA:4:...	C:HRA:2:...	500.0	553.2	53.2	331.2	0.0	66.2	+222.0	+44.4	C:V411:1
C:V208:1	98.2	C:MIL:2:W...	C:CST:2:W3	724.0	710.9	0.0	90.0	0.0	12.4	+620.9	+85.8	C:V411:1
D8:ROH:T442	95.9	D8:ROH:4:...	D8:ROH:4:...	1440.0	1380.9	0.0	824.8	0.0	57.3	+556.1	+38.6	C:V445:1
C:CHD:T403	90.3	C:CHD:4:...	C:CHD:1:...	350.0	315.9	0.0	167.7	0.0	47.9	+148.2	+42.3	C:CHD:T401
C:CHD:T401	90.2	C:CHD:4:...	C:CHD:1:...	350.0	315.7	0.0	147.9	0.0	42.2	+167.8	+48.0	C:CHD:T403
C:V445:1	90.0	C:HRD:4:...	D8:ROH:4:...	2225.0	2003.4	0.0	1308.8	0.0	58.8	+694.6	+31.2	C:V446:1
C:V223:1	88.9	C:HRA:2:...	C:VIT:2:W...	1165.0	1035.2	0.0	557.1	0.0	47.8	+478.1	+41.0	C:V411:1
C:VIT:2:nSP:1	88.8	C:VIT:2:W...	C:VIT:2:W...	1165.0	1034.2	0.0	552.5	0.0	47.4	+481.7	+41.4	C:V411:1
C:HRD:4:nSRW2:1	88.4	C:HRA:4:...	C:HRA:4:...	2837.0	2507.3	0.0	1977.4	0.0	69.7	+529.9	+18.7	C:V052:1
C:V411:1	87.4	C:VYS:4:...	C:HRA:4:...	2214.0	1935.8	0.0	1699.7	0.0	76.8	+236.1	+10.7	C:V405:1
C:V446:1	87.3	C:HRA:4:...	D8:ROH:4:...	2225.0	1942.3	0.0	1159.3	0.0	52.1	+783.0	+35.2	C:V445:1
C:HRD:T452	82.4	C:HRA:4:...	C:HRD:4:...	850.0	700.7	0.0	460.7	0.0	54.2	+240.0	+28.2	C:V446:1
C:HRD:T451	82.4	C:HRA:4:...	C:HRD:4:...	850.0	700.7	0.0	460.7	0.0	54.2	+240.0	+28.2	C:V446:1
D8:ROH:T441	82.1	D8:ROH:4:...	D8:ROH:4:...	1440.0	1181.8	0.0	863.6	0.0	60.0	+318.2	+22.1	D8:V572:1
C:KRA:4:nKSP:1	81.8	C:KRA:4:...	C:KRA:4:...	2000.0	1636.5	0.0	288.7	0.0	14.4	+1347.8	+67.4	C:V411:1
C:CST:T401	79.8	C:CST:4:...	C:CST:2:W3	500.0	399.2	0.0	249.6	0.0	49.9	+149.6	+29.9	C:V223:1

Table 2.24: N-1 report from ČEPS control system at 11:51 – per relevant monitored element

Results of N-1 at 11:51:

- » The C:HRA:T402 transformer is overloadable. The solution for the case of N-1 non-fulfilment is to coordinate with the distribution company to relieve consumption at the 220 kV level (e.g. in the area of c:VIT:T402) and switch off the C:CHT:T202 transformer.
- » Immediately before the V411 outage, the N-1 criterion is met: V411/V208 98.2 %, V411/HRA:T402 110.6 %.¹³

¹³ Due to the overloadability of HRA:T402 120 %/3 h, the N-1 criterion is met, and corrective action would be taken only after the V411 outage using the overload capacity time of 3 h.



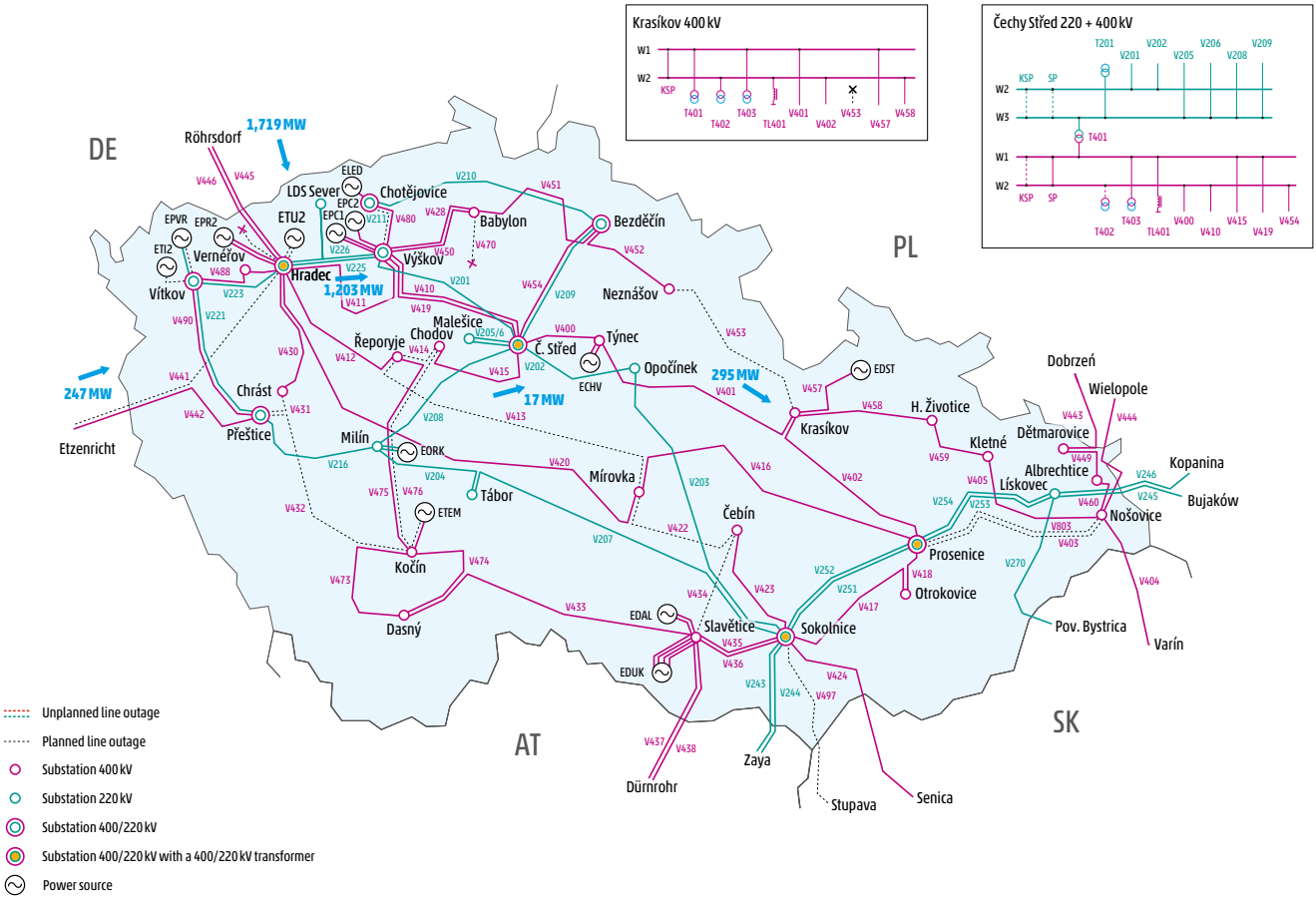


Figure 2.3: Situation of the Czech Republic transmission system on 4 July 2025 at 11:51

	V411/Výškov	V208/Č. Střed	V401/Krasíkov
P [MW]	1,203	17	295
Q [MVar]	-181	32	2
I [A]	1,680	90	392

Table 2.25: Power flow on lines feeding the affected area at 11:51

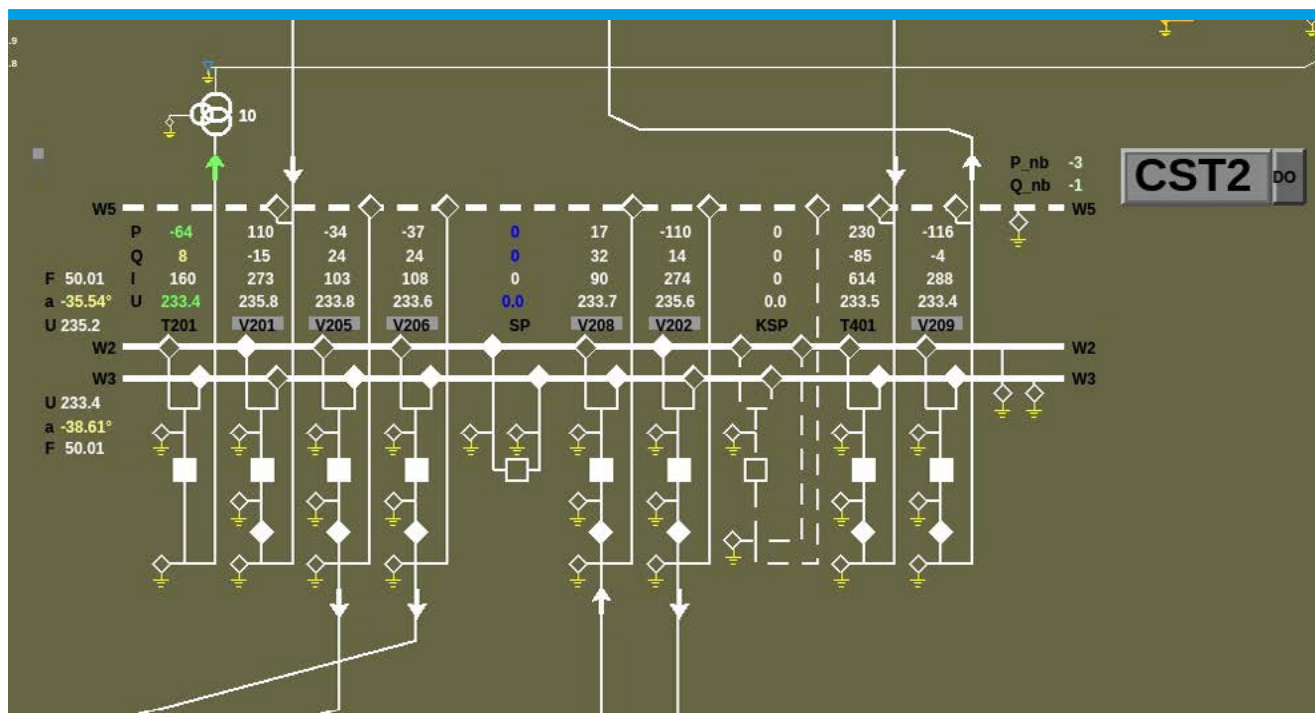


Figure 2.4: Scheme of the Čechy Štřed 220 kV substation at 11:51

Implemented reconfiguration:

- » Busbar W2 – V201, V202
- » Busbar W3 – T201CST, V205, V206, V208, V209, T401



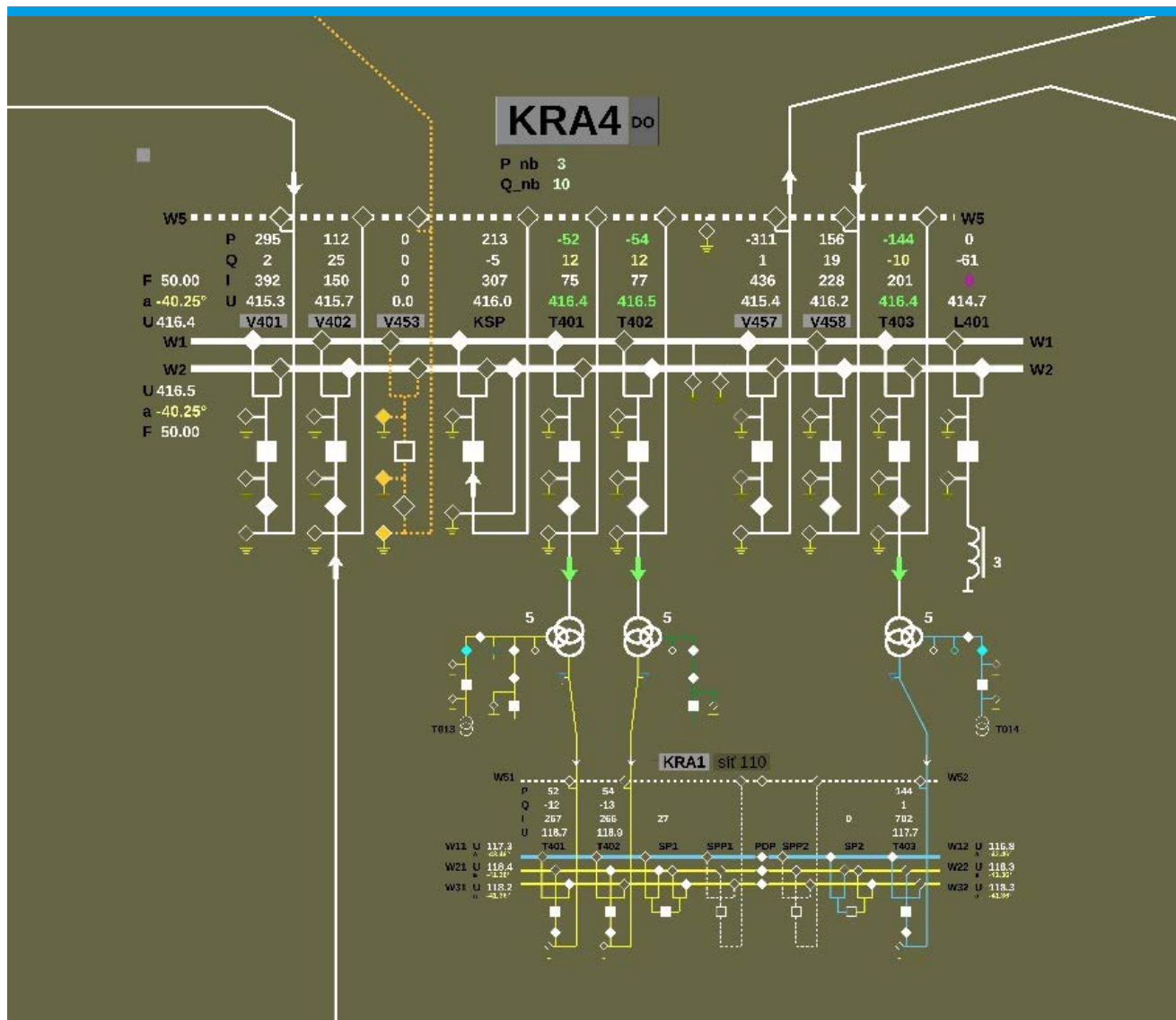


Figure 2.5: Scheme of Krasíkov 400 kV substation at 11:51

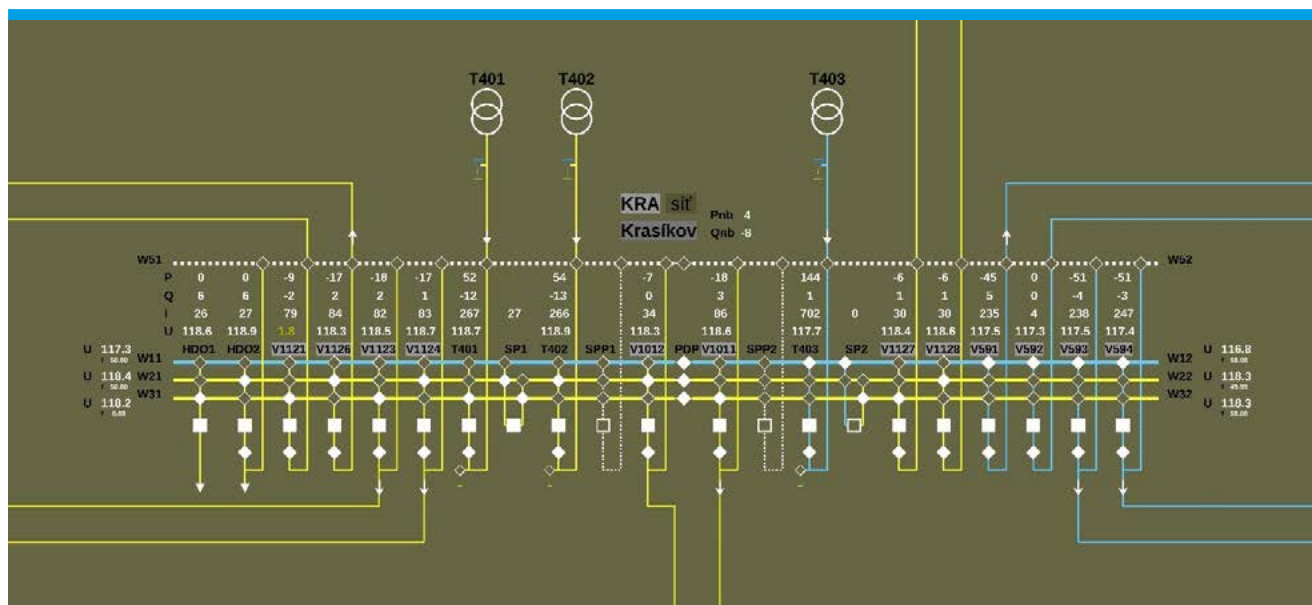
The Krasíkov 400 kV substation was not included in the basic connection due to the combination of the following reasons:

- » The ongoing investment project for line V453
- » Readiness of line V402 or V458 to switch off thus reduce voltage
- » Security of supply, i.e. having at least one incoming line (V401, V402, V458) and a transformer on each busbar
- » Minimising active power flow on the busbar coupler

Therefore, the dispatchers operated the substation in the following connection:

- » Busbar W1 – V401, T401, V457, T403, KSP
- » Busbar W2 – V402, T402, V458, L401, KSP

In this connection, the substation was prepared to switch off the V402 or V458 lines due to high voltage when the EDST was not in operation. Even after switching one of the lines, each busbar would be supplied by one incoming line and prepared for fast re-energisation in case one of the busbars is lost (e.g. due to short-circuit).



The T401KRA and T402KRA transformers and the 110 kV distribution area operated in parallel connection. The busbar coupler SP1 at the Krasíkov 110 kV substation was switched on and supplying the ČEZd Východ area, while T403KRA was in single operation and supplying the ČEZd Morava area.

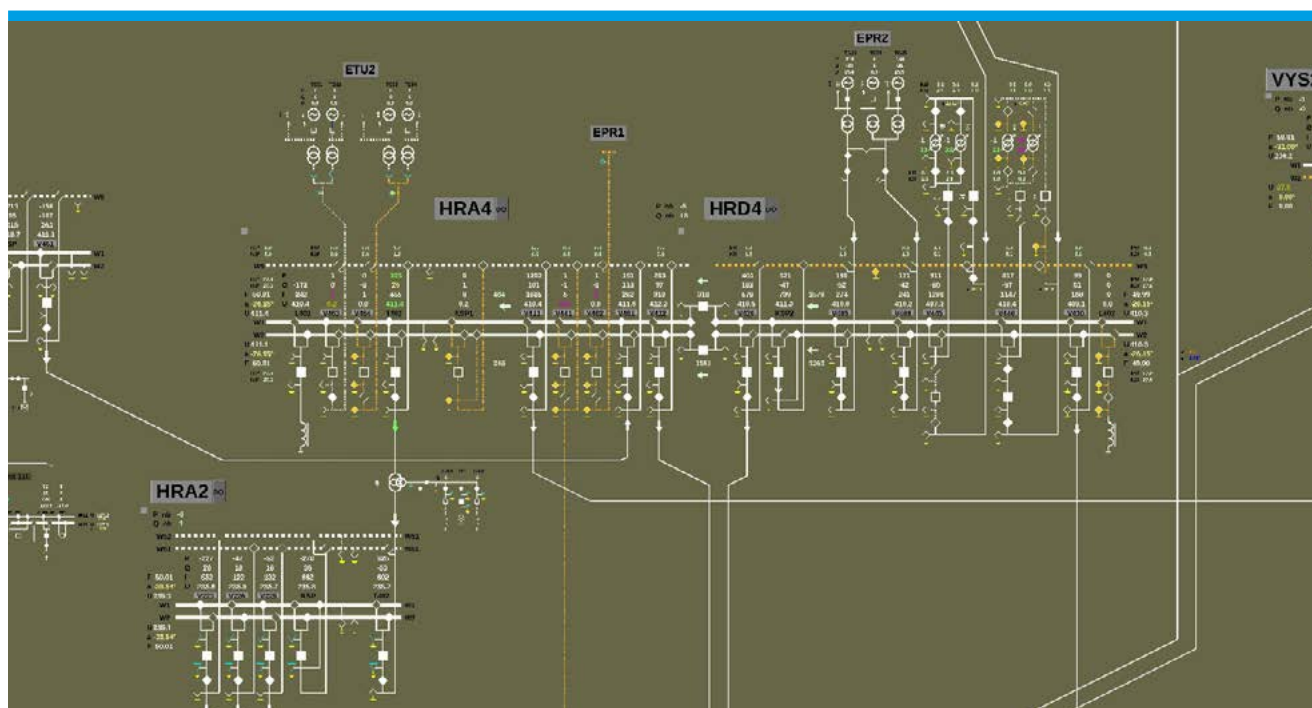


Figure 2.7: Scheme of 400 kV Hradec substation at 11:51

Since many elements of the Hradec 400 kV substation were switched off, the connection of the Hradec substation was modified from the basic configuration. The substation Hradec 220 kV was in the basic connection without direct impact on the incident. Lines V225

and V226 between Hradec and Vyskov (seen in the maps across this report) are only connected to the 400 kV level in one of the two substations (Hradec).

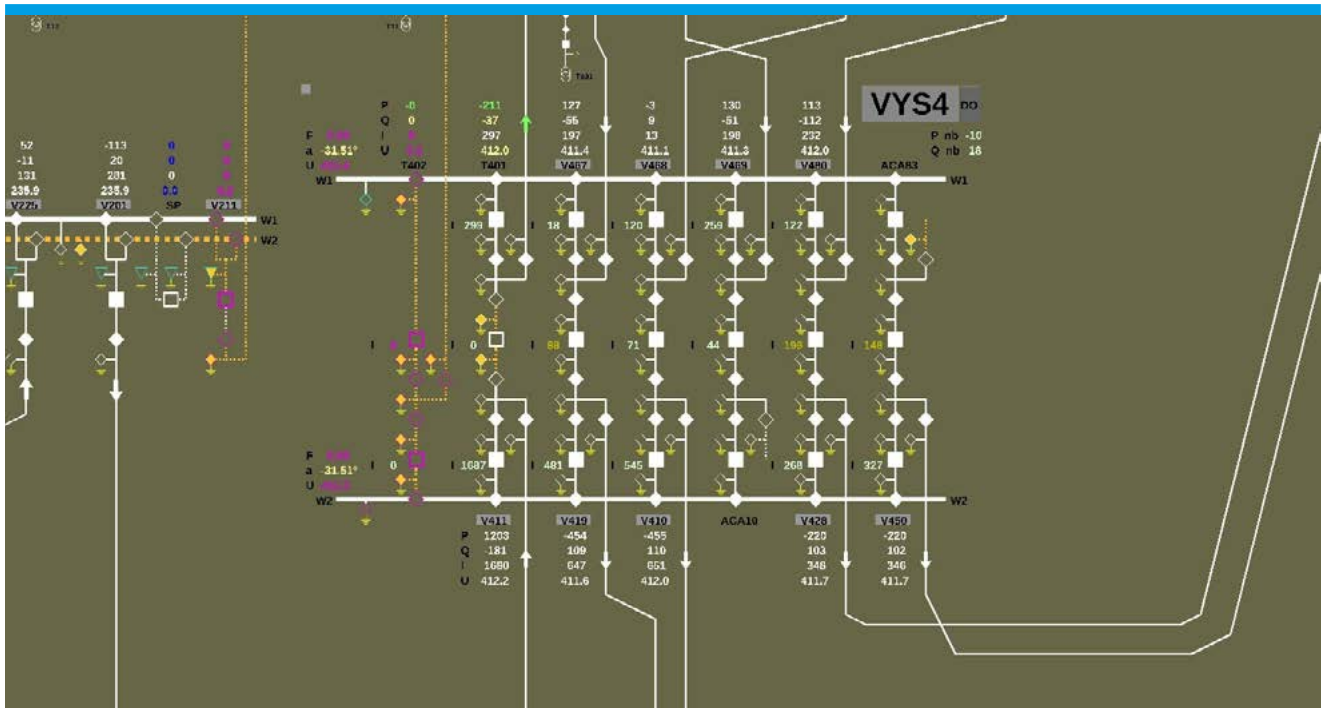


Figure 2.8: Scheme of 400 kV Výškov substation

Except for the T402VYS transformer that was switched off for replacement, the 400 kV Výškov substation was in basic connection.

2.1.6 Unplanned outages

There were no unplanned outages in the ČEPS grid before the event on 4 July 2025.



2.2 Weather conditions

The weather on 4 July 2025 in the Czech Republic was partly clear to cloudy, with showers in places. Daytime temperatures ranged from 23 to 27 °C and nighttime temperatures from 14 to 18 °C, with south-westerly winds of 2 to 6 m/s.

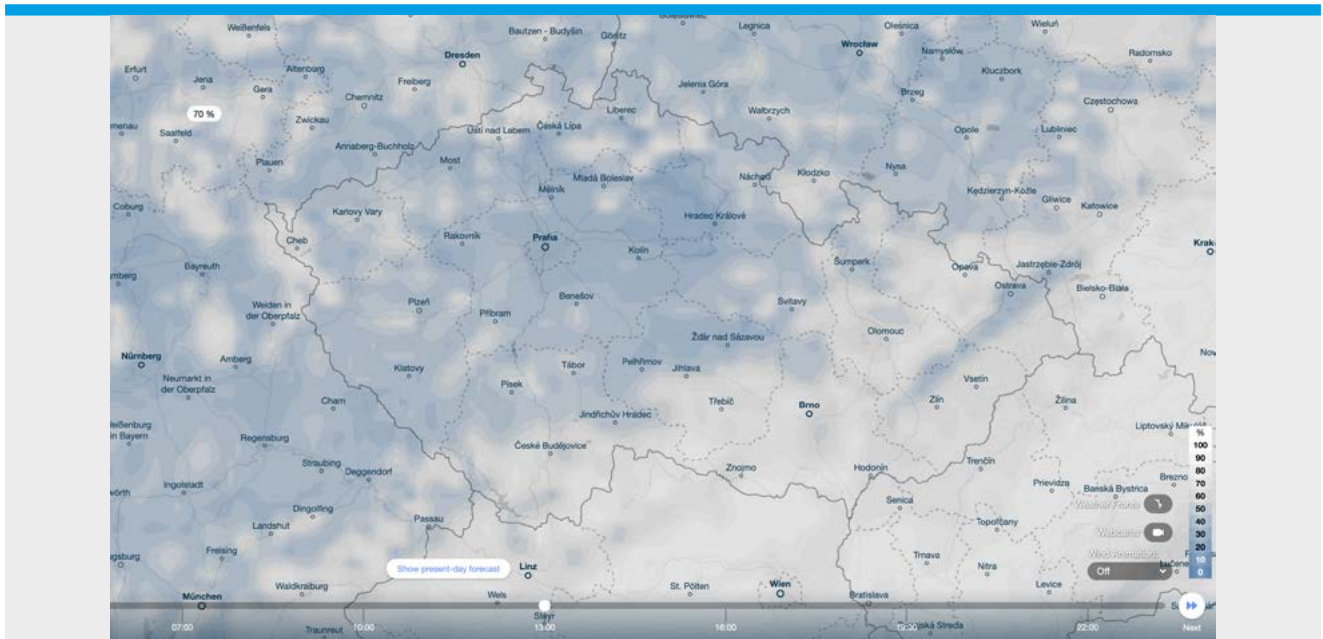


Figure 2.9: Cloudiness in the Czech Republic on 4 July 2025 (source: <https://www.ventusky.com>)

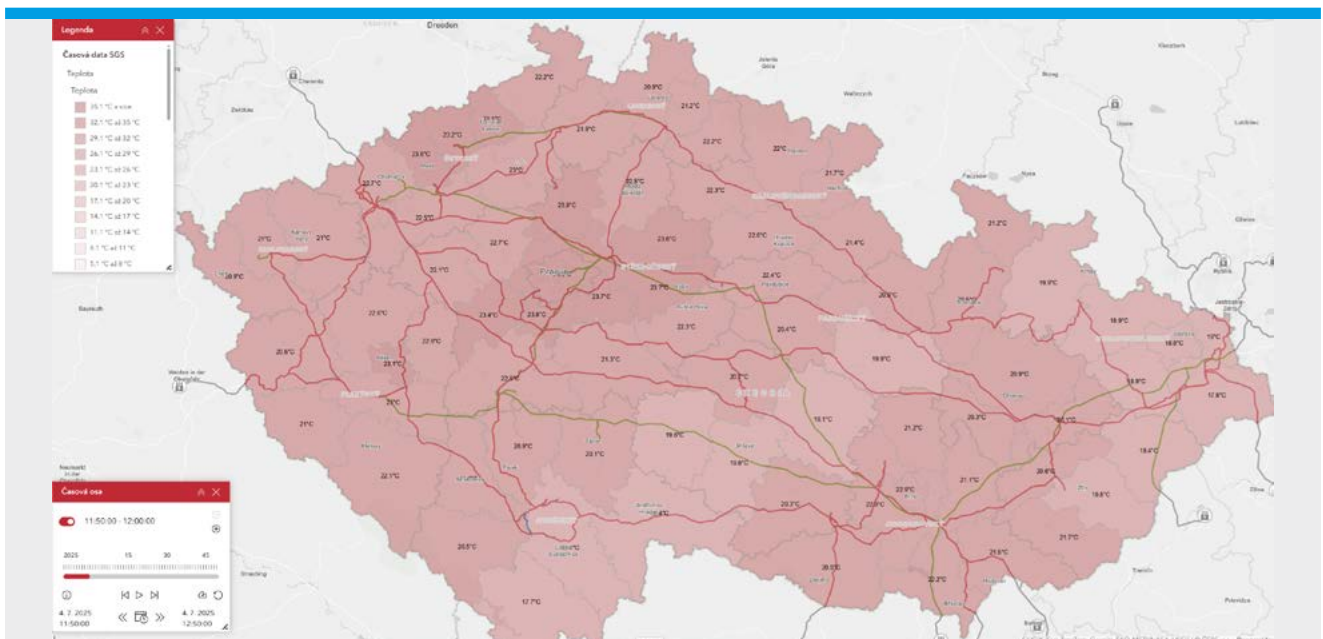


Figure 2.10: Temperature in the Czech Republic on 4 July 2025 (source: SGS ČEPS)



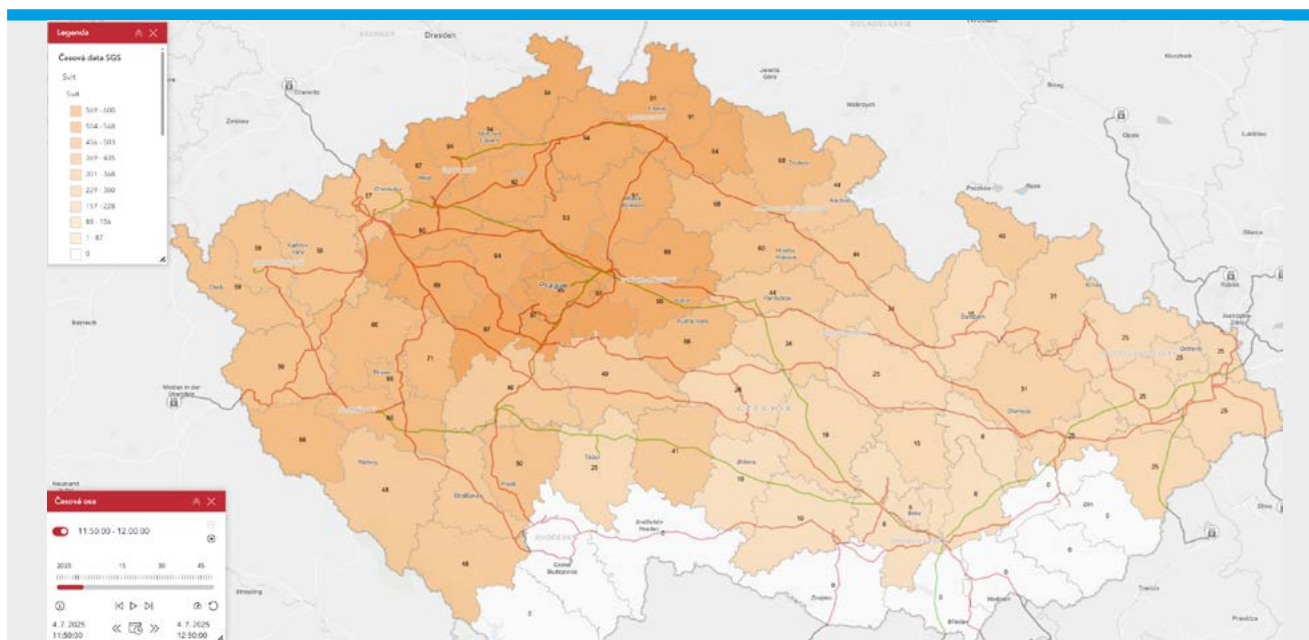


Figure 2.11: Sunshine in the Czech Republic on 4 July 2025 (source: SGS ČEPS)

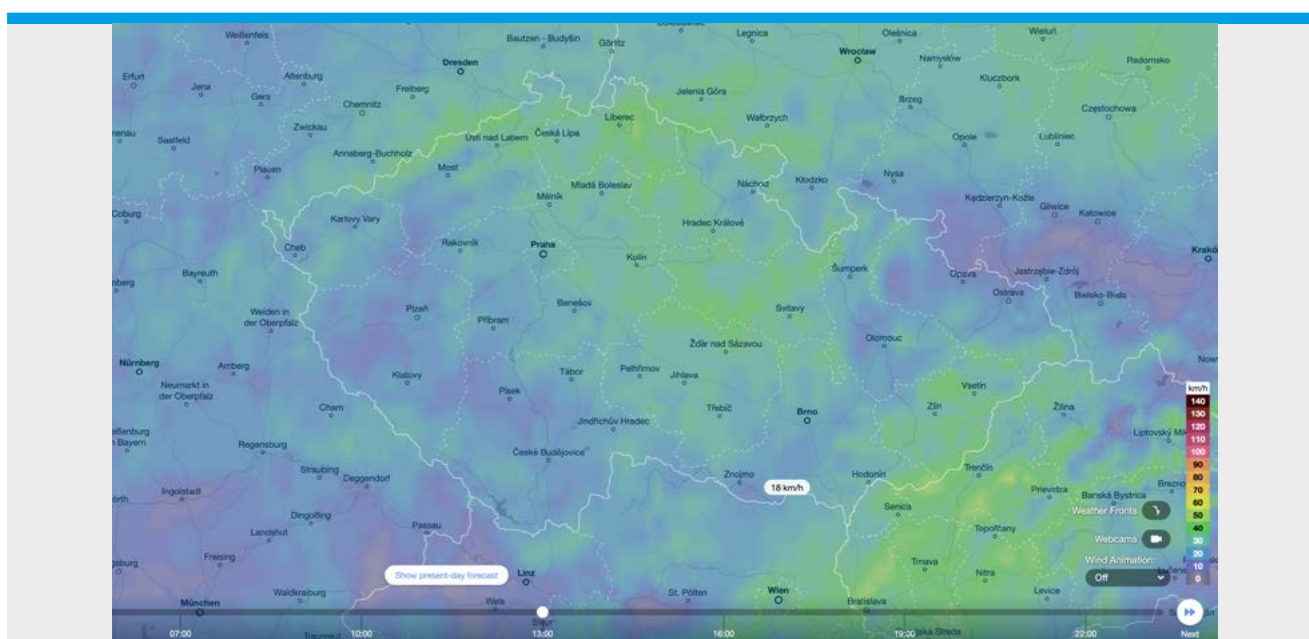


Figure 2.12: Wind gusts in the Czech Republic on 4 July 2025 (source: <https://www.ventusky.com>)

The weather in the Czech Republic had no impact on the failure of the overhead line V411.

2.3 Market situation

The average DA price in the Czech Republic on 4 July 2025 was 98.22 €/MWh, 6.8 % higher than the average price in July 2025 (91.88 €/MWh).

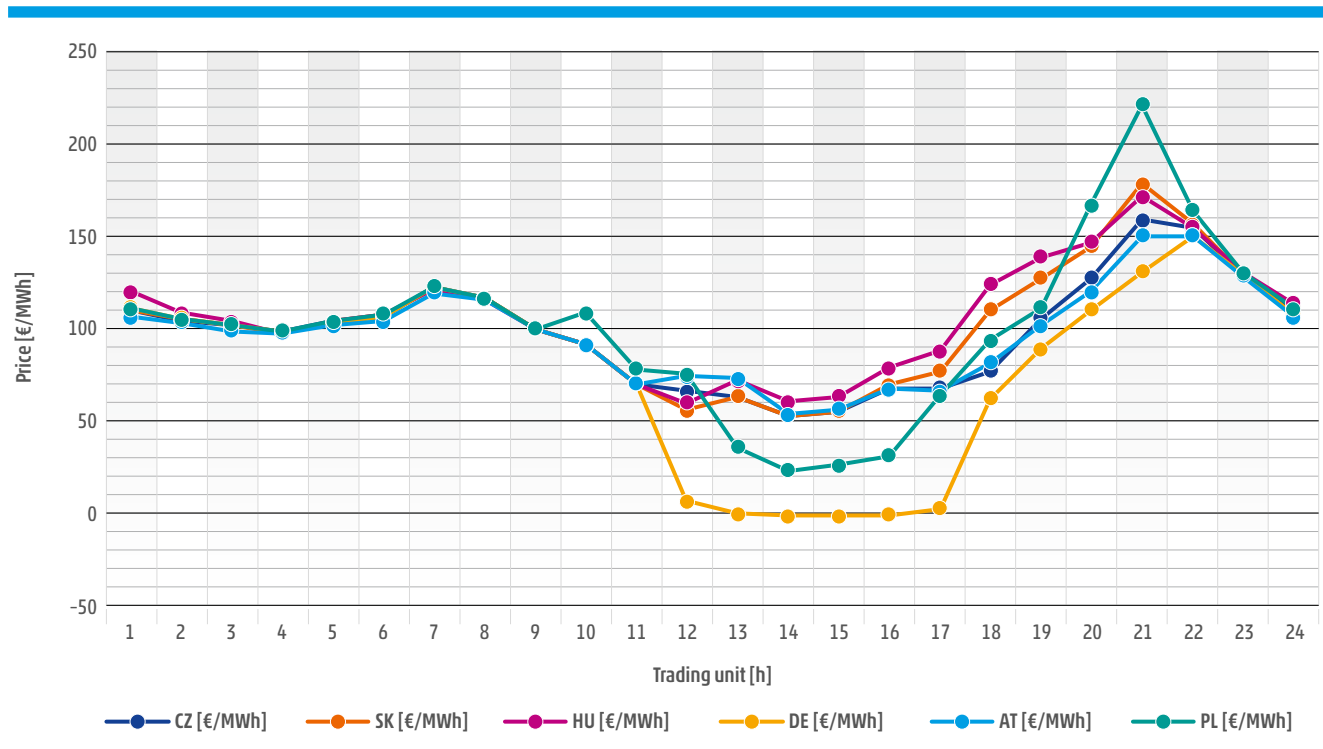


Figure 2.13: Flow-based day-ahead market coupling

The Czech electricity market operated under stable and predictable conditions throughout the day, with price movements largely reflecting regional dynamics within the coupled market. The average price of 98.22 €/MWh positioned the Czech market slightly below the regional mean, indicating a balanced supply-demand situation.

During the early afternoon, prices dipped to a daily low of 52.71 €/MWh, coinciding with similar downward trends in neighbouring countries. In the evening, prices surged to a peak of 158.84 €/MWh, reflecting increased consumption during post-working hours.

This peak was part of a broader regional trend, indicating synchronised demand patterns and potential transmission constraints or limited generation flexibility across Central and Eastern Europe.

From a system operation perspective, the day can be classified as operationally standard, with no significant disruptions, imbalances or market failures. The Czech market responded effectively to regional price signals and maintained alignment with neighbouring markets.



2.3.1 Load patterns

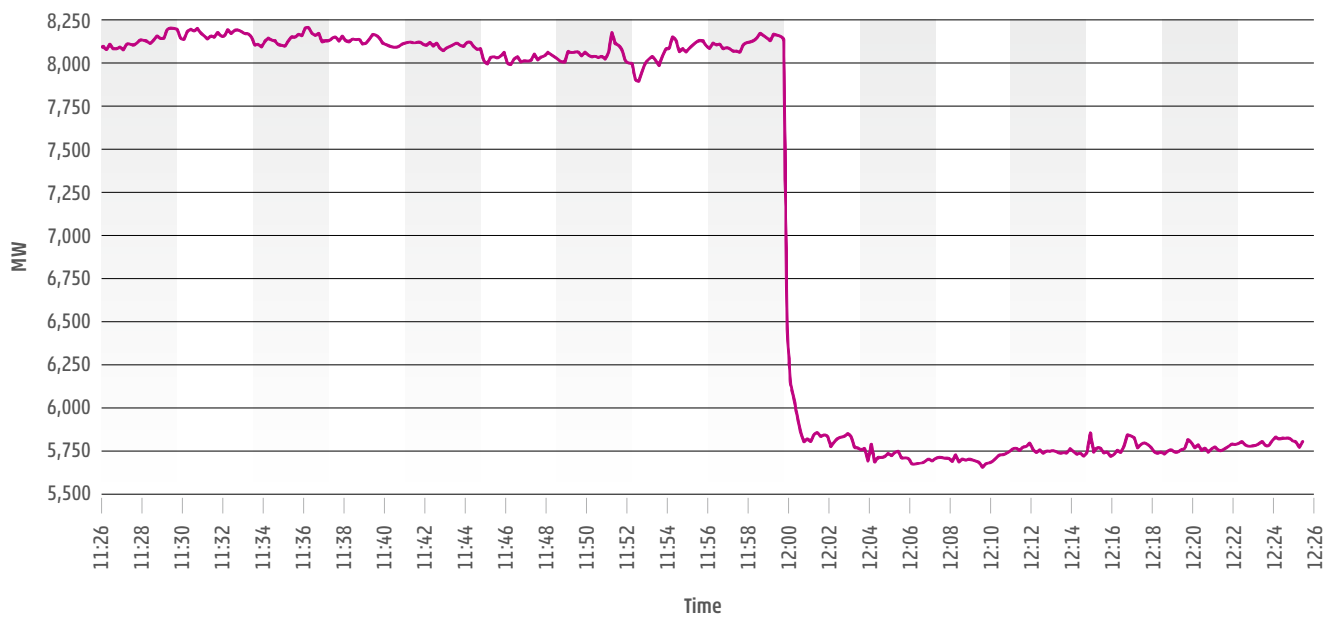


Figure 2.14: Load pattern in the Czech Republic on 4 July 2025

Before switching off the overhead line V411 at 11:51:07, the load on the electricity grid in the Czech Republic was approximately 8,200 MW.

The load value in Figure 2.18 is calculated based on the production and balance values. Most production is metered; for renewable sources, approximately one-third is measured, and two-thirds are calculated based on location and metered renewables. This unmeasured part of production can introduce an error into the load value.



2.3.2 Production patterns

Figure 2.15 shows that the total generation at 11:51 was 7,150 MW. The largest share of production came from NPPs at approximately 3,077 MW, photovoltaic (PV) power plants at approximately 1,973 MW, and TTPs at approximately 1,815 MW.

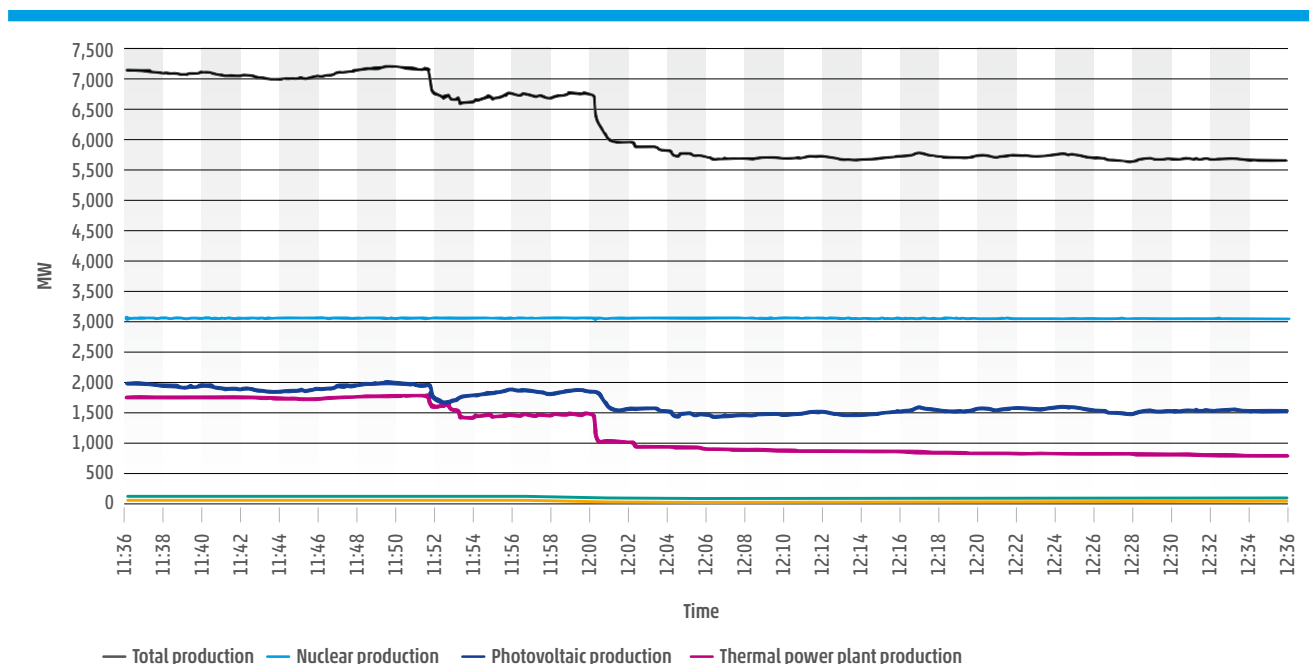


Figure 2.15: Production pattern in the Czech Republic on 4 July 2025

Figure 2.16 shows the voltage in all 400 kV substations in the Czech Republic between 11:51 and 00:00. The voltage in the affected area was within limits.

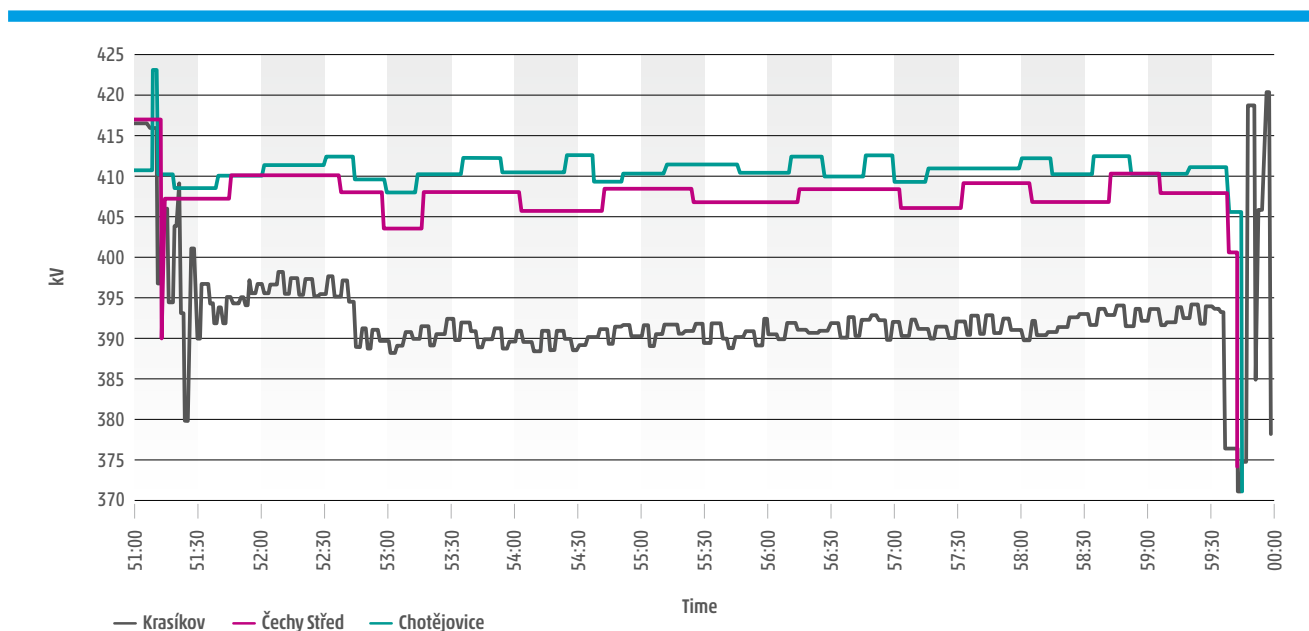


Figure 2.16: Voltage in 400 kV substations between 11:51 and 00:00 in the Czech Republic on 4 July 2025



2.3.3 Cross-border flows: scheduled commercial and physical flows

The following figures show the real and scheduled flows on the borders with neighbouring TSOs, as well as the real and scheduled balance. Before the fault on line V411, the Czech Republic was importing around 1,600 MW (scheduled 1,524 MW). There can be significant differences between market and real flows at the border because ČEPS is located in the middle of the interconnected continental European zone, and loop flows influence real flows.

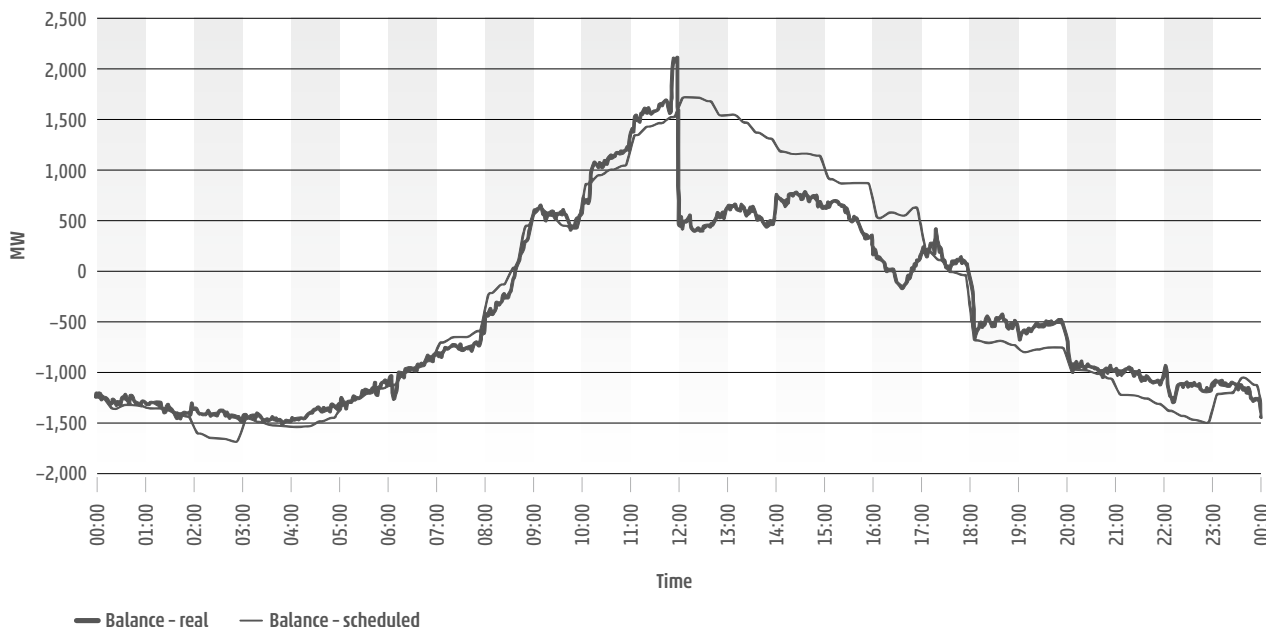


Figure 2.17: Real and scheduled balance in the Czech Republic on 4 July 2025

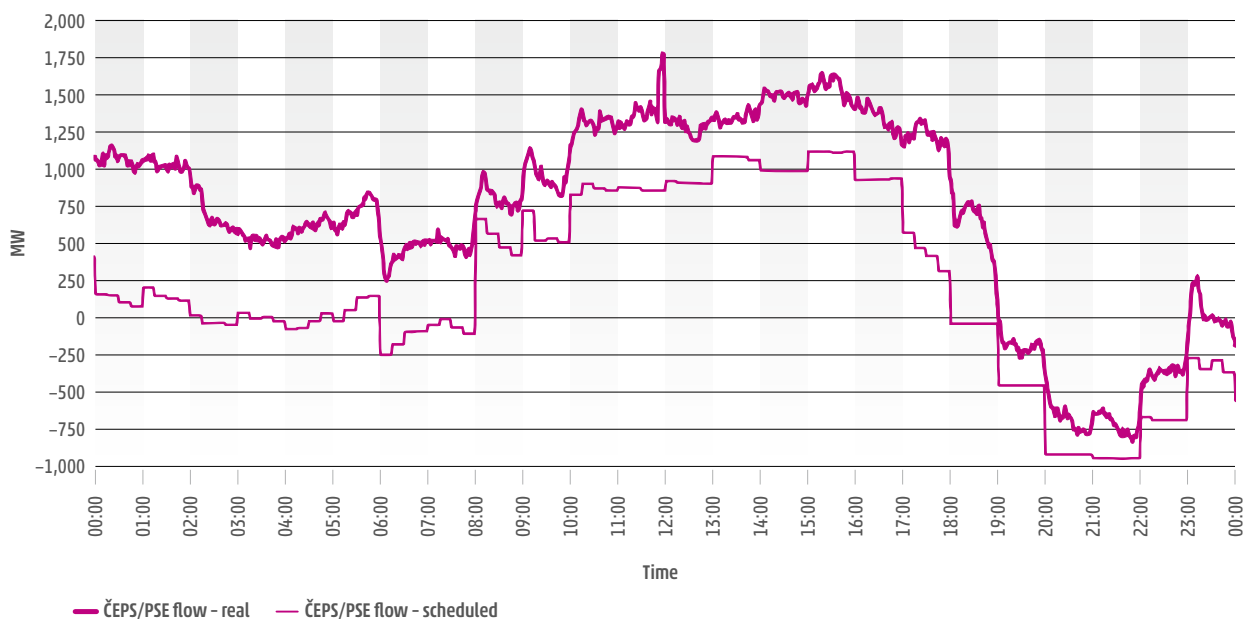


Figure 2.18: Real and scheduled flow between ČEPS and PSE on 4 July 2025



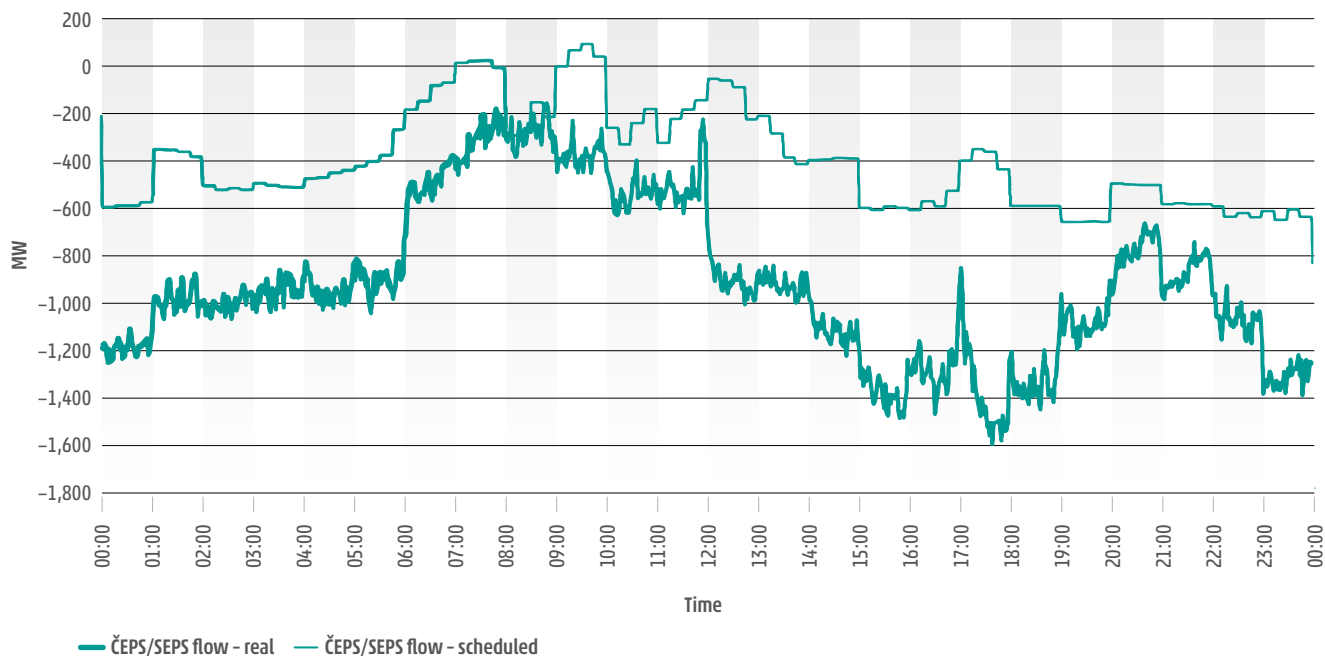


Figure 2.19: Real and scheduled flow between ČEPS and SEPS on 4 July 2025

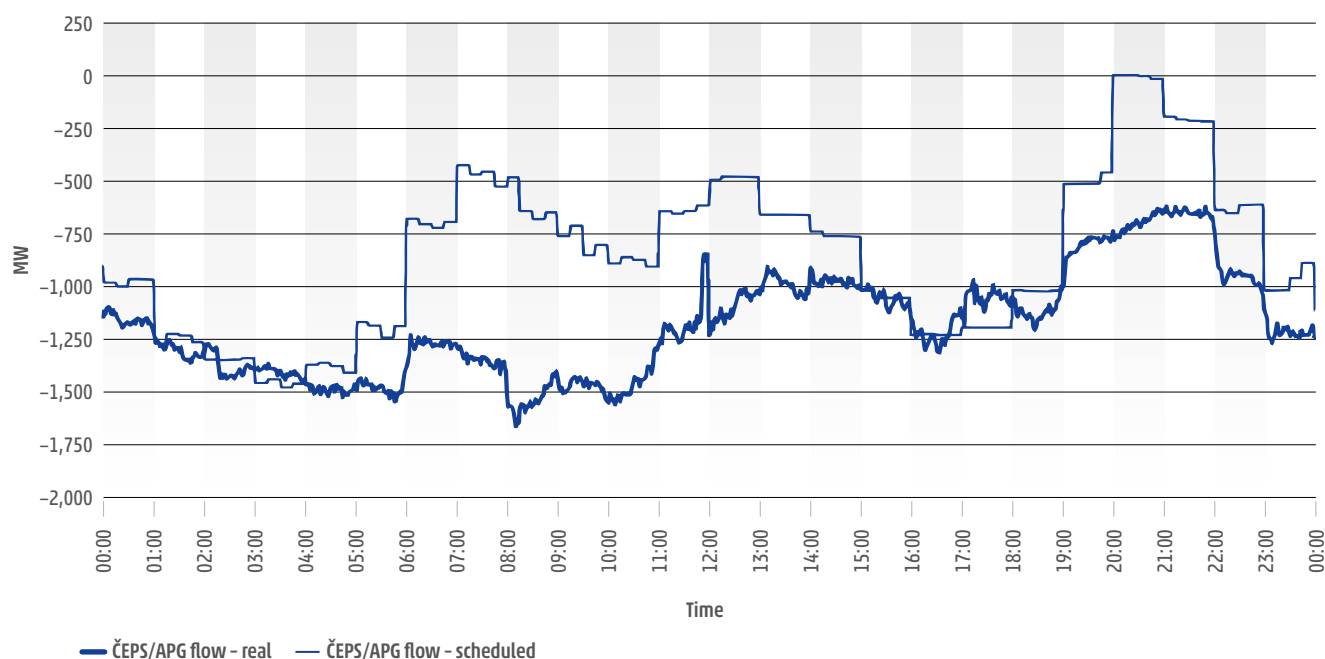


Figure 2.20: Real and scheduled flow between ČEPS and APG on 4 July 2025



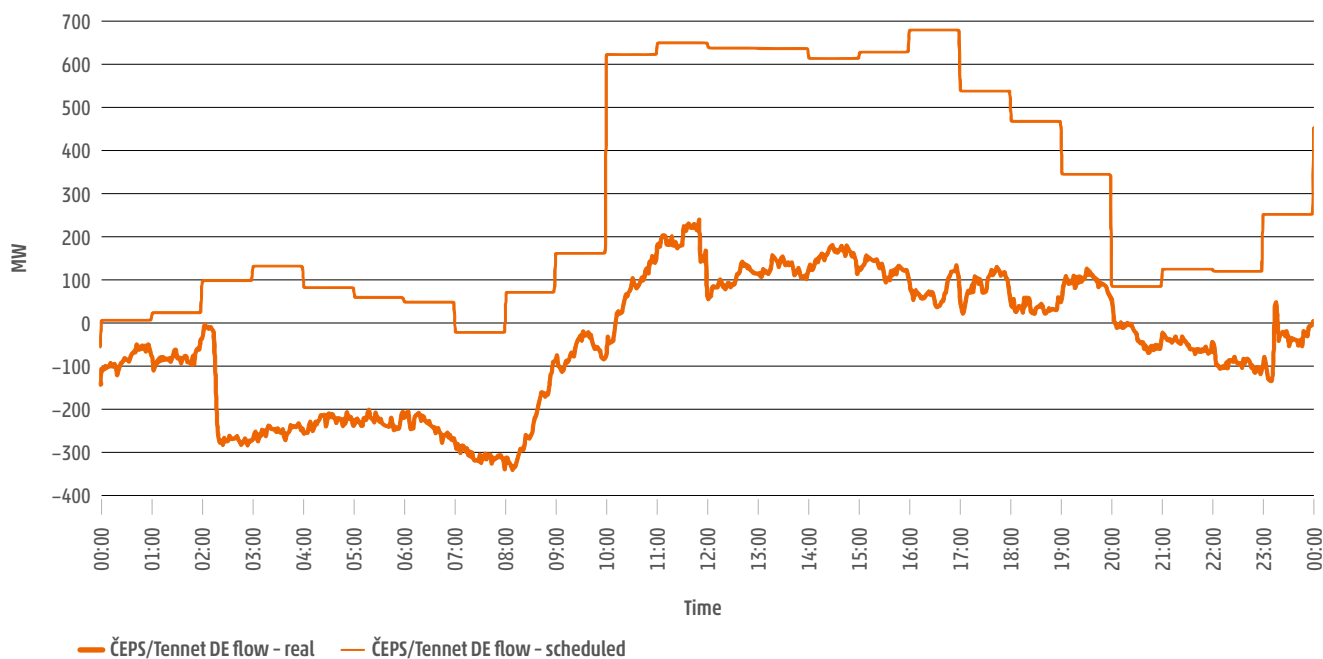


Figure 2.21: Real and scheduled flow between ČEPS and Tennet DE on 4 July 2025

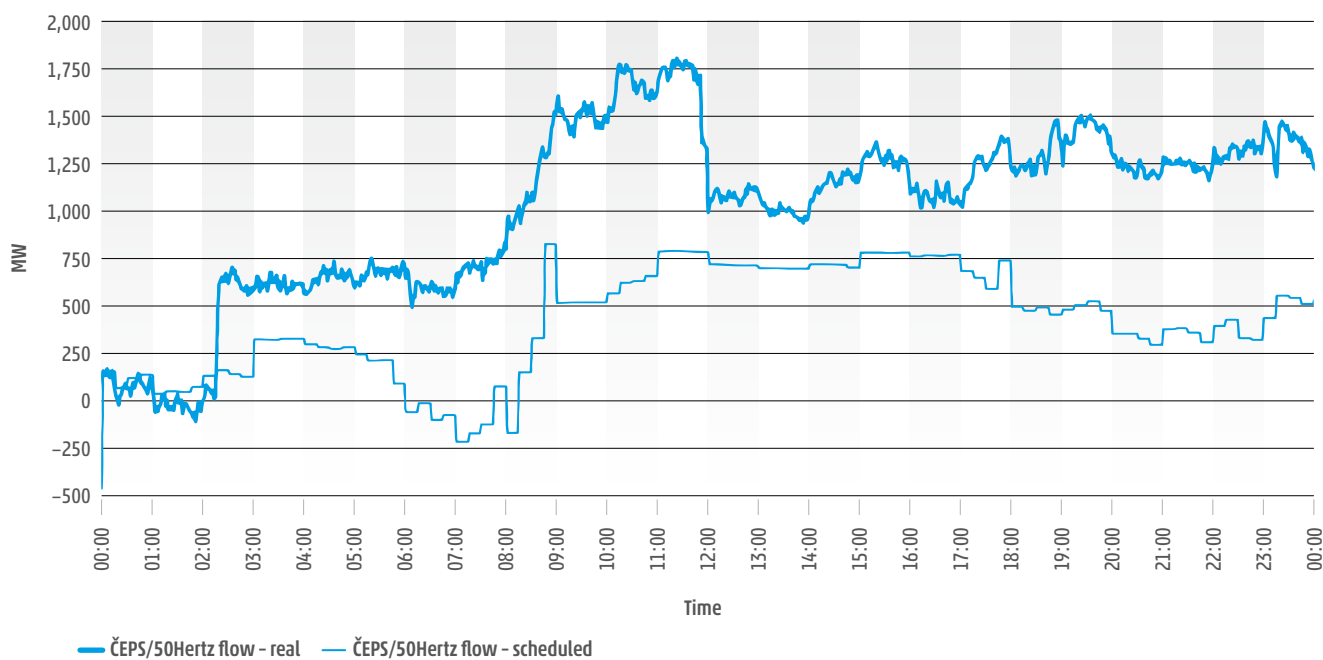


Figure 2.22: Real and scheduled flow between ČEPS and 50Hertz on 4 July 2025

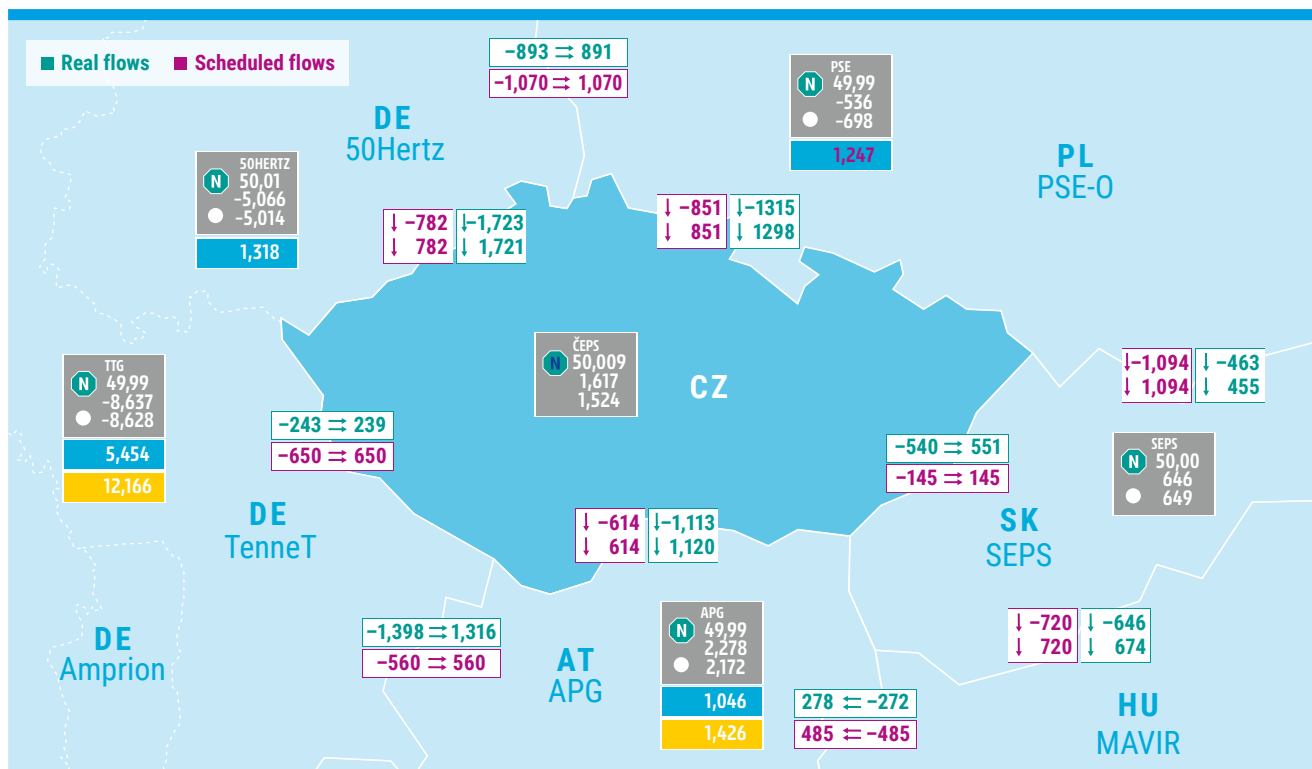
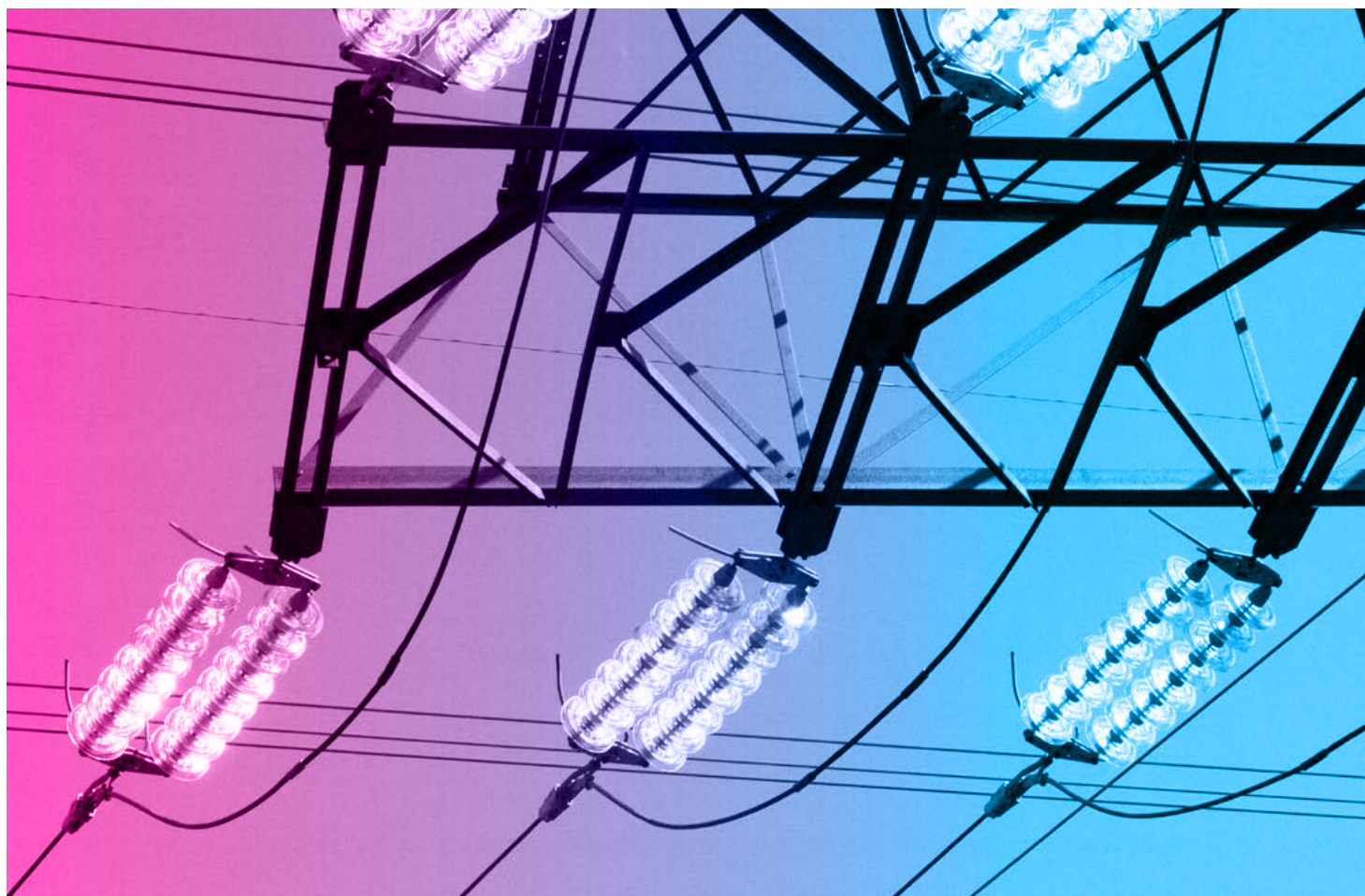


Figure 2.23: Power balance situation in the region on 4 July 2025 at 11:51



3 EVOLUTION OF SYSTEM CONDITIONS DURING THE EVENT

3.1 Factual sequence of events

- » **11:51:06:187** – Line V411 fault detected in phase L2 by distance protections.
 - » **11:51:07.559** – Following the unsuccessful automatic reclosing attempt in phase 2, circuit breakers of line V411 at the VYS4 and HRA4 substations were tripped in all phases.
 - » **11:51:08** – Ledvice unit power plant 6 transitioned from standard power control mode to IO mode (droop speed control mode) based on a locally recorded frequency (speed) deviation exceeding 200 mHz.¹⁴
 - » **11:51:11** – Ledvice power plant unit 4 transitioned from standard power control mode to IO mode (droop speed control mode) based on a locally recorded frequency (speed) deviation exceeding 200 mHz.
 - » **11:51:12** – Počerady power plant units 2 and 6 transitioned from standard power control mode to IO mode (droop speed control mode) based on a locally recorded frequency (speed) deviation exceeding 200 mHz.
 - » **11:51:46** – Ledvice power plant unit 6¹⁵ boiler outage caused by steam temperature behind the high-pressure bypass stations (according to the information provided by the power plant owner) and began losing its remaining active power.
- Summary of operational parameters at this time**
- » The failure of line V411, the immediate reduction in production in both the transmission and distribution systems, and the resulting overload of line V208 and other elements led to an emergency state, according to Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SOGL).
 - » The current on line V208 exceeded 900 A, which is the measurement range of the current converters at the Čechy Střed and Milín 220 kV substations. ($I_{\max} = 724 \text{ A}$ according to dynamic rating).
 - » Line V223 current was 1,180 A ($I_{\max} = 1,165 \text{ A}$ according to dynamic rating).
 - » The busbar coupler at the Vítkov 220 kV substation had a current of 1,195 A ($I_{\max} = 1,165 \text{ A}$).
 - » The busbar coupler at the Krasíkov 400 kV substation had a current of 2,100 A ($I_{\max} = 2,000 \text{ A}$; $I_{\text{trip}} = 2,880 \text{ A}$).
- » 11:52 N-1 report from the ČEPS control system (list below is not complete)
- » Due to immediate production outages in both the transmission and distribution grid (between 340–440 MW)
 - Identified in the transmission system: 127 MW
 - Identified in the distribution system (so far): 160 MW
 - » There were overloaded elements even in N-0:
 - 220 kV line V208: 126.1 % (912 A estimated value)
 - Autotransformer T402 at the 400 kV Hradec substation: 119.3 % (within transitory admissible overloading limits)
 - Busbar coupler at the Krasíkov 400 kV substation: 105.1 %
- Accordingly, at this stage, the grid was not secure even in the absence of an additional N-1 contingency.

¹⁴ Refers to the frequency deviation from the nominal value of 50 Hz. This setting is applied to all units that provide IO capability service.

¹⁵ This unit is certified for providing non-frequency ancillary service IO capability.



Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V401:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V400:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V402:1	209.6	1517.7	793.7	912.8	188.8	126.1	+604.9	+83.6	C:V208:1
C:V405:1	199.8	1446.4	722.4	912.8	188.8	126.1	+533.6	+73.7	C:V208:1
C:V459:1	174.2	1261.1	537.1	912.8	188.8	126.1	+348.3	+48.1	C:V208:1
C:V458:1	168.6	1221.0	497.0	912.8	188.8	126.1	+308.2	+42.6	C:V208:1
C:V417:1	167.4	1212.1	488.1	912.8	188.8	126.1	+299.3	+41.3	C:V208:1
C:V420:1	148.5	1074.8	350.8	912.8	188.8	126.1	+162.0	+22.4	C:V208:1
C:V418:1	146.9	1063.7	339.7	912.8	188.8	126.1	+150.9	+20.8	C:V208:1
C:V433:1	138.9	694.5	194.5	596.5	96.5	119.3	+98.0	+19.6	C:HRA:T402
C:VIT:T201	135.3	979.2	255.2	912.8	188.8	126.1	+66.4	+9.2	C:V208:1
C:V208:1	133.5	2670.8	670.8	2101.7	101.7	105.1	+569.2	+28.5	C:KRA:4:nKS...
C:V444:1	133.1	963.8	239.8	912.8	188.8	126.1	+51.0	+7.0	C:V208:1
C:V443:1	132.6	959.8	235.8	912.8	188.8	126.1	+47.0	+6.5	C:V208:1
C:V460:1	131.2	949.8	225.8	912.8	188.8	126.1	+37.0	+5.1	C:V208:1
C:V449:1	131.2	949.6	225.6	912.8	188.8	126.1	+36.8	+5.1	C:V208:1
C:TAB:T201	130.8	947.3	223.3	912.8	188.8	126.1	+34.5	+4.8	C:V208:1
C:V412:1	130.2	942.9	218.9	912.8	188.8	126.1	+30.1	+4.2	C:V208:1
C:PRE:T202	129.5	937.8	213.8	912.8	188.8	126.1	+25.0	+3.4	C:V208:1
C:V202:1	128.9	933.4	209.4	912.8	188.8	126.1	+20.6	+2.8	C:V208:1
Z:V456:1	128.9	933.2	209.2	912.8	188.8	126.1	+20.4	+2.8	C:V208:1
C:V201:1	128.8	932.8	208.8	912.8	188.8	126.1	+20.0	+2.8	C:V208:1
C:V223:1	127.9	2557.9	557.9	2101.7	101.7	105.1	+456.2	+22.8	C:KRA:4:nKS...
Z:V412:1	127.7	924.8	200.8	912.8	188.8	126.1	+12.0	+1.7	C:V208:1
Z:V413:1	127.7	924.6	200.6	912.8	188.8	126.1	+11.8	+1.6	C:V208:1
C:OPO:T202	127.6	924.2	200.2	912.8	188.8	126.1	+11.4	+1.6	C:V208:1
D2:V465B:1	127.6	923.7	199.7	912.8	188.8	126.1	+10.9	+1.5	C:V208:1
C:V207:1	127.5	637.4	137.4	596.5	96.5	119.3	+40.9	+8.2	C:HRA:T402
Z:V400:1	127.3	922.0	198.0	912.8	188.8	126.1	+9.2	+1.3	C:V208:1
C:V435:1	127.3	921.5	197.5	912.8	188.8	126.1	+8.7	+1.2	C:V208:1
C:V436:1	127.3	921.3	197.3	912.8	188.8	126.1	+8.5	+1.2	C:V208:1
C:CHR:T401	127.1	920.2	196.2	912.8	188.8	126.1	+7.4	+1.0	C:V208:1
C:V430:1	127.1	920.2	196.2	912.8	188.8	126.1	+7.4	+1.0	C:V208:1
L:V410:1	127.1	920.2	196.2	912.8	188.8	126.1	+7.4	+1.0	C:V208:1
Q:V492:1	127.1	920.0	196.0	912.8	188.8	126.1	+7.2	+1.0	C:V208:1
D2:V465A:1	127.0	919.8	195.8	912.8	188.8	126.1	+7.0	+1.0	C:V208:1
Q:V493:1	127.0	919.2	195.2	912.8	188.8	126.1	+6.4	+0.9	C:V208:1
C:OPO:T201	126.9	919.0	195.0	912.8	188.8	126.1	+6.2	+0.9	C:V208:1
D8:V568:1	126.9	918.8	194.8	912.8	188.8	126.1	+6.0	+0.8	C:V208:1
D8:V567:1	126.9	918.8	194.8	912.8	188.8	126.1	+6.0	+0.8	C:V208:1
Q:V408:1	126.9	918.7	194.7	912.8	188.8	126.1	+5.9	+0.8	C:V208:1
Q:V495:1	126.9	918.5	194.5	912.8	188.8	126.1	+5.7	+0.8	C:V208:1
C:HRD:T4512_TAP+5	126.8	918.0	194.0	912.8	188.8	126.1	+5.2	+0.7	C:V208:1
C:HRD:T45x_TAP+5	126.8	918.0	194.0	912.8	188.8	126.1	+5.2	+0.7	C:V208:1
O:V436B:1	126.8	917.8	193.8	912.8	188.8	126.1	+5.0	+0.7	C:V208:1
C:V270:1	126.7	917.3	193.3	912.8	188.8	126.1	+4.5	+0.6	C:V208:1
C:VER:T401	126.7	917.1	193.1	912.8	188.8	126.1	+4.3	+0.6	C:V208:1
Q:V407:1	126.6	916.9	192.9	912.8	188.8	126.1	+4.1	+0.6	C:V208:1
C:V203:1	126.5	916.0	192.0	912.8	188.8	126.1	+3.2	+0.4	C:V208:1
O:V443B:1	126.5	915.6	191.6	912.8	188.8	126.1	+2.8	+0.4	C:V208:1
D8:V554:1	126.4	915.4	191.4	912.8	188.8	126.1	+2.6	+0.4	C:V208:1
D8:V553:1	126.4	915.4	191.4	912.8	188.8	126.1	+2.6	+0.4	C:V208:1
C:PRE:T401	126.4	915.3	191.3	912.8	188.8	126.1	+2.6	+0.4	C:V208:1
C:V473:1	126.4	915.2	191.2	912.8	188.8	126.1	+2.4	+0.3	C:V208:1
O:V435A:1	126.4	914.8	190.8	912.8	188.8	126.1	+2.0	+0.3	C:V208:1
Z:V212:1	126.3	914.7	190.7	912.8	188.8	126.1	+1.9	+0.3	C:V208:1
Q:V440:1	126.3	914.6	190.6	912.8	188.8	126.1	+1.8	+0.3	C:V208:1
C:V474:1	126.3	914.6	190.6	912.8	188.8	126.1	+1.8	+0.2	C:V208:1
C:V253:1	126.3	914.4	190.4	912.8	188.8	126.1	+1.6	+0.2	C:V208:1
C:V254:1	126.3	914.4	190.4	912.8	188.8	126.1	+1.6	+0.2	C:V208:1
C:LIS:T202	126.3	914.4	190.4	912.8	188.8	126.1	+1.6	+0.2	C:V208:1
C:V252:1	126.3	914.3	190.3	912.8	188.8	126.1	+1.5	+0.2	C:V208:1
C:V251:1	126.3	914.3	190.3	912.8	188.8	126.1	+1.5	+0.2	C:V208:1
C:LIS:T203	126.3	914.2	190.2	912.8	188.8	126.1	+1.4	+0.2	C:V208:1
D2:V226:1	126.2	914.0	190.0	912.8	188.8	126.1	+1.2	+0.2	C:V208:1

Table 3.1: N-1 report from the ČEPS control system at 11:52 - per relevant contingency



Zařízení	N-1%	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
	DIVERGENT			0.0	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVERG...	DIVERG...	C:V400:1
C:V208:1	209.6	C:MIL:2:W...	C:CST:2:W3	724.0	1517.7	793.7	912.8	188.8	126.1	+604.9	+83.6	C:V402:1
C:HRA:T402	139.5	C:HRA:4:...	C:HRA:2:...	500.0	697.5	197.5	596.5	96.5	119.3	+100.9	+20.2	C:V420:1
C:V405:1	135.0	C:KLT:4:...	C:NOS:4:...	1968.0	2656.3	688.3	1369.0	0.0	69.6	+1287.3	+65.4	C:V402:1
C:KRA:4:nKSP:1	133.5	C:KRA:4:...	C:KRA:4:...	2000.0	2670.8	670.8	2101.7	101.7	105.1	+569.2	+28.5	C:V208:1
C:V223:1	128.0	C:HRA:2:...	C:VIT:2:W...	1165.0	1491.1	326.1	1157.7	0.0	99.4	+333.3	+28.6	C:V402:1
C:VIT:2:nSP:1	127.9	C:VIT:2:W...	C:VIT:2:W...	1165.0	1489.5	324.5	1155.9	0.0	99.2	+333.6	+28.6	C:V402:1
C:V402:1	119.3	C:KRA:4:...	C:PRN:4:...	2338.0	2788.8	450.8	1219.6	0.0	52.2	+1569.2	+67.1	C:V405:1
C:V216:1	118.9	C:PRE:2:W1	C:MIL:2:W...	845.0	1005.0	160.0	688.3	0.0	81.5	+316.7	+37.5	C:V402:1
C:V417:1	115.3	C:OTR:4:...	C:SOK:4:...	2000.0	2305.8	305.8	1013.8	0.0	50.7	+1291.9	+64.6	C:V405:1
C:V458:1	111.0	C:HZI:4:W...	C:KRA:4:...	2000.0	2220.0	220.0	965.8	0.0	48.3	+1254.3	+62.7	C:V402:1
C:V459:1	104.0	C:HZI:4:W...	C:KLT:4:...	2265.0	2356.0	91.0	1090.6	0.0	48.1	+1265.5	+55.9	C:V402:1
C:KLT:4:nKSP:1	103.2	C:KLT:4:...	C:KLT:4:...	2400.0	2477.0	77.0	1204.8	0.0	50.2	+1272.2	+53.0	C:V402:1
C:OTR:4:nKSP:1	101.1	C:OTR:4:...	C:OTR:4:...	2000.0	2021.6	21.6	742.8	0.0	37.1	+1278.8	+63.9	C:V405:1
C:V207:1	95.2	C:TAB:2:W1	C:SOK:2:...	856.0	814.8	0.0	337.7	0.0	39.4	+477.1	+55.7	C:V223:1
C:MIL:2:nSP:1	94.7	C:MIL:2:W...	C:MIL:2:W...	1600.0	1515.8	0.0	911.2	0.0	57.0	+604.6	+37.8	C:V402:1
C:HZI:4:nKSP:1	93.1	C:HZI:4:W...	C:HZI:4:W...	2530.0	2356.1	0.0	1089.1	0.0	43.0	+1267.0	+50.1	C:V402:1
C:HRA:2:nKSP:1	90.9	C:HRA:2:...	C:HRA:2:...	1800.0	1636.5	0.0	1332.1	0.0	74.0	+304.4	+16.9	C:V402:1
C:CHD:T403	90.0	C:CHD:4:...	C:CHD:1:...	350.0	315.0	0.0	167.7	0.0	47.9	+147.3	+47.1	C:CHD:T401
C:CHD:T401	90.0	C:CHD:4:...	C:CHD:1:...	350.0	314.9	0.0	146.9	0.0	42.0	+168.1	+48.0	C:CHD:T403
C:V444:1	87.6	C:NOS:4:...	C:WIL:4:...	2000.0	1752.9	0.0	1017.4	0.0	50.9	+735.6	+36.8	C:V443:1
C:V203:1	83.8	C:OPO:2:...	C:SOK:2:...	756.0	633.6	0.0	71.1	0.0	9.4	+562.5	+74.4	C:HRA:T402
C:V418:1	83.2	C:OTR:4:...	C:PRN:4:...	2243.0	1866.0	0.0	601.6	0.0	26.8	+1264.4	+56.4	C:V405:1
C:NOS:4:nKSP:1	82.0	C:NOS:4:...	C:NOS:4:...	2000.0	1639.5	0.0	547.2	0.0	27.4	+1092.3	+54.6	C:V402:1
C:V401:1	81.5	C:TYN:4:...	C:KRA:4:...	2312.0	1883.9	0.0	1360.1	0.0	58.8	+523.8	+22.7	C:V208:1
C:V443:1	81.5	C:DET:4:...	C:DBN:4:...	2000.0	1629.4	0.0	1155.3	0.0	57.8	+474.1	+23.7	C:V444:1
C:V204:1	81.1	C:MIL:2:W...	C:TAB:2:W1	852.0	690.6	0.0	233.2	0.0	27.4	+457.4	+53.7	C:V223:1
C:V435:1	79.7	C:SLV:4:...	C:SOK:4:...	2000.0	1594.8	0.0	908.2	0.0	45.4	+686.6	+34.3	C:V436:1

Table 3.2: N-1 report from the ČEPS control system at 11:52 – per relevant monitored element

» **11:52:45** – Ledvice power plant unit 6 lost the remaining 182 MW of active power output from the generator (compared to the pre-incident level) due to boiler outage, while the generator remained synchronised with the system. The delay between the boiler outage at 11:51:46 and the loss of power was caused by residual steam accumulation in the boiler, which kept residual steam available even after the boiler tripped.

» **11:52:51** – The Počerady power plant informs the ČEPS operator that units TG2 and TG6 have switched to IO mode (droop speed control mode). The ČEPS operator informs about the event in the grid.



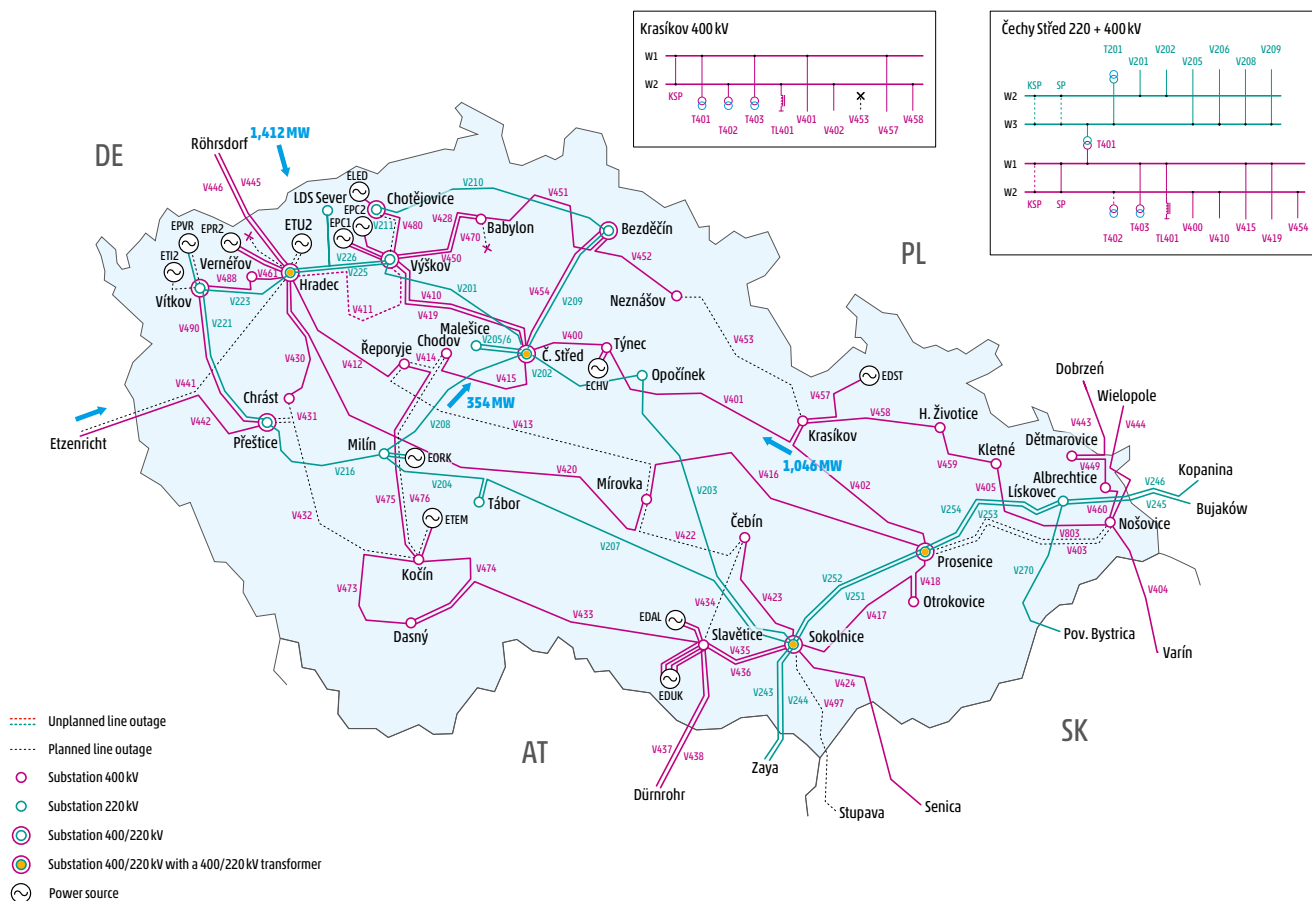


Figure 3.1: Situation of the Czech Republic transmission system on 4 July 2025 at 11:53

	V411/Vyškov	V208/Čechy Střed	V401/Krasíkov
P [MW]	0	354	-1,046
Q [Mvar]	0	-131	167
I [A]	0	>900	1,594

Table 3.3: Power flow on lines feeding the affected area at 11:53

11:53:00 – 11:59:00

» Physical overload up to:

- › 220 kV line V208: 142.9 % (1,035 A estimated value)
- › Autotransformer T402 at the Hradec 400 kV substation: 121.6 %
- › Busbar coupler at the Krasíkov 400 kV substation: 115.5 %

- » The main reason for the increase in loading was a further decrease in production (between 11:52 and 11:53, Ledvice unit 6 lost a further 182 MW of production, effectively losing all active power output).
- » 11:55 N-1 report from the ČEPS control system (Table 3.4 is not complete).

Kontingence	N-1% ▲	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Zařízení
C:V405:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V402:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V401:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V400:1	DIVERGENT	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVER...	DIVERG...	
C:V459:1	207.6	1502.9	778.9	1034.7	310.7	142.9	+468.1	+64.7	C:V208:1
C:V417:1	201.1	1455.7	731.7	1034.7	310.7	142.9	+421.0	+58.1	C:V208:1
C:V458:1	196.8	1425.1	701.1	1034.7	310.7	142.9	+390.4	+53.9	C:V208:1
C:V418:1	170.7	1235.8	511.8	1034.7	310.7	142.9	+201.1	+27.8	C:V208:1
C:V420:1	165.9	1201.5	477.5	1034.7	310.7	142.9	+166.7	+23.0	C:V208:1
C:VIT:T201	151.8	1099.4	375.4	1034.7	310.7	142.9	+64.7	+8.9	C:V208:1
C:V433:1	150.8	1092.1	368.1	1034.7	310.7	142.9	+57.3	+7.9	C:V208:1
C:V444:1	150.2	1087.2	363.2	1034.7	310.7	142.9	+52.5	+7.2	C:V208:1
C:V208:1	150.0	2999.4	999.4	2310.4	310.4	115.5	+689.0	+34.4	C:KRA:4:nKS...
C:V443:1	149.2	1080.1	356.1	1034.7	310.7	142.9	+45.3	+6.3	C:V208:1
C:V460:1	148.1	1072.1	348.1	1034.7	310.7	142.9	+37.4	+5.2	C:V208:1
C:V449:1	148.1	1072.0	348.0	1034.7	310.7	142.9	+37.3	+5.1	C:V208:1
C:V412:1	146.7	1061.8	337.8	1034.7	310.7	142.9	+27.0	+3.7	C:V208:1
C:PRE:T202	146.6	1061.4	337.4	1034.7	310.7	142.9	+26.6	+3.7	C:V208:1
Z:V456:1	145.7	1054.8	330.8	1034.7	310.7	142.9	+20.1	+2.8	C:V208:1
C:V202:1	145.7	1054.5	330.5	1034.7	310.7	142.9	+19.8	+2.7	C:V208:1
C:TAB:T201	145.6	1054.2	330.2	1034.7	310.7	142.9	+19.5	+2.7	C:V208:1
C:V201:1	145.6	1053.9	329.9	1034.7	310.7	142.9	+19.2	+2.7	C:V208:1
Z:V412:1	144.6	1046.7	322.7	1034.7	310.7	142.9	+12.0	+1.7	C:V208:1
Z:V413:1	144.5	1046.5	322.5	1034.7	310.7	142.9	+11.7	+1.6	C:V208:1
D2:V465B:1	144.4	1045.4	321.4	1034.7	310.7	142.9	+10.7	+1.5	C:V208:1
C:OPO:T202	144.3	1044.9	320.9	1034.7	310.7	142.9	+10.2	+1.4	C:V208:1
Z:V400:1	144.2	1044.1	320.1	1034.7	310.7	142.9	+9.4	+1.3	C:V208:1
C:V435:1	144.2	1044.0	320.0	1034.7	310.7	142.9	+9.2	+1.3	C:V208:1
C:V436:1	144.2	1043.7	319.7	1034.7	310.7	142.9	+9.0	+1.2	C:V208:1
Q:V492:1	144.0	1042.4	318.4	1034.7	310.7	142.9	+7.7	+1.1	C:V208:1
D2:V465A:1	143.9	1041.7	317.7	1034.7	310.7	142.9	+7.0	+1.0	C:V208:1
Q:V493:1	143.9	1041.6	317.6	1034.7	310.7	142.9	+6.8	+0.9	C:V208:1
L:V410:1	143.9	1041.5	317.5	1034.7	310.7	142.9	+6.8	+0.9	C:V208:1
Q:V408:1	143.8	1041.1	317.1	1034.7	310.7	142.9	+6.4	+0.9	C:V208:1
C:CHR:T401	143.8	1041.0	317.0	1034.7	310.7	142.9	+6.3	+0.9	C:V208:1
C:OPO:T201	143.8	1040.9	316.9	1034.7	310.7	142.9	+6.2	+0.9	C:V208:1
Q:V495:1	143.7	1040.7	316.7	1034.7	310.7	142.9	+6.0	+0.8	C:V208:1
C:V430:1	143.7	1040.6	316.6	1034.7	310.7	142.9	+5.9	+0.8	C:V208:1
D8:V567:1	143.7	1040.1	316.1	1034.7	310.7	142.9	+5.4	+0.7	C:V208:1
D8:V568:1	143.7	1040.1	316.1	1034.7	310.7	142.9	+5.4	+0.7	C:V208:1
C:HRD:T45x_TAP+5	143.6	1039.8	315.8	1034.7	310.7	142.9	+5.1	+0.7	C:V208:1
C:HRD:T4512_TAP+5	143.6	1039.8	315.8	1034.7	310.7	142.9	+5.1	+0.7	C:V208:1
C:V270:1	143.6	1039.6	315.6	1034.7	310.7	142.9	+4.9	+0.7	C:V208:1
O:V436B:1	143.6	1039.5	315.5	1034.7	310.7	142.9	+4.8	+0.7	C:V208:1
Q:V407:1	143.5	1039.2	315.2	1034.7	310.7	142.9	+4.5	+0.6	C:V208:1
C:VER:T401	143.5	1038.7	314.7	1034.7	310.7	142.9	+4.0	+0.6	C:V208:1
C:V203:1	143.5	1038.6	314.6	1034.7	310.7	142.9	+3.9	+0.5	C:V208:1
C:V473:1	143.3	1037.1	313.1	1034.7	310.7	142.9	+2.4	+0.3	C:V208:1
D8:V553:1	143.2	1037.0	313.0	1034.7	310.7	142.9	+2.3	+0.3	C:V208:1
D8:V554:1	143.2	1037.0	313.0	1034.7	310.7	142.9	+2.3	+0.3	C:V208:1
O:V443B:1	143.2	1036.8	312.8	1034.7	310.7	142.9	+2.1	+0.3	C:V208:1
Z:V212:1	143.2	1036.7	312.7	1034.7	310.7	142.9	+1.9	+0.3	C:V208:1
O:V435A:1	143.2	1036.6	312.6	1034.7	310.7	142.9	+1.9	+0.3	C:V208:1
Q:V440:1	143.2	1036.6	312.6	1034.7	310.7	142.9	+1.9	+0.3	C:V208:1
C:PRE:T401	143.2	1036.6	312.6	1034.7	310.7	142.9	+1.8	+0.3	C:V208:1
C:V474:1	143.2	1036.5	312.5	1034.7	310.7	142.9	+1.8	+0.2	C:V208:1
C:LIS:T202	143.1	1036.4	312.4	1034.7	310.7	142.9	+1.6	+0.2	C:V208:1
C:V253:1	143.1	1036.3	312.3	1034.7	310.7	142.9	+1.5	+0.2	C:V208:1
C:V254:1	143.1	1036.3	312.3	1034.7	310.7	142.9	+1.5	+0.2	C:V208:1
C:V252:1	143.1	1036.1	312.1	1034.7	310.7	142.9	+1.4	+0.2	C:V208:1
C:V251:1	143.1	1036.1	312.1	1034.7	310.7	142.9	+1.4	+0.2	C:V208:1
Q:V429:1	143.1	1035.9	311.9	1034.7	310.7	142.9	+1.2	+0.2	C:V208:1
C:V454:1	143.1	1035.9	311.9	1034.7	310.7	142.9	+1.2	+0.2	C:V208:1
D2:V226:1	143.1	1035.9	311.9	1034.7	310.7	142.9	+1.1	+0.2	C:V208:1
C:LIS:T203	143.1	1035.8	311.8	1034.7	310.7	142.9	+1.1	+0.2	C:V208:1
D2:SCH:T421	143.0	1035.7	311.7	1034.7	310.7	142.9	+0.9	+0.1	C:V208:1
Z:V409:1	143.0	1035.6	311.6	1034.7	310.7	142.9	+0.9	+0.1	C:V208:1

Table 3.4: N-1 report from the ČEPS control system at 11:55 - per relevant monitored element



Zařízení	N-1%	Uzel1	Uzel2	Limit	N-1	Přes N-1	N-0	Přes N-0	N-0%	Rozdíl	Rozdíl%	Kontingence
	DIVERGENT			0.0	DIVER...	DIVER...	DIVER...	DIVER...	DIVERG...	DIVERG...	DIVERG...	C:V400:1
C:V208:1	207.6	C:MIL:2:W...	C:CST:2:W3	774.0	1502.9	778.9	1034.7	310.7	142.9	+468.1	+64.7	C:V459:1
C:KRA:4:nKSP:1	150.0	C:KRA:4:...	C:KRA:4:...	2000.0	2999.4	999.4	2310.4	310.4	115.5	+689.0	+34.4	C:V208:1
C:HRA:T402	139.9	C:HRA:4:...	C:HRA:2:...	500.0	699.7	199.7	596.7	96.7	119.3	+103.0	+20.6	C:V420:1
C:V223:1	125.5	C:HRA:2:...	C:VIT:2:W...	1165.0	1462.0	297.0	1191.2	26.2	102.2	+270.8	+23.2	C:V459:1
C:VIT:2:nSP:1	125.4	C:VIT:2:W...	C:VIT:2:W...	1165.0	1461.0	296.0	1190.2	25.2	102.2	+270.9	+23.3	C:V459:1
C:V405:1	120.2	C:KLT:4:...	C:NOS:4:...	1968.0	2364.9	396.9	1459.3	0.0	74.1	+905.7	+46.0	C:V417:1
C:V402:1	115.7	C:KRA:4:...	C:PRN:4:...	2338.0	2704.5	366.5	1339.8	0.0	57.3	+1364.7	+58.4	C:V459:1
C:V216:1	115.4	C:PRE:2:W1	C:MIL:2:W...	845.0	974.9	129.9	728.8	0.0	86.2	+246.1	+29.1	C:V459:1
C:V417:1	111.4	C:OTR:4:...	C:SOK:4:...	2000.0	2227.4	227.4	1100.4	0.0	55.0	+1127.0	+56.4	C:V459:1
C:V207:1	99.9	C:TAB:2:W1	C:SOK:2:...	856.0	855.1	0.0	357.9	0.0	41.8	+497.3	+58.1	C:V223:1
C:OTR:4:nKSP:1	97.9	C:OTR:4:...	C:OTR:4:...	2000.0	1957.7	0.0	840.5	0.0	42.0	+1117.3	+55.9	C:V459:1
C:V458:1	96.6	C:HZI:4:W...	C:KRA:4:...	2000.0	1931.3	0.0	1052.0	0.0	52.6	+879.3	+44.0	C:V417:1
C:V401:1	95.2	C:TYN:4:...	C:KRA:4:...	2312.0	2201.4	0.0	1563.6	0.0	67.6	+637.8	+27.6	C:V208:1
C:MIL:2:nSP:1	93.4	C:MIL:2:W...	C:MIL:2:W...	1600.0	1494.8	0.0	1027.5	0.0	64.2	+467.3	+29.2	C:V459:1
C:CHD:T403	91.8	C:CHD:4:...	C:CHD:1:...	350.0	321.4	0.0	171.0	0.0	48.8	+150.4	+43.0	C:CHD:T401
C:CHD:T401	91.8	C:CHD:4:...	C:CHD:1:...	350.0	321.2	0.0	150.0	0.0	42.9	+171.2	+48.9	C:CHD:T403
C:V459:1	91.6	C:HZI:4:W...	C:KLT:4:...	2265.0	2074.6	0.0	1182.7	0.0	52.2	+891.9	+39.4	C:V417:1
C:V204:1	91.4	C:MIL:2:W...	C:TAB:2:W1	852.0	778.8	0.0	304.4	0.0	35.7	+474.4	+55.7	C:V223:1
C:KLT:4:nKSP:1	91.1	C:KLT:4:...	C:KLT:4:...	2400.0	2187.2	0.0	1294.7	0.0	53.9	+892.5	+37.2	C:V417:1
C:V444:1	89.4	C:NOS:4:...	Z:WIE:4:...	2000.0	1788.5	0.0	1046.6	0.0	52.3	+741.9	+37.1	C:V443:1
C:HRA:2:nKSP:1	89.2	C:HRA:2:...	C:HRA:2:...	1800.0	1604.8	0.0	1349.8	0.0	75.0	+255.0	+14.2	C:V459:1
C:V400:1	87.3	C:CST:4:...	C:TYN:4:...	2351.0	2051.7	0.0	1438.1	0.0	61.2	+613.6	+26.1	C:V208:1
C:TYN:4:nKSP:1	85.6	C:TYN:4:...	C:TYN:4:...	2400.0	2054.3	0.0	1415.1	0.0	59.0	+639.2	+26.6	C:V208:1
C:V203:1	82.8	C:OPO:2:...	C:SOK:2:...	756.0	626.3	0.0	77.1	0.0	10.2	+549.2	+72.6	C:HRA:T402
C:V443:1	82.6	C:DET:4:...	Z:DBN:4:...	2000.0	1651.7	0.0	1160.2	0.0	58.0	+491.5	+24.6	C:V444:1
C:HZI:4:nKSP:1	82.0	C:HZI:4:W...	C:HZI:4:W...	2530.0	2074.6	0.0	1182.7	0.0	46.7	+891.9	+35.3	C:V417:1
C:V435:1	81.9	C:SLV:4:...	C:SOK:4:...	2000.0	1638.6	0.0	930.5	0.0	46.5	+708.1	+35.4	C:V436:1
C:NOS:4:nKSP:1	81.9	C:NOS:4:...	C:NOS:4:...	2000.0	1638.6	0.0	636.8	0.0	31.8	+1001.8	+50.1	C:V443:1
C:V436:1	81.7	C:SLV:4:...	C:SOK:4:...	2000.0	1633.5	0.0	917.9	0.0	45.9	+715.6	+35.8	C:V435:1
C:V418:1	80.5	C:OTR:4:...	C:PRN:4:...	2243.0	1806.2	0.0	701.6	0.0	31.3	+1104.6	+49.2	C:V459:1
D8:ROH:T441	77.5	D8:ROH:4...	D8:ROH:4...	1440.0	1115.4	0.0	820.2	0.0	57.0	+295.2	+20.5	D8:V572:1

Table 3.5: N-1 report from the ČEPS control system at 11:55 – per relevant monitored element

Immediately after the V411 outage, dispatchers began to address the fault. The analysis of the operational situation was complicated by the state of Ledvice unit 6, where the circuit breaker remained closed until 11:59:47, even though the unit had zero active power following the boiler trip.

The Počerady power plant immediately reported the transition to droop speed control mode of both units in operation. ČEPS operators were unable to identify specific PGMs that lost active power, and thus the cause of the system imbalance.¹⁶

To address the overload on V208, the dispatchers first sought topological measures (reconfiguration) and then verified the solution by calculating the change in the output of the PGMs in operation (redispatching) in the simulation environment (also known as “study mode”) of the control system. They were unable to find an effective topological measure in the rapidly changing, deteriorating situation, and they assessed the activation of redispatching production sources as time-consuming, and, therefore ineffective for addressing the severe overload on V208.

11:58:25

The ČEPS operator asks the ČEZ technical centre¹⁷ about the status of the Ledvice power plants (units 4 and 6).

- » Ledvice power plant unit 4 is in IO mode (droop speed control mode).
- » Ledvice power plant unit 6 is in outage, with zero power, and the generator circuit breaker is still closed.

11:59:44

The ČEPS operator switched off the significantly overloaded line V208 due to the risk of sagging lines, possible danger to inhabitants, and to prevent permanent damage to the line. The details of the dispatcher’s decision are explained in the Chapter 6.4.

16 Either type A modules that are not required to provide data, or other types that do not provide any data and constitute the 151 MW of unidentified imbalance.

17 ČEZ is the owner of the power plants.



11:59:47

- » Krasíkov 400 kV substation busbar coupler switched off by the overcurrent relay (setting 2,880 A/3 s).
- » The 400/110 kV T401KRA transformer at the Krasíkov substation switched off at the 110 kV level by the distribution company's distance protection (T401KRA was the last connection to supply the deficit island 1,800 MW and therefore was tripped by its protection).
- » Creation of a deficit island (approximately 1,800 MW):
 - Substations in the island: Babylon 400 kV, Bezděčín 400 kV, Chodov 400 kV, Chotějovice 220 and 400 kV, Čechy Střed 220 and 400 kV, Krasíkov 400 kV, Malešice 220 kV, Neznášov 400 kV, Týnec 400 kV, Výškov 400 kV.

11:59:49

- » V016 unit line to the Ledvice unit 6 power plant switched off at the CHT4 substation.
- » Line V984 switched off at the 110 kV CHT1 substation (unit line of Ledvice unit 4 power plant).
- » Line V472 switched off (unit line of the Chvaletice unit 4 power plant), unit successfully tripped to the house-load supply.
- » Line V467 switched off at the VYS4 substation (unit line of the Počeradý unit 2 power plant), unit successfully tripped to the house-load supply.
- » Line V469 switched off at the VYS4 substation (unit line of the Počeradý unit 6 power plant), unit successfully tripped to the house-load supply.

11:59:48

Pumped-storage EDST HG2 switched off by protection from the pumping mode.

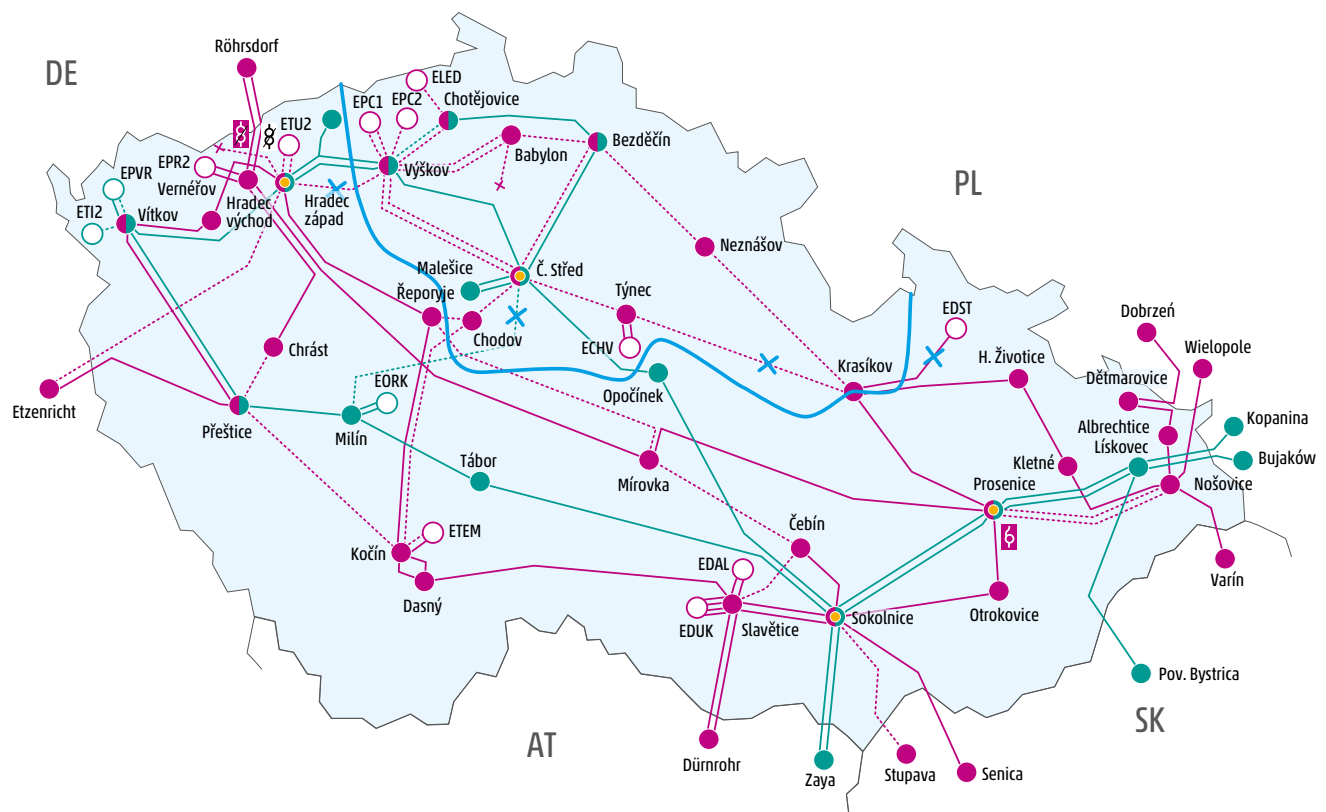


Figure 3.2: Situation of the Czech Republic transmission system on 4 July 2025 with indication of the area affected by the fault



11:59:50

- » Ledvice unit 4 power plant generator circuit breaker switch off.

11:59:51

- » Ledvice unit 6 power plant generator circuit breaker switch off.
- » Chvaletice unit 4 power plant generator circuit breaker incorrectly signalled switch off (unit 4 still in operation on house load supply).

12:00

The ČEZ technical centre informs about the shutdown of the Ledvice unit 4 power plant and the plan to shut down the pumping at the Dlouhé Stráně pumped storage. Before hanging up, the ČEPS operator mentions that the pump storage has gone out.

12:00:48

The operator of the Temelin NPP inquires about the status of the network. The ČEPS operator informs about a major fault in the grid, which is currently being resolved.

12:01:36

The ČEPS operator inquires about the status of the Počerady 1 power plant after the failure. The operator of Počerady 1 confirms the failure of unit 2 and unit 6, with no unit remaining in operation for self-consumption.

12:02:20

The ČEPS operator receives information from the ČEZ technical centre about the plan to shut down the Dalešice pumped storage. The ČEPS shift leader informs the ČEZ technical centre about the major outage. The ČEZ technical centre asks whether the change of Dalešice operation (from pumping to generation) will worsen the operation.

12:04:42

Počerady 2 power plant operator asks what is happening. The ČEPS grid operator informs about a large-scale outage and asks about the status of the Počerady 2 units. The power plant's house load is supplied from the diesel generator. After applying voltage to the unit lines, they can start up.

12:06:20

The Powertica (power plant operator and ancillary service provider) operator asks why the power plants are in IO mode. The ČEPS network operator requests summary information on the status of the units and when they could start up.

12:08:21

EAS traffic light set to "emergency", critical event



Figure 3.3 to Figure 3.6 show active and reactive power flow and current on the element supplying the affected area for the period from 11:50 to 12:00.

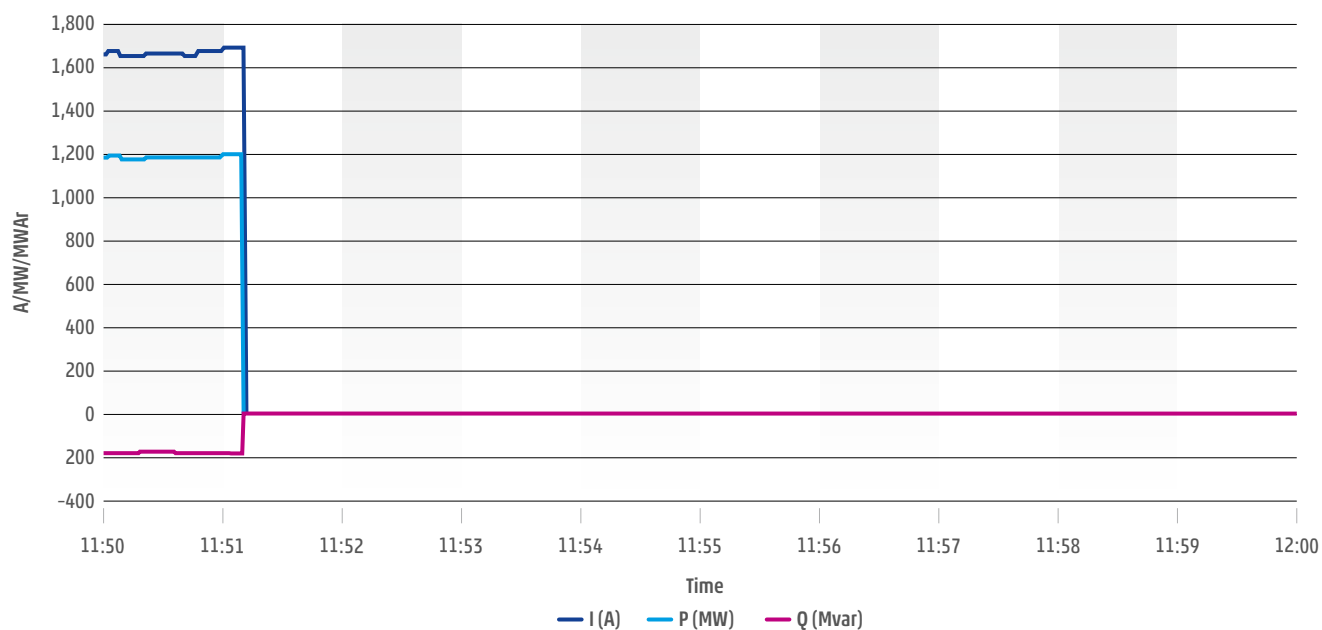


Figure 3.3: Current, active power and reactive power on Výškov line V411

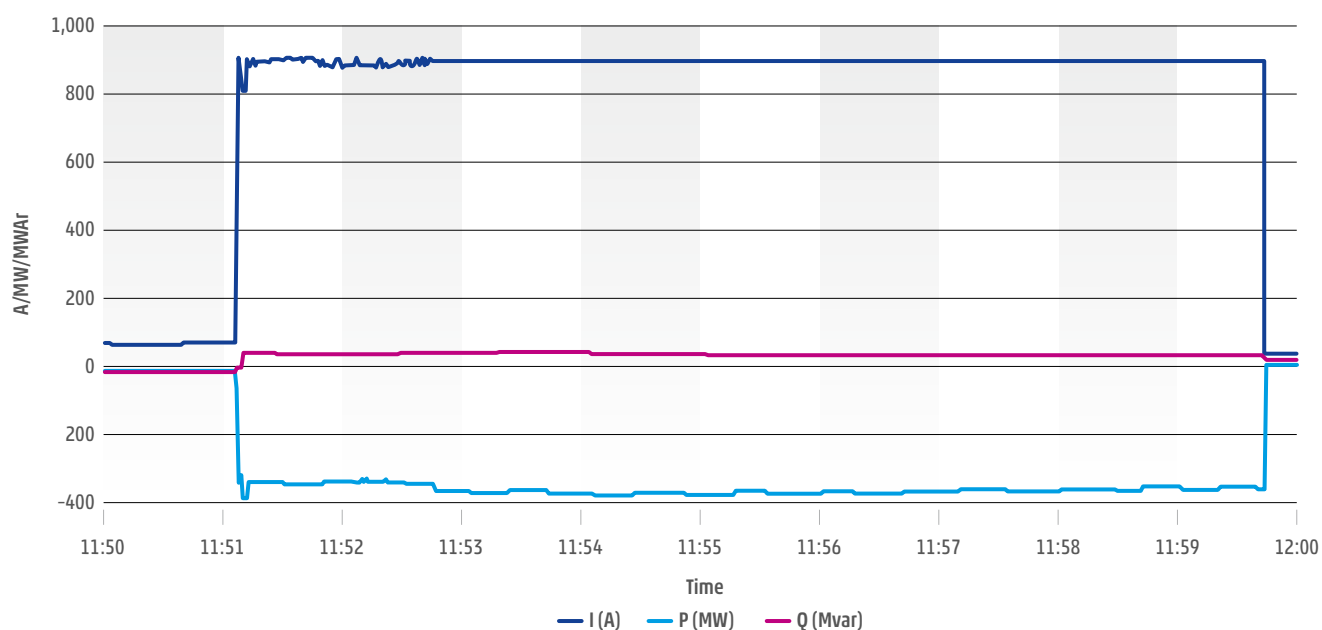


Figure 3.4: Current, active power and reactive power on Milín line V208



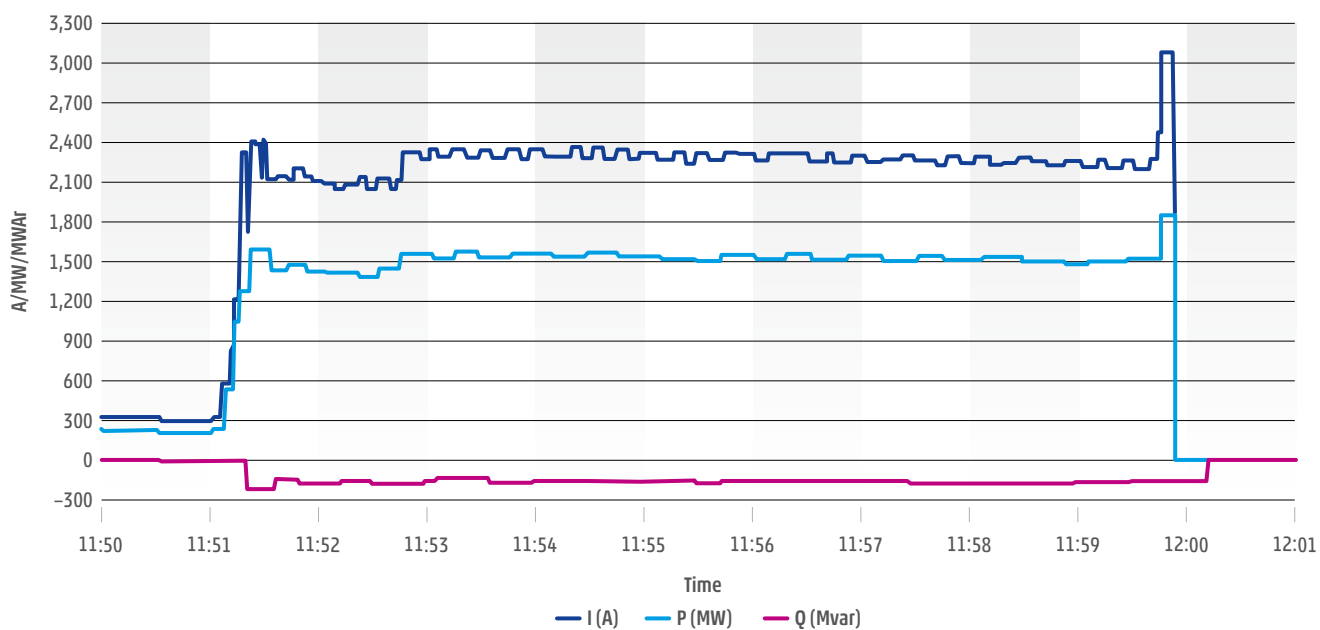


Figure 3.5: Current, active and reactive power on KSP Krasíkov

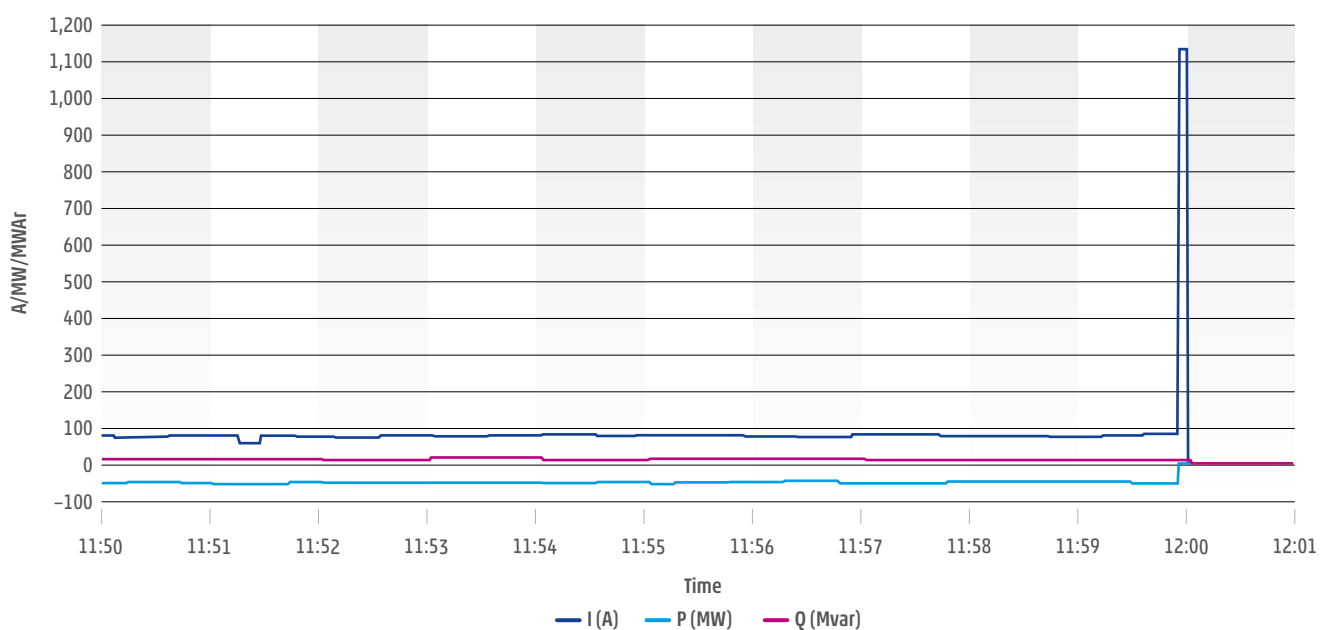


Figure 3.6: Current, active power and reactive power on Krasíkov T401 transformer



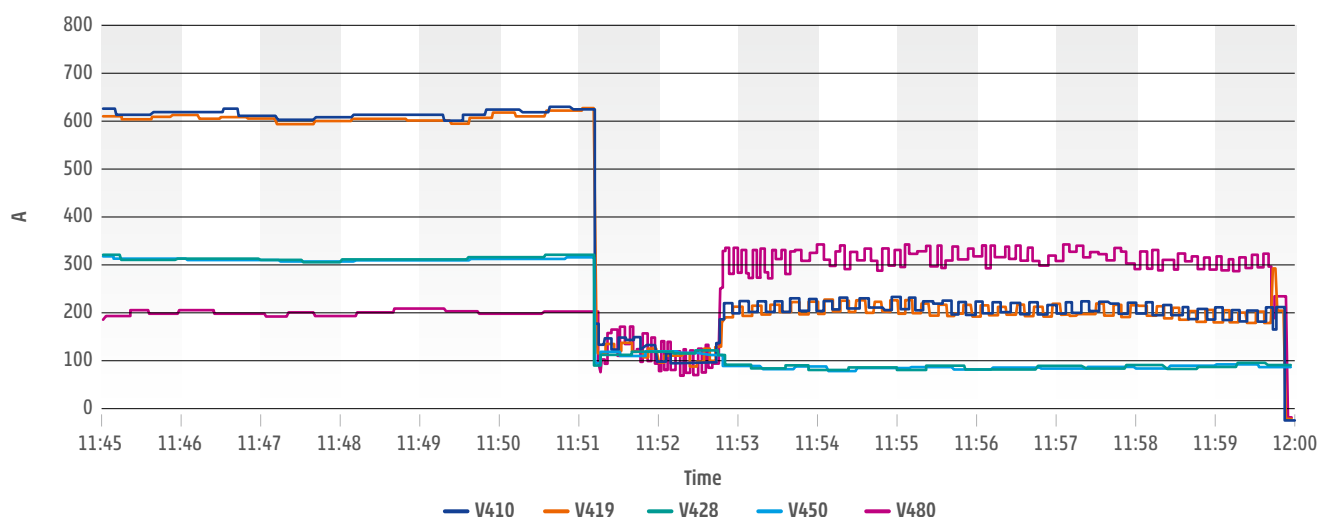


Figure 3.7: Flows on lines in the Výškov substation¹⁸

3.2 Generation and load

Almost immediately after the V411 outage, production decreased at both the transmission and distribution grids (between 340 and 440 MW, according to ČEPS data).

11:52

» Identified in the transmission system:

- › Decrease in the power of the Ledvice unit 6 power plant of about 110 MW.
- › Decrease in the power of the Počeradý power plant of 17 MW.
- › The reason for this behaviour was that, during the disturbance caused by a short circuit and the disconnection of line V411, a turbine controller in the power control mode (normal operation mode) responded rapidly to the active power deviation induced by the disturbance in an attempt to maintain the originally scheduled active power output. This response of the turbine controller in the power control mode led to rapid variations in control valves opening. Subsequently, the valve position at reduced opening was captured during their switch to droop speed control mode as a new setpoint.

» Identified in the distribution system

- › ČEZd 150 MW (including Ledvice unit 4 power plant, approximately 25 MW)
- › PREdi 10 MW, reason unknown

Following the switch of unit 4 of Ledvice power plant to droop speed control mode and due to the 0 % setting of the droop, the unit started oscillating.

This production further decreased in output at the Ledvice power plant unit 6.

11:53

- » Decrease in the output of the Ledvice power plant unit 6 by another 182 MW due to boiler outage.
- » Due to the oscillations, the reverse power protection did not open the unit circuit breaker. The generator therefore remained connected to the grid but supplied no active power.

12:00

After the island's collapse, all sources operating on it were lost. The total volume of shutdown production was approximately 1,294 MW.

» Identified in the transmission system

- › Decrease in the output of unit 6 of the Ledvice power plant by 292 MW
- › Power plant Počeradý 262 MW
- › Power plant Chvaletice 125 MW

» Identified in the distribution system (so far), decrease in the output of sources by:

- › 397 MW ČEZd
- › 51 MW PREdi
- › 16 MW EG.D

¹⁸ Oscillations of active power on lines V480, V410 and V419 were caused by power oscillations on units 4 and 6 of TPP Ledvice. These were caused by setting (0 %) of the droop speed control mode of unit 4 of TPP Ledvice.



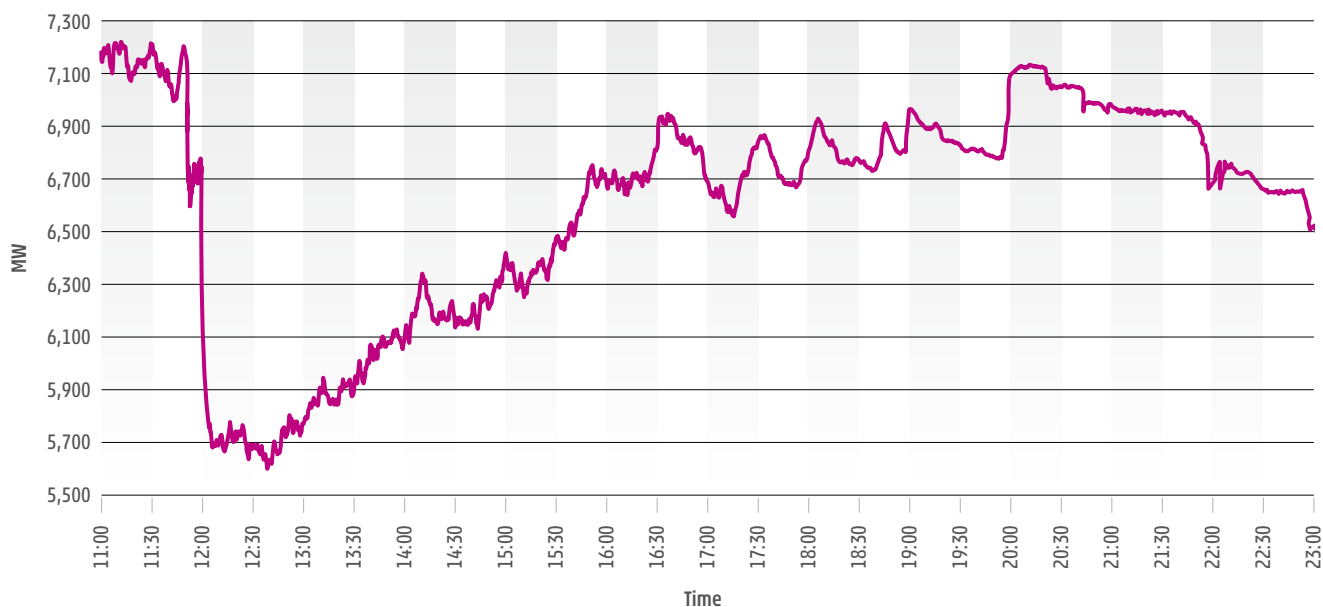


Figure 3.8: Total generation in the Czech Republic power system

Unlike production, there was no reduction in consumption after the V411 line failure. The load was around 8,100 MW.

After the island's collapse, the load dropped from approximately 8,144 MW to 5,900 MW, reflecting a difference of 2,244 MW (according to ČEPS data).

The load remained at this value until approximately 12:42, when it was gradually restored at the distribution system level.

Based on information from the DSOs, the restoration process at the distribution system level was completed at 17:35.

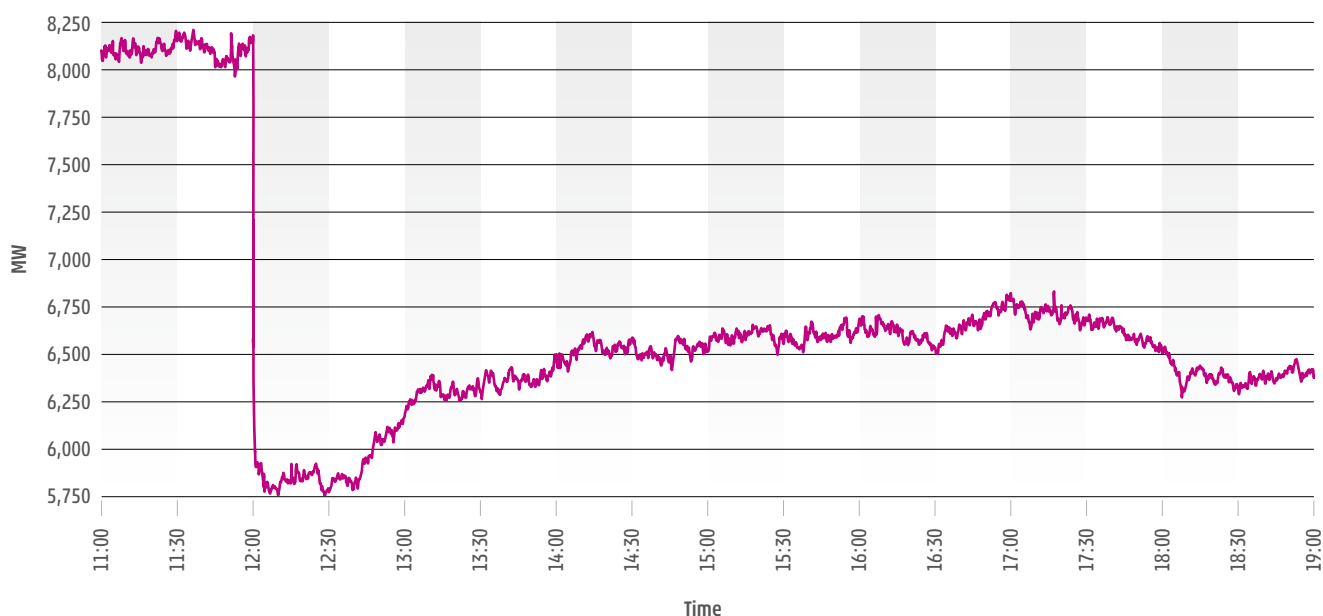


Figure 3.9: Total load in the Czech power system (source: ČEPS data)

Based on information from distribution companies, the total consumption loss was 1,988 MW.



3.3 System's dynamic behaviour during the event

Prior to the incident, no extraordinary dynamic behaviour was recorded in the system.

Immediately before the incident, line V411 was loaded to approximately 1,200 MW, with power flowing from the Hradec substation to the Výškov substation. The tripping of line V411 redistributed power flows within the system, causing a power surge that affected nearby generation. From the perspective of nearby synchronous generators, there was a transition from the power control mode to the IOCM (droop speed control mode). The following units, connected to the transmission system, were affected:

- » TPP Ledvice unit 6
- » TPP Počeradý units 2 and 6

IOCM (droop speed control mode) was also activated on the following units operating within the distribution system (at the 110 kV voltage level):

- » TPP Ledvice unit 4
- » TPP Opatovice unit 5

The transition to the IOCM was based on local frequency measurements from individual units. The switch to the IOCM is triggered by a frequency deviation of ± 200 mHz from the nominal value of 50 Hz. After the transition, the units change their control mode and remain connected to the grid.

The following series of graphs illustrates the dynamic behaviour of TPP Ledvice unit 6. The graph of active power output shows periodic oscillations for unit 6 at TPP Ledvice. Such oscillations are not present in the telemetered active power data transmitted to the ČEPS dispatching control system.

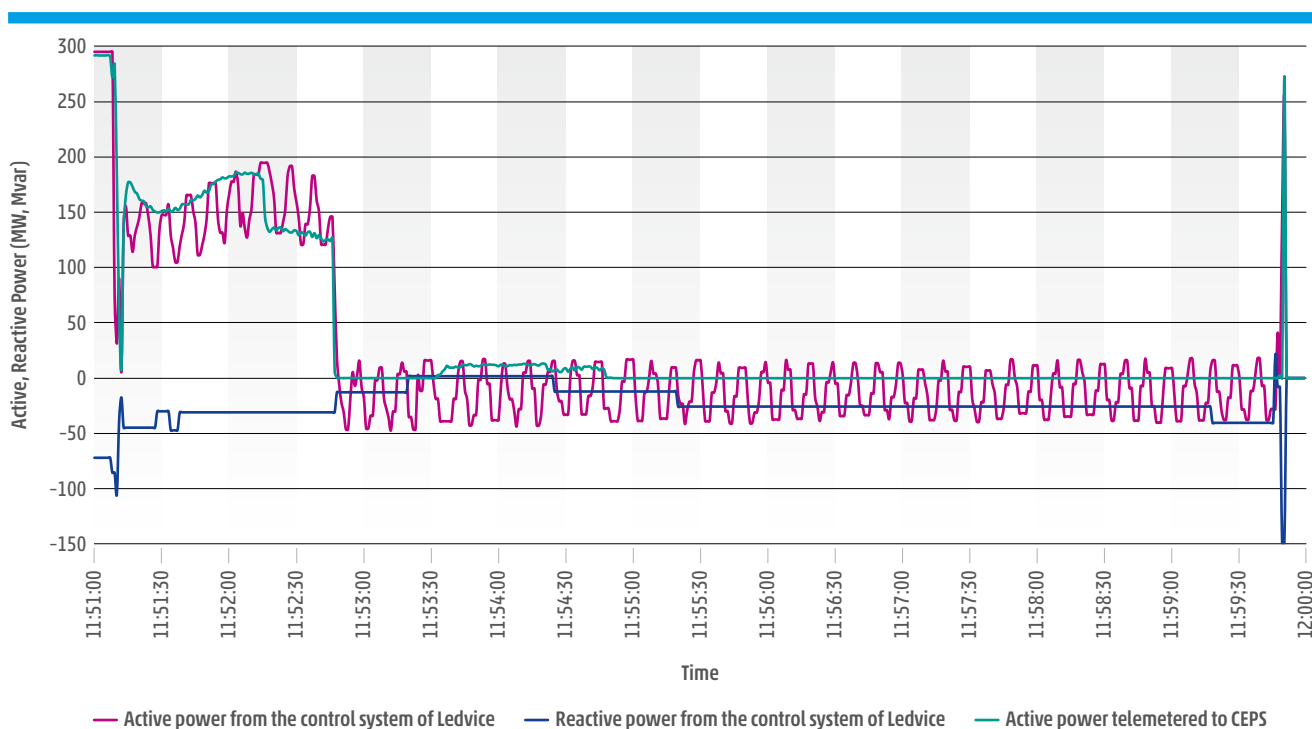


Figure 3.10: Trend of power output at generator terminals of ELED unit 6 from 11:51 to 12:00

According to the power plant's statement, the cause of the difference between the signals is as follows (translated into English by ČEPS):

"We assume that the issue arises during signal validation in the TCS (Turbine Control System) when the input signals are oscillating, which was exactly the case here. A 1-second filter is included in the validation loop. We would like to emphasise again that each of the three input signals is connected to a different input card.

Each card is read at a different moment in time. However, the validation block evaluates all three signals simultaneously. This means it processes samples that are time-shifted, and in the case of oscillating input signals combined with the implemented 1-second filter, this can cause the observed issue."



For comparison, Figure 3.11 shows measurements from the control system of unit 6 and line V016. The measurement on line V016 is adjusted for the power plant house load.

The graph clearly shows that the measurements overlap, and the line measurement also indicates oscillations (even with a shorter period) in the active power of generator unit 6.

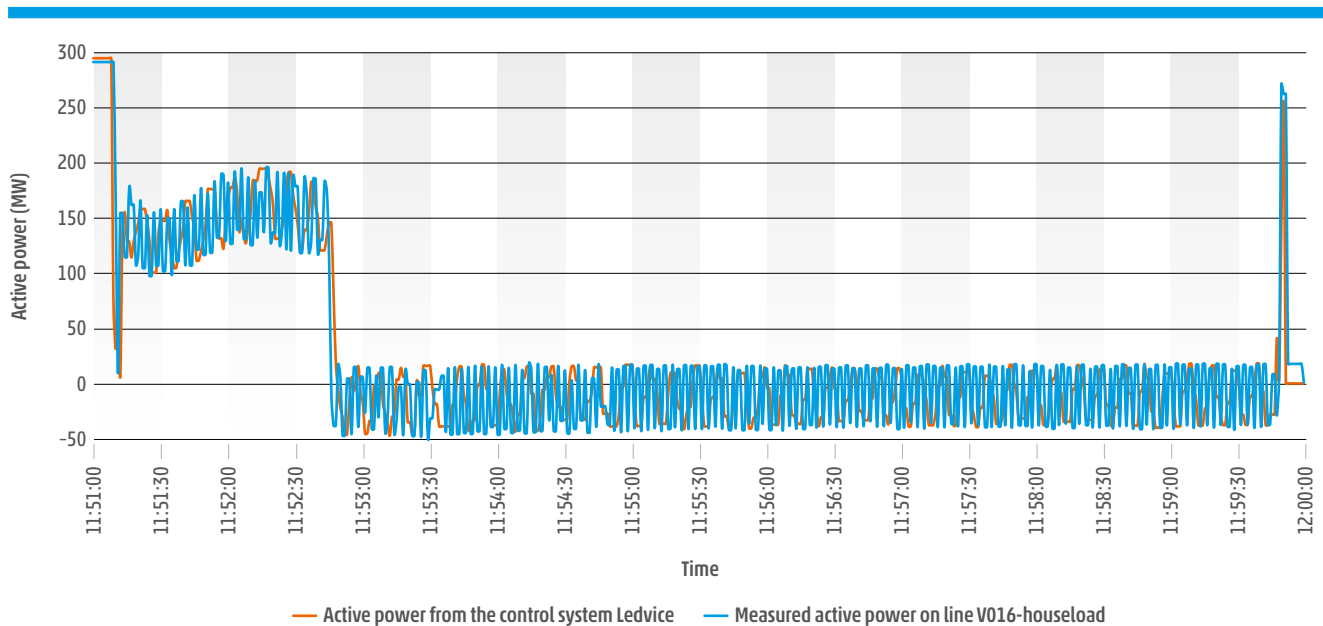


Figure 3.11: Comparison of the active power trend of the generator with the measurement on line V016 adjusted for the house load of ELED from 11:51 to 12:00

According to the statement from TPP Ledvice, at 11:51:46, a boiler outage occurred due to the activation of protection triggered by a high-temperature steam signal behind the high-pressure bypass stations. This was caused by an unforeseen technical fault in one of the high-pressure steam temperature control valves in the turbine bypasses steam piping. The valve failed to open due to an actuator motor malfunction, which was specifically caused by a defective relay.

At 11:52:45, the turbogenerator was shut down with a delay determined by the boiler's immediate steam output at the time of the trip. The generator remained synchronised with the system, with zero turbine power, because the criteria for reverse power flow protection were not met due to oscillations in the generator's active power output. The generator was disconnected from the grid during the frequency collapse of the separated part of the system, triggered by frequency protection upon detecting underfrequency at 11:59:51.



The following graphs show the turbogenerator speed profile at TPP Ledvice unit 6. Figure 3.12 displays the period from 11:51 to 12:00, capturing both the V411 outage event and the subsequent frequency collapse in the affected part of the grid. The graph also shows that even after the boiler outage, the generator remained synchronised with the grid (i.e. operating at synchronous speed).

For unit 6, it is a two-pole turbogenerator; therefore, the synchronous speed corresponding to a 50 Hz grid frequency is 3,000 rpm. Small oscillations are also visible in the speed profile after the V411 outage. For better clarity, a zoomed-in view of the generator speed at the time of the V411 outage was also created.

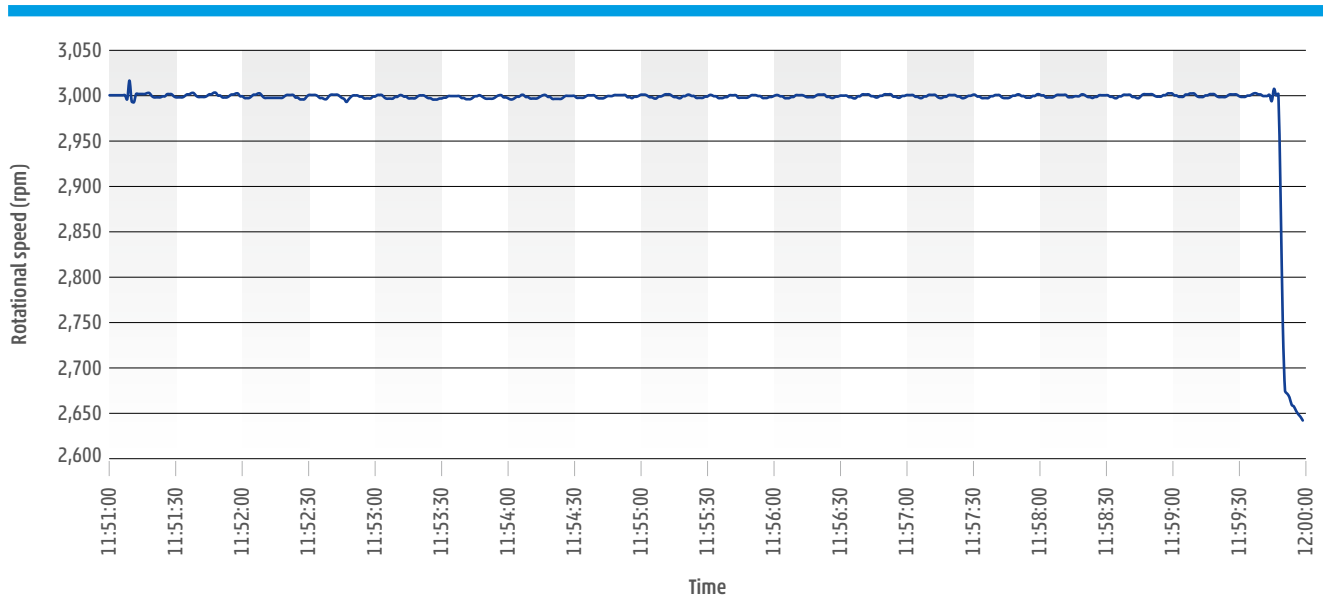


Figure 3.12: Trend of measured turbogenerator speed of ELED unit 6 from 11:51 to 12:00

From the speed measurement, it is evident that a transient change was recorded following the outage of line V411, during which the rotor speed reached approximately 3,016 rpm at 11:51:09.

Since a frequency deviation of 200 mHz as a threshold for transition to droop speed control mode corresponds to 12 rpm, unit 6 recorded a deviation greater than the set limit.

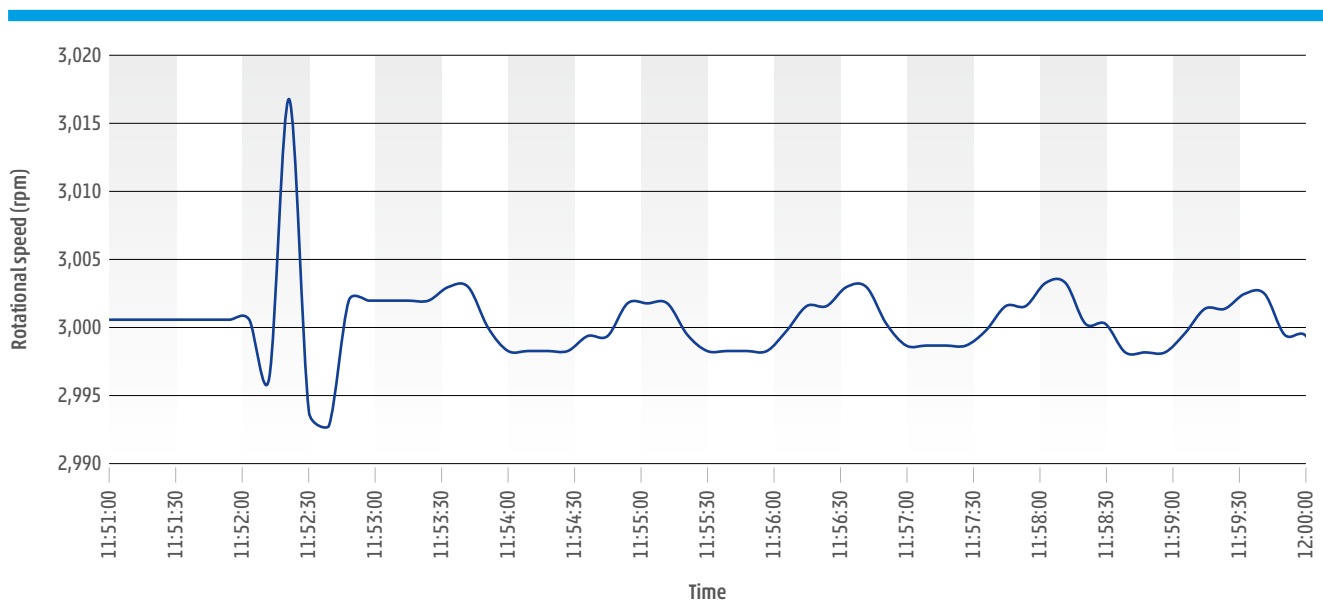


Figure 3.13: Zoomed-in view of speed measurement during the V411 outage

The following graphs show profiles of the opening of bypass stations and control valves of TPP Ledvice unit 6. The graphs show that changes in the variables occurred already after the V411 outage.

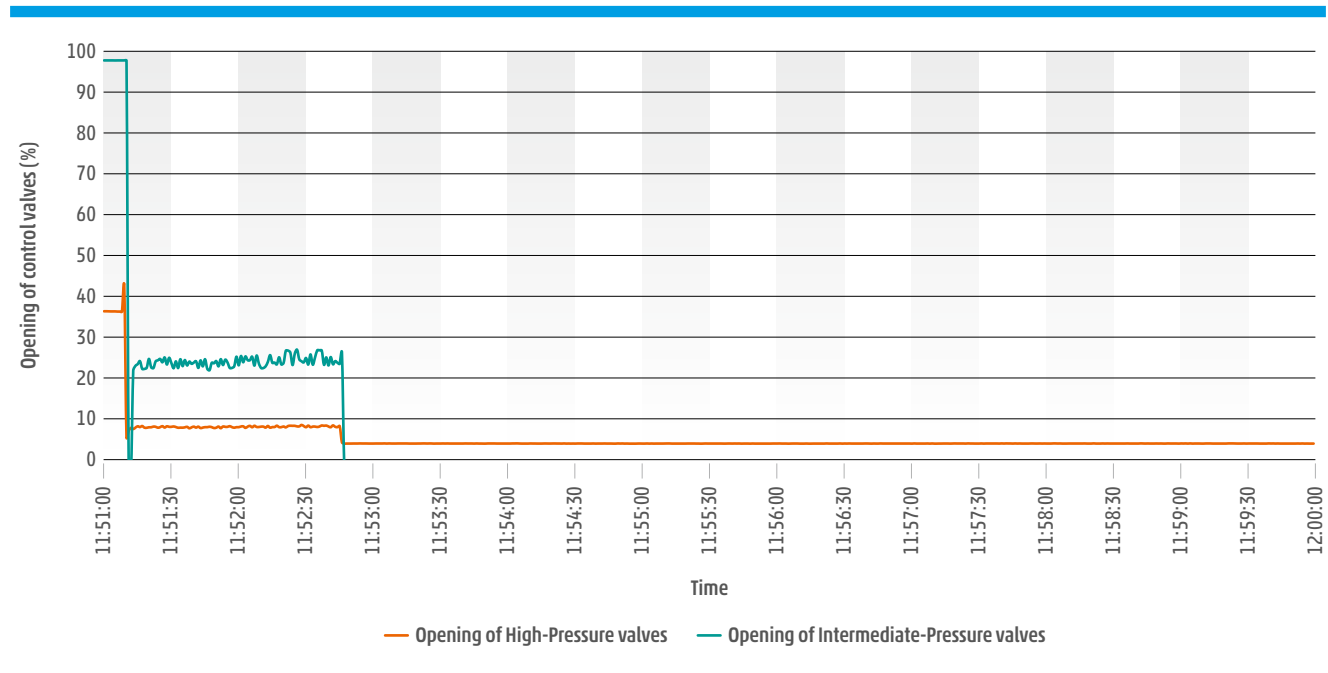


Figure 3.14: Trend of control valves opening for ELED unit 6 from 11:51 to 12:00

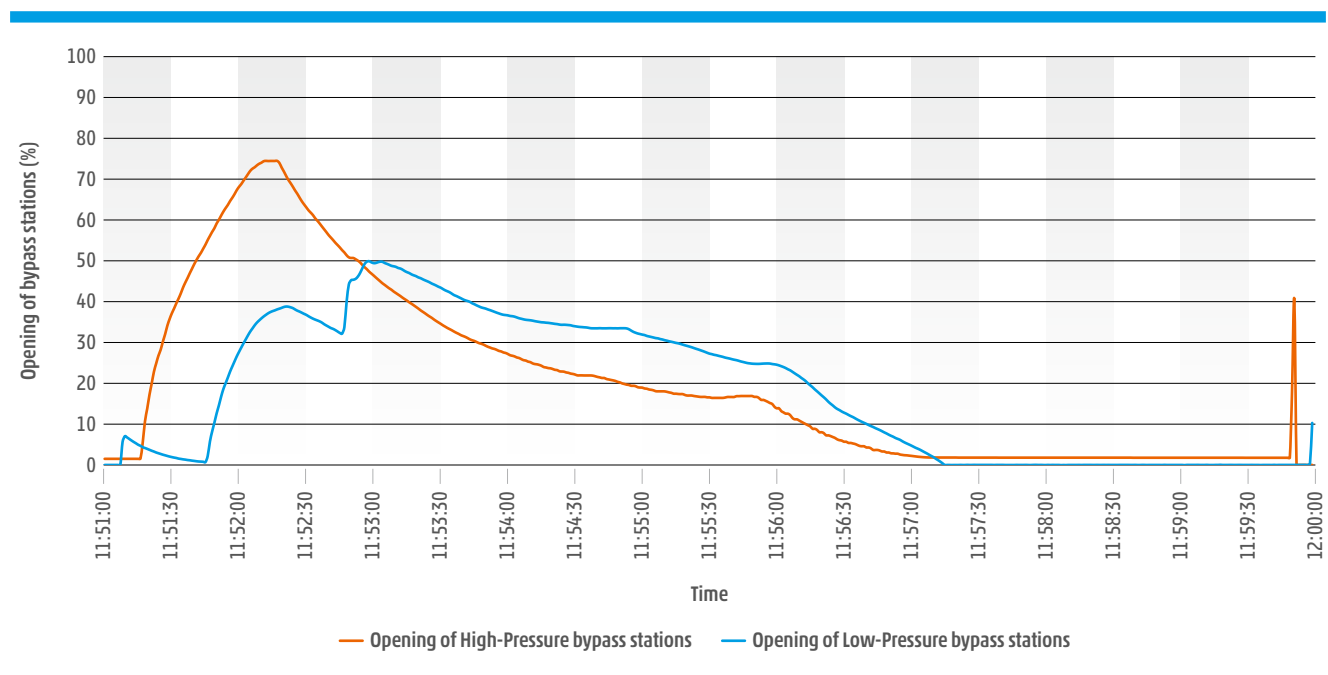


Figure 3.15: Trend of bypass stations opening for ELED unit 6 from 11:51 to 12:00



From the perspective of dynamic behaviour affecting the system's operation, the behaviour of TPP Ledvice unit 4, connected to the distribution network at the 110 kV level, is further shown. It should be noted that the power plant sent the data from its control system for unit 4 with the following remark:

"Due to the possibilities of monitoring feedback, loading historical trends, and the operating mode of Unit 4 in Island Operation Control Mode, not all time-aligned data can be considered fully relevant; some potential inconsistencies need to be further investigated as far as possible."

Figure 3.16 shows the output of the TPP Ledvice unit 4 generator, again compared with the values from the Ledvice power plant control system and the telemetered values to the ČEPS dispatch control system. From the trends, it is evident that unit 4 experienced oscillations, and the output active power telemetered to the ČEPS dispatch control system differs from the output power recorded in the power plant control system. Therefore, it is also more difficult to calculate the total loss of active power generation after the V411 outage.

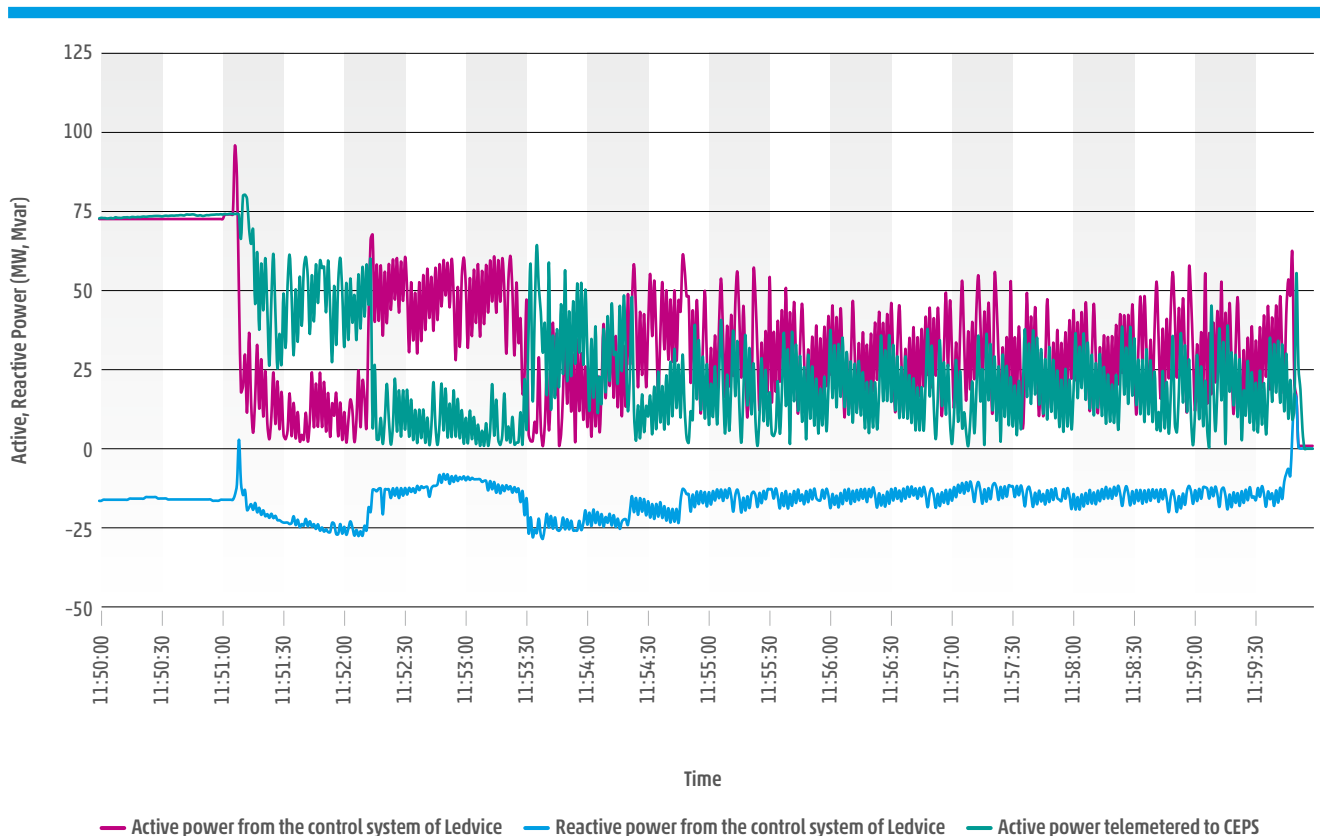


Figure 3.16: Trend of power output at generator terminals of ELED unit 4 from 11:50 to 12:00

According to the power plant statement, unit 4 of TPP Ledvice had a droop setting of 0% in droop speed control mode, meaning that the proportional speed controller's gain was theoretically infinite. Such a gain would theoretically mean that, for any positive frequency deviation from 50 Hz, the unit would drop to zero active power, and for any negative deviation, it would go to its maximum available output. The gain is limited in practice by the mechanical equipment's capabilities. In accordance with information provided by the power plant, this droop setting does not seem to be in line with the expected performance.

It should also be noted that, according to the Transmission System Grid Code, the droop setting for IOCM should be in the range of 4–10%. However, unit 4 of TPP Ledvice is not certified for IO capability as an ancillary service, as it is connected to the distribution system. ČEPS does not procure this service from units connected to the distribution system, which also implies that the unit is not subject to regular certification for IO capability, as are units providing this service in the transmission system.

According to the power plant statement, the reason for the differences between the telemetered active power and the active power from the control system of Ledvice for unit 4 is as follows (again translated from Czech):

"The sent active power values come from one of three measurements taken before evaluation in the control system. These three values are then validated within the control system, a median of the three is calculated, and only afterward is the signal used for regulation and sent to the terminal."¹⁹

Due to incorrectly configured droop settings, which caused an overload of the control system's computational capacity, the signal from the terminal cannot be considered valid. It should be noted that the active power value, when the unit is operating in Island Operation Control mode, is not applied in any regulation."

Oscillations are also evident in the opening of the turbine control valves on TPP Ledvice unit 4 following the V411 trip and the switch to droop speed control mode.

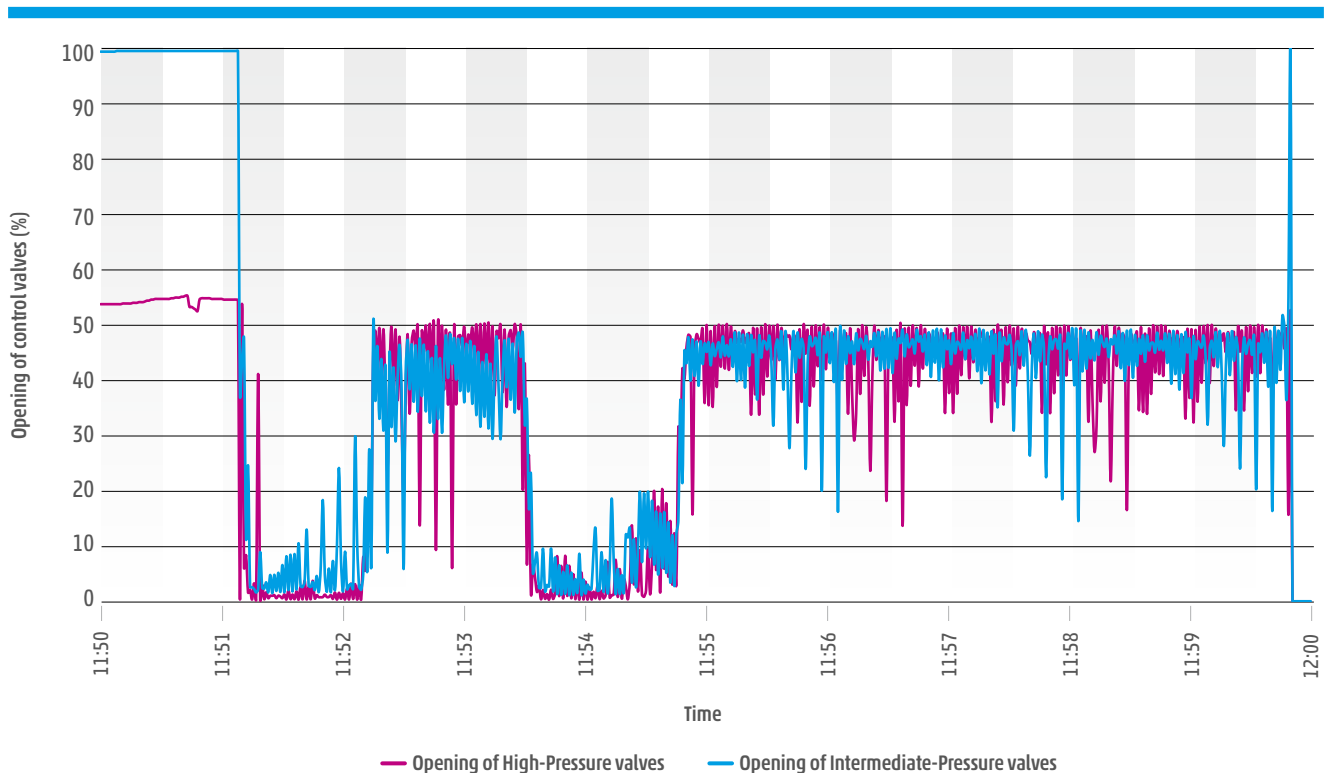


Figure 3.17: Trend of control valves opening for ELED unit 4 from 11:50 to 12:00

Regarding the grid's behaviour, Figure 3.18 shows frequency measurements from the WAMS system at the Čechy Střed substation between 11:50 and 12:00, with a displayed granularity of 50 samples per second. This is the only substation in the transmission system area equipped with WAMS measurement that was affected by a voltage outage at 11:59. The graph clearly shows the moment when line V411 was disconnected at 11:51:07, which caused a frequency oscillation in the area.

Although the frequency value stabilised around the nominal value 50 Hz after the disconnection of line V411 – since the affected part of the grid remained synchronously connected to the surrounding system – frequency oscillations are still visible. Figure 3.19 therefore shows a zoomed-in view of the frequency measurement over a 10-s interval, revealing ongoing oscillations with a period of approximately 1 s with a peak-to-peak amplitude of 30 mHz.

¹⁹ The values from the terminal are values telemetered to the ČEPS dispatch control system. The terminal of the power plant is a technical device for the control of the units and for communication with other systems, including the ČEPS dispatch control system.



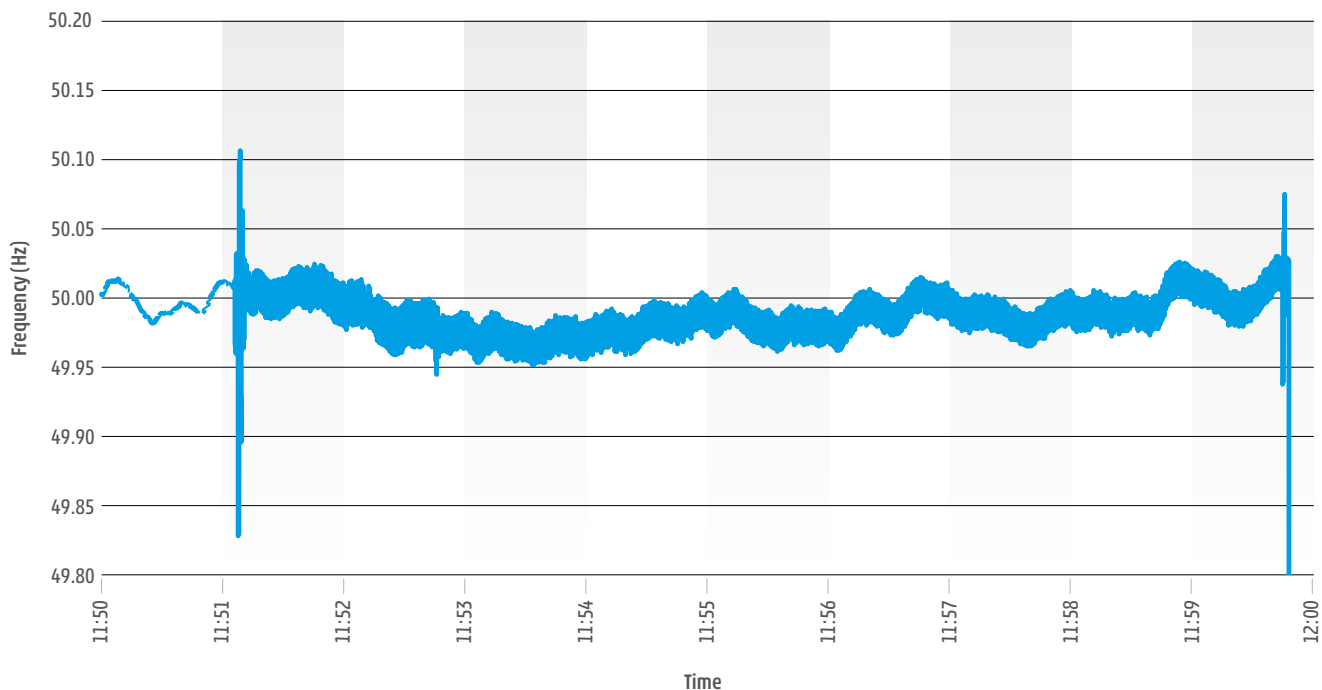


Figure 3.18: WAMS frequency measurement at the CST substation in the V400 line bay from 11:50 to 12:00

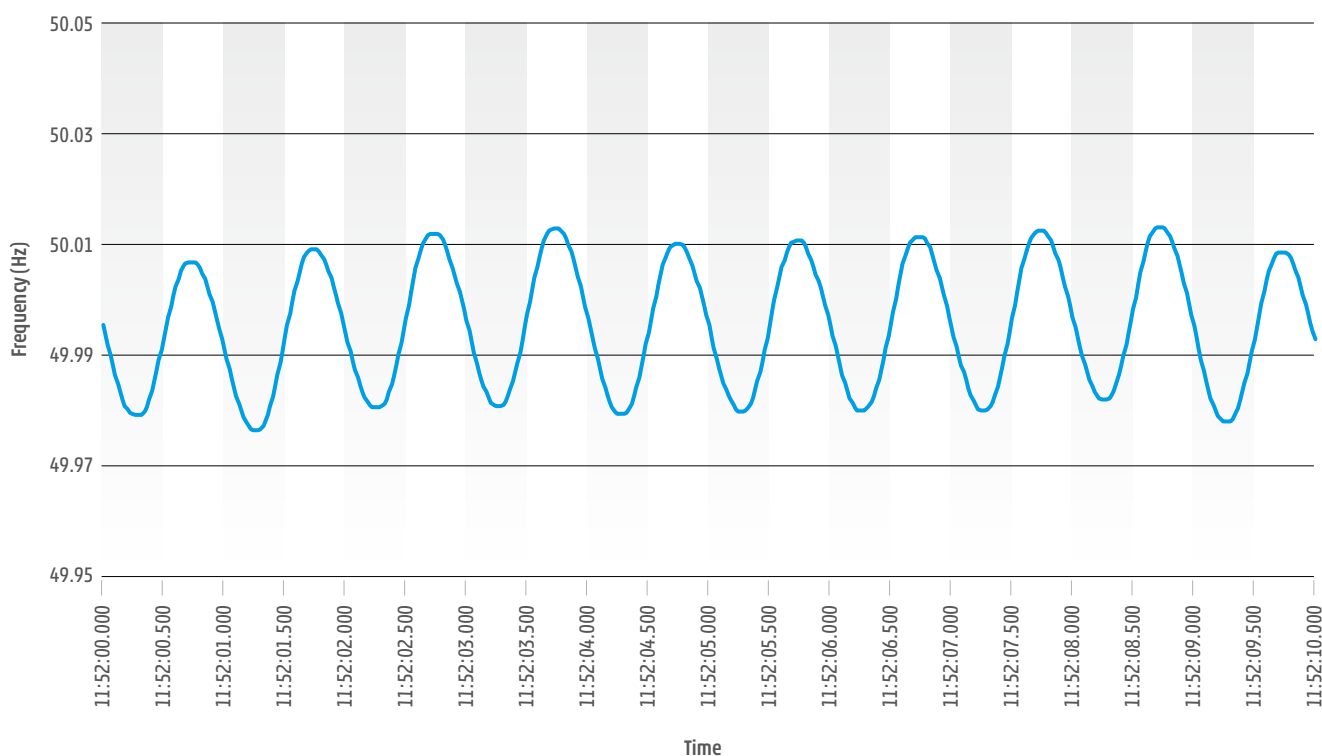


Figure 3.19: Zoomed-in view of the WAMS frequency measurement at the CST substation in the V400 line bay



This oscillation was observed only in the area (at least according to available WAMS measurements) that was subsequently affected by a voltage outage. The graph below shows frequency measurements from the Hradec substation, which the V411 line connects to. The data is taken from the V412 Hradec–Řeporyje line bay.

In this waveform, oscillations following the V411 outage are not visible. Furthermore, the frequency measurement from the Hradec substation clearly shows that a frequency deviation greater than 200 mHz was recorded during the V411 line outage, representing the WAMS measurement closest to the V411 line.

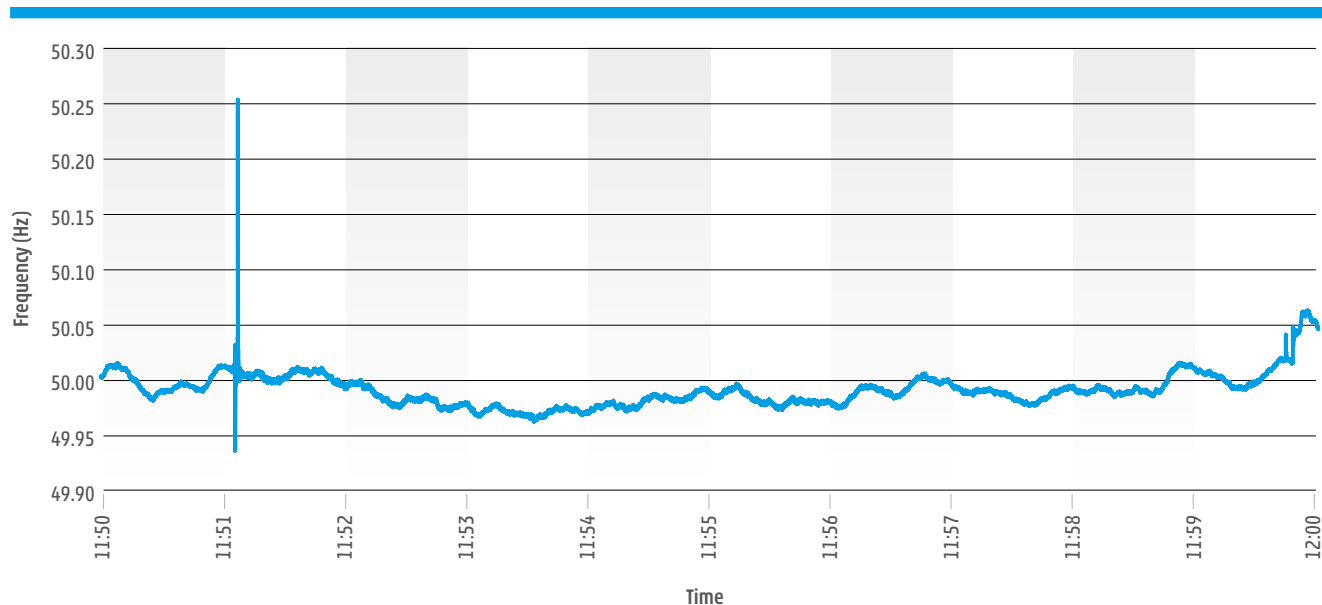


Figure 3.20: WAMS frequency measurement at the HRA substation in the V412 line bay from 11:50 to 12:00

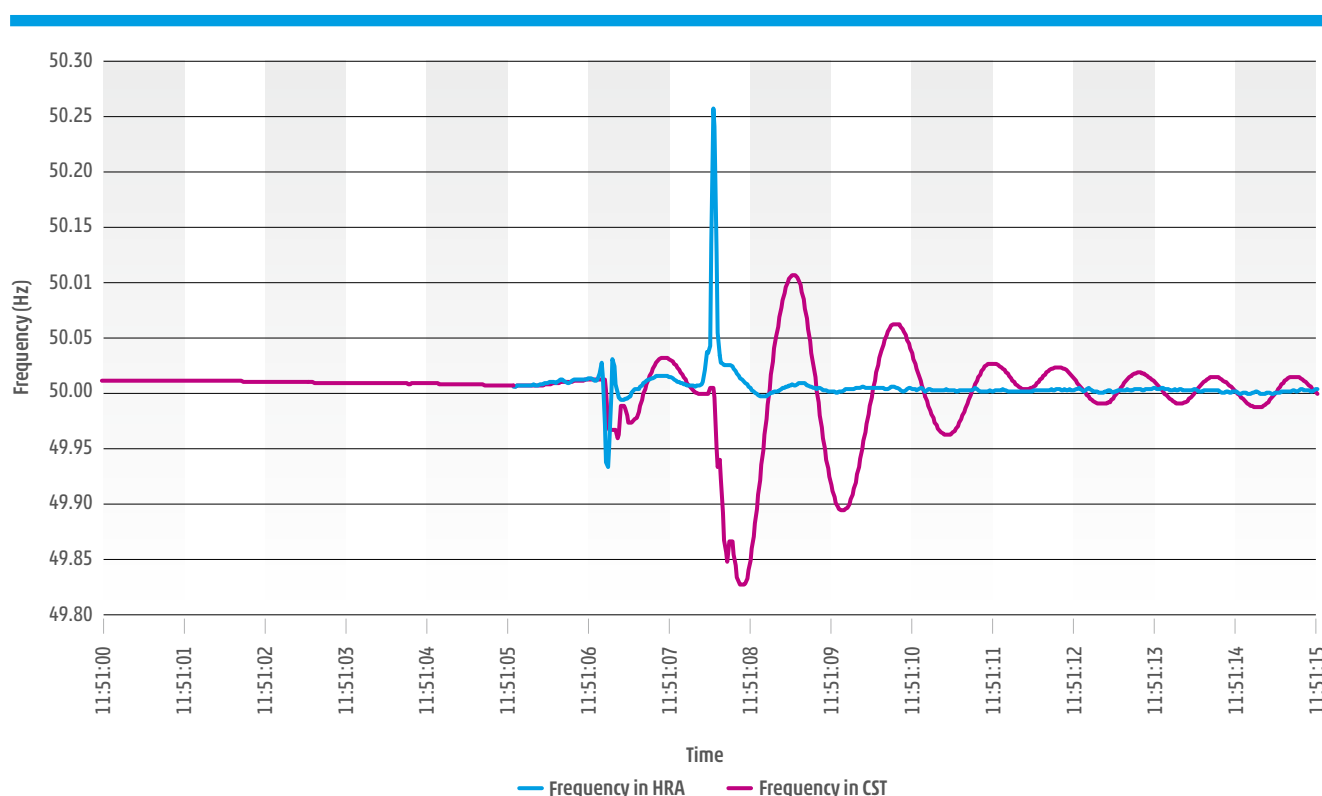


Figure 3.21: Zoomed-in view of the frequency profile during the V411 outage



From the V411 outage at 11:51 until the collapse of the affected part of the grid at 11:59, the frequency remained within normal operating limits.

As mentioned above, the WAMS measurement in the area affected by the voltage outage is installed at the Čechy Střed substation. The following course of the frequency collapse of the already-formed deficit island after the Krasíkov busbar coupler was switched off at 11:59:47 is also taken from this measurement.

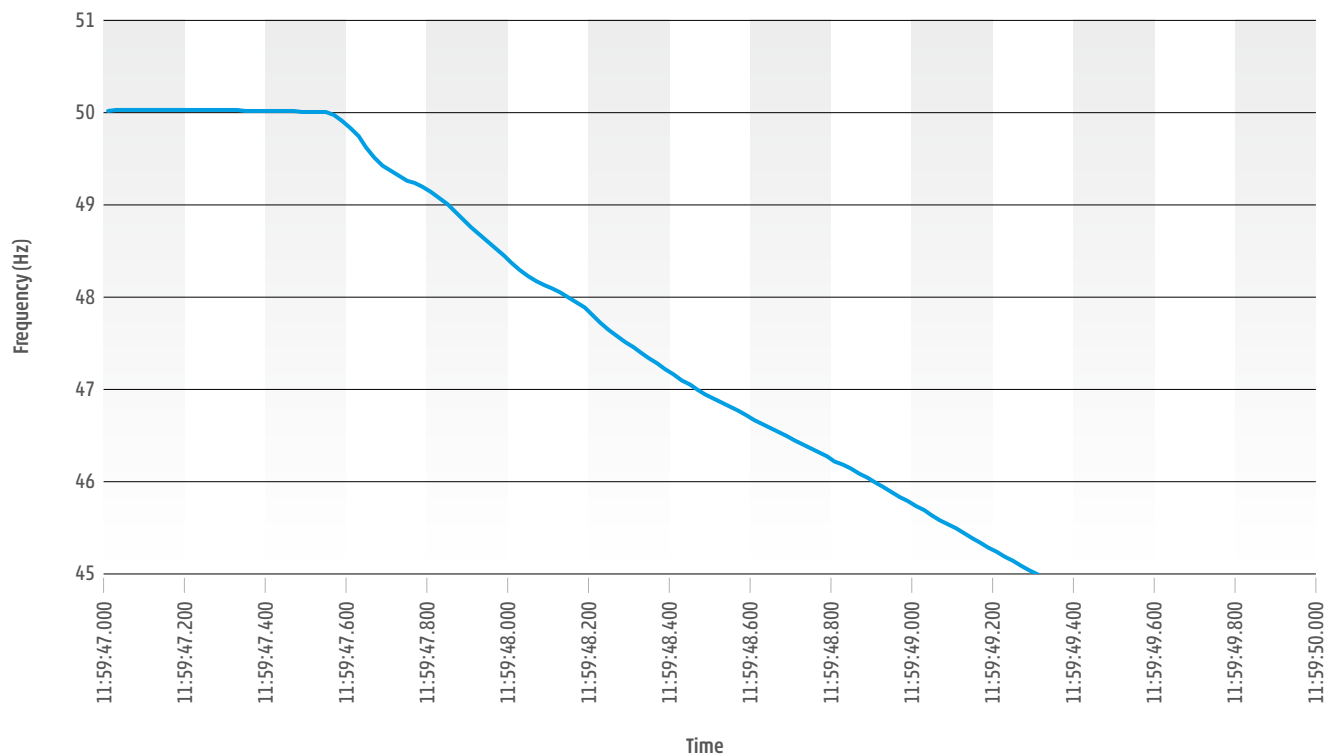


Figure 3.22: Recorded frequency collapse in the WAMS frequency measurement at the CST substation



Based on WAMS frequency measurements, the RoCoF value was also calculated as the mean value over a 500-ms interval.

The RoCoF value during the frequency collapse is shown in Figure 3.23. The highest recorded RoCoF value was around -3.5 Hz/s.

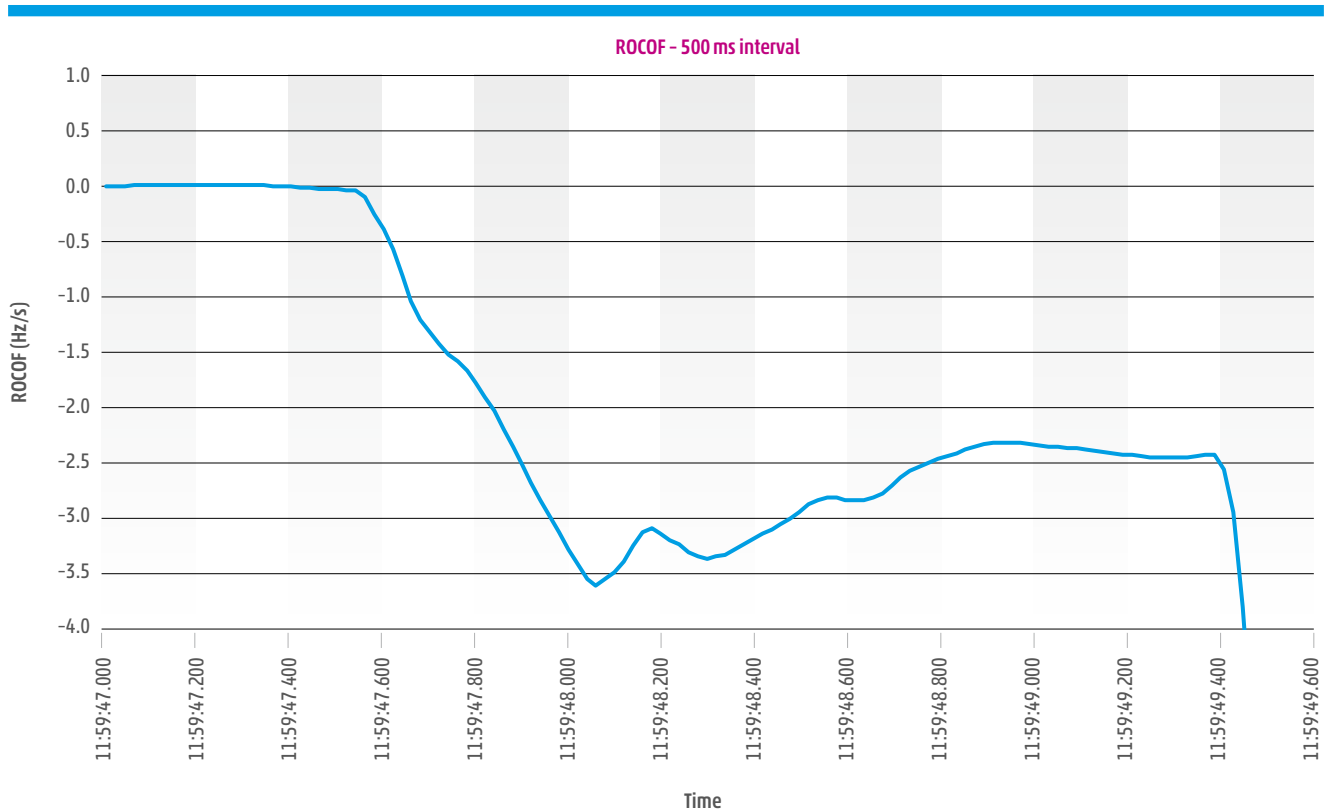


Figure 3.23: RoCoF profile during the frequency collapse

During the frequency collapse, all steps of the load frequency demand disconnection scheme were activated based on data from the DSO. Overall, 766 MW of net demand was disconnected as part of the shedding process in the IO. The LFDD scheme is implemented as a six-step system in accordance with the Commission Regulation (EU) 2017/2196 establishing a network code on electricity emergency and restoration (NC ER).

The estimated load disconnected was ca. 980 MW, calculated proportionally based on demand to be disconnected in the affected area and scaled from the maximum total load to actual load (ca. 8,100 MW on the day vs. ca. 10,500 MW of yearly maximum).



Due to the significant deficit – estimated at approximately 1,800 MW based on the power flow through the busbar coupler at the Krasíkov substation at the time of its disconnection – and the resulting high RoCoF of the IO

even the activation of LFDD was insufficient to prevent the final collapse. Figure 3.24 illustrates the expected activation sequence of individual LFDD steps.

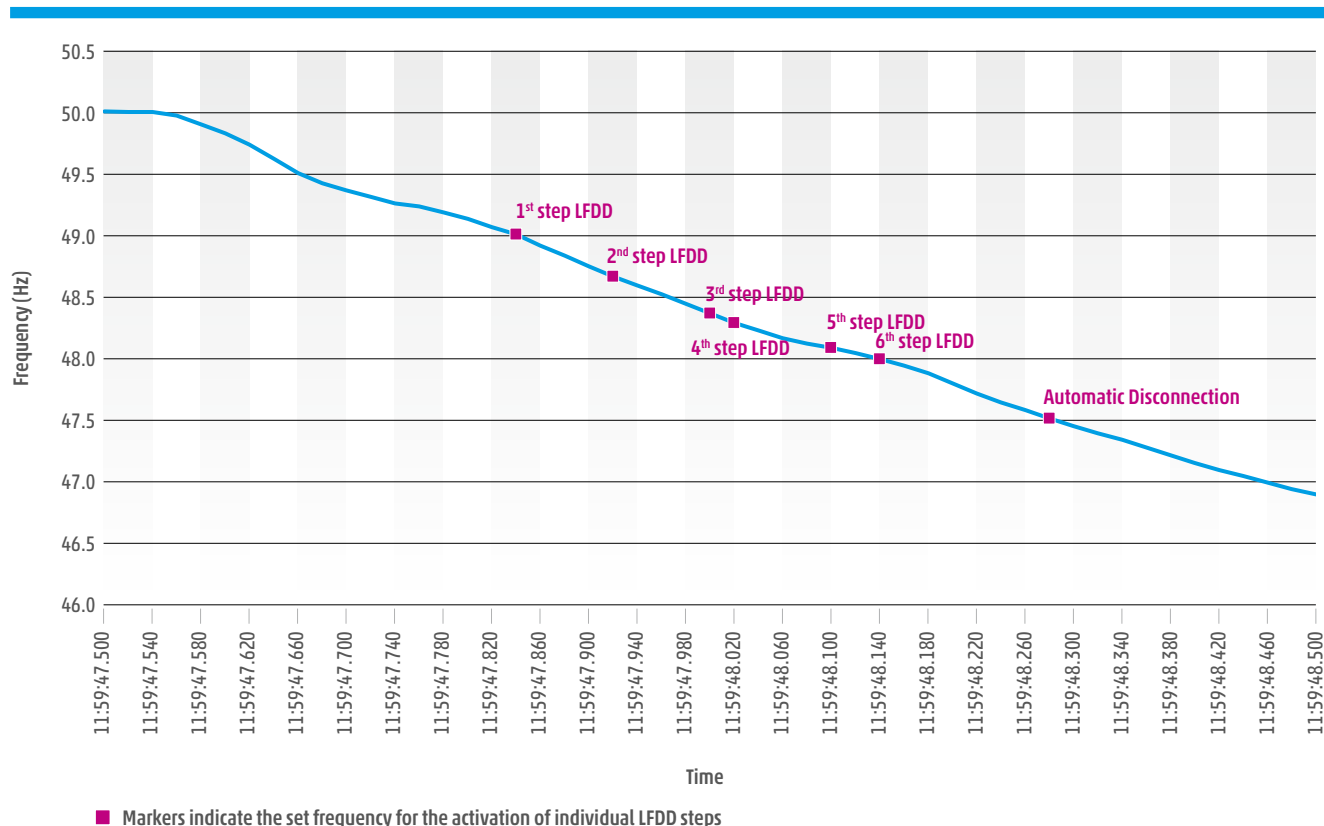


Figure 3.24: Frequency profile during the frequency collapse with indication of the set limits for LFDD steps

The graph clearly shows that due to the rapid frequency drop, there was insufficient time to activate all LFDD steps. The Synchronous Area Framework Agreement for Regional Group Continental Europe²⁰ requires the load to be disconnected within 300 ms. During the incident, only steps 1 and 2 were disconnected before the point of disconnections of all PGMs (at 47.5 Hz) in the island was reached.

Steps 3, 4, 5, and 6 were activated less than 300 ms before reaching 47.5 Hz and therefore had no effect.

The net disconnected value and time difference between reaching the frequency threshold for the activation of each step and the time of reaching the point of disconnection (at 47.5 Hz) is as follows:

Step Number	Frequency Threshold (Hz)	Net Active Power Shed (MW)	Time between frequency threshold and reaching 47.5 Hz (ms)
1	49.0	116.8	440
2	48.7	150.4	360
3	48.4	172	280
4	48.3	78.7	260
5	48.1	136.9	180
6	48.0	111.2	140

Table 3.6: The net disconnected value and time difference between reaching the frequency threshold for activating each step and time of reaching point of disconnection (at 47.5 Hz) during the frequency collapse

During the frequency collapse, the units connected to the transmission system were successfully switched to house-load operation in the affected part of the grid. Specifically, this concerns units 2 and 6 of TPP Počerady and unit 4 of TPP Chvaletice. The generator of Dlouhé Stráně pumped storage was disconnected from pumping mode.

Table 3.7 shows the measured voltage values at individual substations affected by the subsequent voltage outage, recorded at 1-minute intervals from 11:50 to 12:00. These are substations operating at the 400 kV and 220 kV voltage levels.

Substation name (Busbar/line)	11:50	11:51	11:52	11:53	11:54	11:55	11:56	11:57	11:58	11:59	12:00
Babylon (W1)	415.3	415.1	415.0	409.8	412.1	414.8	413.1	415.4	413.8	415.2	0.0
Bezděčín (W1)	418.2	418.3	416.3	413.1	415.2	413.2	413.4	414.1	413.7	415.4	0.2
Chodov (W11)	415.6	415.6	415.6	415.6	416.0	415.6	409.4	409.0	409.5	410.3	0.0
Chotějovice (W11)	410.8	410.8	410.0	409.6	410.5	410.3	410.4	412.4	411.0	410.3	0.0
Čechy Střed (W1)	417.0	416.8	410.1	403.5	408.0	408.4	406.8	408.4	409.2	410.3	0.0
Krasíkov (W1)	415.5	416.4	396.6	389.7	389.6	390.3	389.2	392.3	392.5	391.6	385.0
Neznášov (W1)	418.8	418.8	415.8	415.8	414.8	416.0	415.3	416.6	415.3	414.8	0.0
Týnec (W1)	416.7	416.7	411.1	405.2	404.7	405.3	404.2	405.7	406.4	406.9	0.0
Vyškov (V419)	411.6	411.6	413.1	410.7	412.6	410.6	410.9	410.9	413.2	412.9	0.0

Table 3.7: Measured voltage at impacted 400 kV substations from 11:50 to 12:00

Substation name (Busbar)	11:50	11:51	11:52	11:53	11:54	11:55	11:56	11:57	11:58	11:59	12:00
Bezděčín (W1)	231.6	231.6	222.7	218.5	219.6	217.7	218.6	217.9	218.4	218.7	0.1
Chotějovice (W1)	230.7	230.4	222.8	218.8	219.1	215.9	218.0	218.4	218.7	218.5	0.3
Čechy Střed (W3)	233.4	233.4	223.4	219.5	220.0	220.4	220.6	220.2	221.0	221.0	0.0
Malešice (W11)	234.3	234.1	224.2	222.4	221.9	221.1	221.6	223.0	223.2	222.7	0.0

Table 3.8: Measured voltage at impacted 220 kV substations from 11:50 to 12:00

Although the V411 outage caused a redistribution of power flows, leading to changes in voltage levels, no voltage deviations beyond the normal operating range were observed.

The lowest voltage values at the 400 kV level were consistently recorded at the Krasíkov substation, at around 390 kV.



3.4 Protection system performance during the event

Just as in any electrical system, the basic objectives that one aims to achieve with the design, setup and maintenance of a protection system in large interconnected power systems are to avoid dangerous situations for people, limit the damage to the components of the electrical system when an anomaly or failure occurs, minimise the consequences of the discontinuity of

service in any network situation, and mitigate the risk of transient instability in the transmission network.

In this section, the operation of the protection system will be analysed using available data, primarily the SCADA event lists and the disturbance fault recordings (DFRs).

Sequence of events

*All indicated times are GPS-based times from protections.
They might differ from the times indicated by SCADA in the rest of the report.*

11:51:06.187

One subconductor from the bundled phase conductor of phase 2 of the line V411 broke and fell to the ground. The length of the line is 45.4 km. Distance protection relays detected a fault 15 km from the HRA4 substation and 35 km from the VYS4 substation.

The fault was ultimately located 14 km from the HRA4 substation. The fault was switched off in 81 ms.

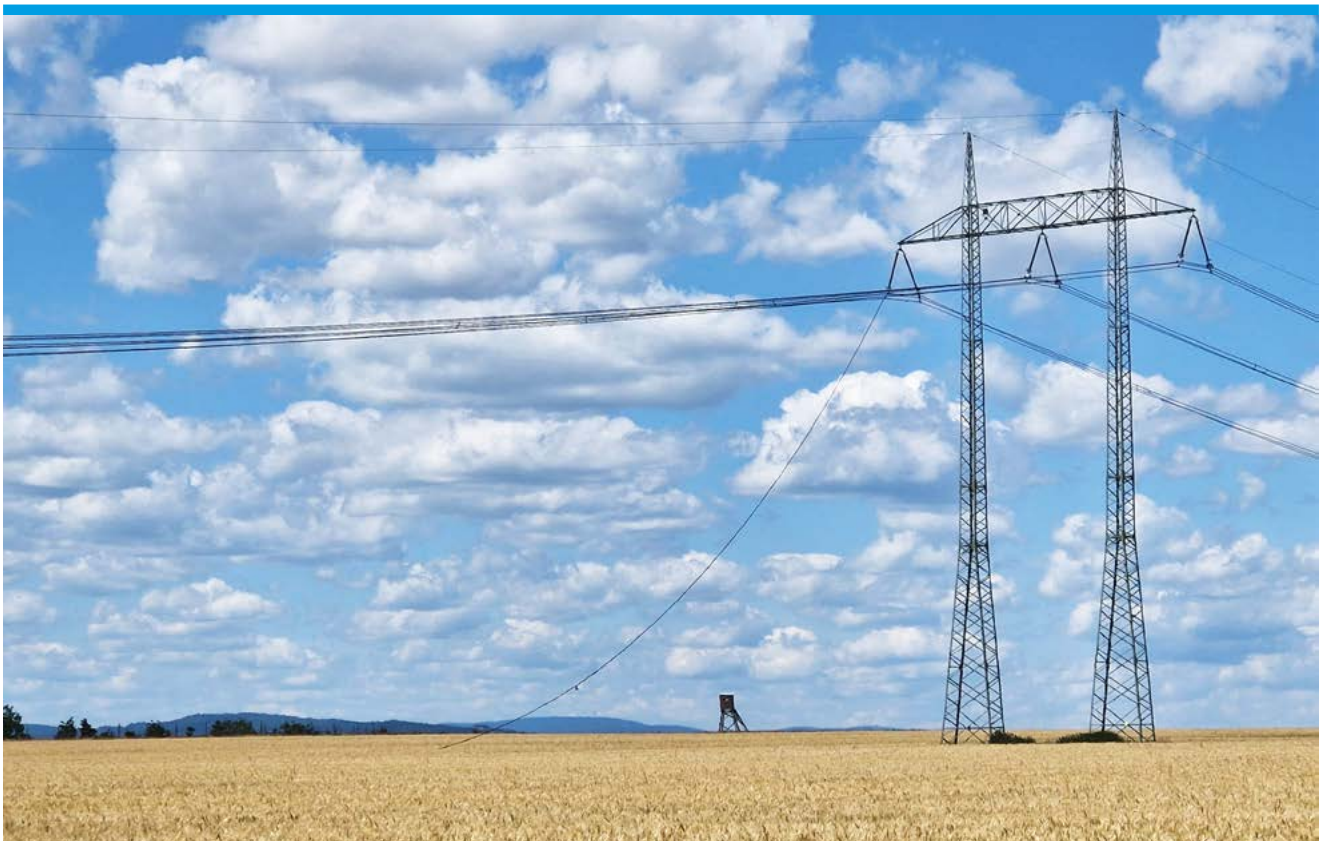


Figure 3.25: Photo of the fallen conductor



11:51:06.268

The fault current flow to the affected phase of line V411 was interrupted by opening circuit breakers in phase 2 at both ends.

11:51:07.559

Following the unsuccessful automatic reclosing attempt, circuit breakers of line V411 at the VYS4 and HRA4 substations were tripped in all phases. The protection system operated in accordance with its setting.

In the area of the future island, a loss of generated power occurred in both transmission- and distribution-connected systems.

11:59:44.066

Based on a manual command from the SCADA, issued by the dispatcher, transmission line V208 was disconnected by opening a circuit breaker at the CST2 substation. Prior to the disconnection of line V208, current measurements exceeded the measuring transducer's range. The line loading must have exceeded 900 A. The line has a nominal ampacity of 650 A. Nevertheless, the mathematical dynamic line rating (DLR) model is applied. According to DLR, actual ampacity was $I_{\max} = 724 \text{ A}$. No protection relays of line V208 operated, consistent in accordance with their settings.

11:59:44.488

Overcurrent protection pickup in a busbar coupler at the KRA4 substation. The busbar coupler was connecting two busbars. Transmission line V401, together with the unit line to the Dlouhé Stráně pumped storage hydroelectric power plant (EDST), was connected to one of the busbars. The remaining two transmission lines were connected to the other busbar. The pumped storage plant was operating in pumping mode. The load active power of the plant was about 311 MW. The overcurrent protection setting is 2,880 A, with an operating time delay of 3 s. The relay's drop-out ratio is 0.95. The nominal current of the busbar coupler is 2,000 A. The peak current during protection initiation was 2,810 A in phase L2, which falls within the manufacturer's specified tolerance of 5 % of the configured setting.

11:59:47.486

The overcurrent protection at the KRA4 substation issued a trip signal to the busbar coupler circuit breaker. At the time of tripping, the highest current was still 2,780 A. The overcurrent protection operated in accordance with its settings. The reason was an exceedance of the defined current limit of 2,880 A for a duration longer than 3 s. After the protection has been activated, the measured current must decrease to 0.95 times the set value, i.e. $0.95 \times 2,880 = 2,736 \text{ A}$, to allow the time-delay element to reset and prevent tripping within the configured time. Since the feeder was still carrying a current of 2,780 A when the trip command was issued to the circuit breaker, the feeder was tripped.

11:59:47.534

The circuit breaker in the busbar coupler at the KRA4 substation was tripped in all three phases.

11:59:47.574

The distance protection of the T401 transformer at the KRA4 substation issued a trip signal. The T401KRA and T402KRA transformers were connected to different busbars on the primary side and were operating in parallel. After the busbar coupler on the primary side was tripped, current began to flow between the busbars through these transformers. The transformer T401 was overloaded, causing the measured impedance to enter the protected zone in the direction toward the transformer, where the distance protection operates without delay. The load encroachment setting is 20.3 Ohms, corresponding to a secondary-side current of 3,110 A at a measured voltage of 63.2 kV. Converted to the primary side via the T401KRA transformer with tap position 7 (400/133 kV), this equals 1,030 A. According to the fault recorder, which records current on the primary side, the current flowing through the transformer was 1,130 A. The nominal current of the transformer on the primary side is 505 A. The distance relay operated in line with the applicable accordance with its settings.

11:59:47.607

The T401KRA transformer was tripped in all three phases. **Islanding conditions were initiated.**



11:59:48.319

Dlouhé Stráně (EDST) pumped storage: Opening of the HG2 EDST generator circuit breaker. Disconnection of HG2 EDST from pumping mode. The tripping impulse was triggered by the frequency protection with a setting of 48.5 Hz and a delay of 0.1 s. This configuration represents the frequency protection of the motor generator in pumping mode. Although the frequency dropped below the activation threshold of other frequency protections set according to the defence plan, the frequency drop was so rapid that the preceding protection levels did not have time to activate.

Threshold value f [Hz]	Time delay t [s]	Function
>53.0	1	Trip of the HG
>52.1	60	Trip of the HG
<49.8	1	Controlled shutdown
<49.2	1	Trip of the HG
<48.5	0.1	Trip of the HG

Table 3.9: Setting of frequency protection for pumping mode

11:59:49.346

Ledvice coal-fired power plant (ELED): The transfer trip command was received from the TG6 generator to the circuit breaker of the V016 unit line at CHT4.

The tripping impulse was triggered by the frequency protection. When the frequency deviated by -2.5 Hz from the nominal value, it sent the impulse to trip the circuit breaker.

Threshold value f [Hz]	Time delay t [s]	Function
49.8	0	Island control mode
47.5	1	Trip to house-load operation

Table 3.10: Frequency protection setting for the Ledvice coal-fired power plant (ELED)

11:59:49.349

Chvaletice coal-fired power plant (ECHV): The transfer trip command was received from the TG4 generator to the circuit breaker of the V472 unit line at TYN4.

The frequency protection triggered the tripping impulse. When the frequency deviated by -2.5 Hz from the nominal value, it sent the impulse to trip the circuit breaker.

Threshold value f [Hz]	Time delay t [s]	Function
53.0	30	Trip of the TG
53.0	6	Trip to house-load operation
50.2	0	Island control mode
49.8	0	Island control mode
47.5	1	Trip to house-load operation
46.5	30	Trip of the TG

Table 3.11: Frequency protection setting for the Chvaletice coal-fired power plant (ECHV)

11:59:49.349

Počerady coal-fired power plant: The transfer trip command was received from the TG2 generator to the circuit breaker of the V467 unit line at VYS4. The frequency protection triggered the tripping impulse. When the frequency deviated by -2.5 Hz from the nominal value, it sent the impulse to trip the circuit breaker, and the generator switched to supplying its own auxiliary supply.

Threshold value f [Hz]	Time delay t [s]	Function
53.0	6	Trip to house-load operation
50.2	0	Island control mode
49.8	0	Island control mode
47.5	1	Trip to house-load operation
47.0	1.5	Trip of the TG

Table 3.12: Frequency protection setting for the Počerady coal-fired power plant (EPOC) TG2





11:59:49.367

Počerady (EPOC) coal-fired power plant: The transfer trip command was received from the TG6 generator to the circuit breaker of the V469 unit line at VYS4. The frequency protection triggered the tripping impulse. When the frequency deviated by -2.5 Hz from the nominal value, it sent the impulse to trip the circuit breaker, and the generator switched to supplying its own auxiliary supply.

Threshold value f [Hz]	Time delay t [s]	Function
53.0	6	Trip to house-load operation
50.2	0	Island control mode
49.8	0	Island control mode
47.5	1	Trip to house-load operation
47.0	1.5	Trip of the TG

Table 3.13: Frequency protection setting for the Počerady coal-fired power plant (EPOC) TG6

11:59:49.374

The circuit breaker of the V016 line at CHT4 was tripped in all three phases.

11:59:49.397

The circuit breaker of the V472 line at TYN4 was tripped in all three phases. Successful transition of TG4 ECHV to house-load operation mode.

11:59:49.397

The circuit breaker of the V467 line at VYS4 was tripped in all three phases. Successful transition of TG2 EPOC to house-load operation mode.

11:59:49.414

The circuit breaker of the V469 line at VYS4 was tripped in all three phases. Successful transition of TG6 EPOC to house-load operation mode.



4 RESTORATION PROCESS

4.1 Restoration sequences

At 11:59:47, the busbar coupler at the Krasíkov 400 kV substation and the 400 kV/110 kV T401 transformer at the Krasíkov/110 kV substation were tripped due to overloading.

This led to the separation from the grid of eight 400 kV substations and three 220 kV substations. The IO was unbalanced and immediately collapsed.

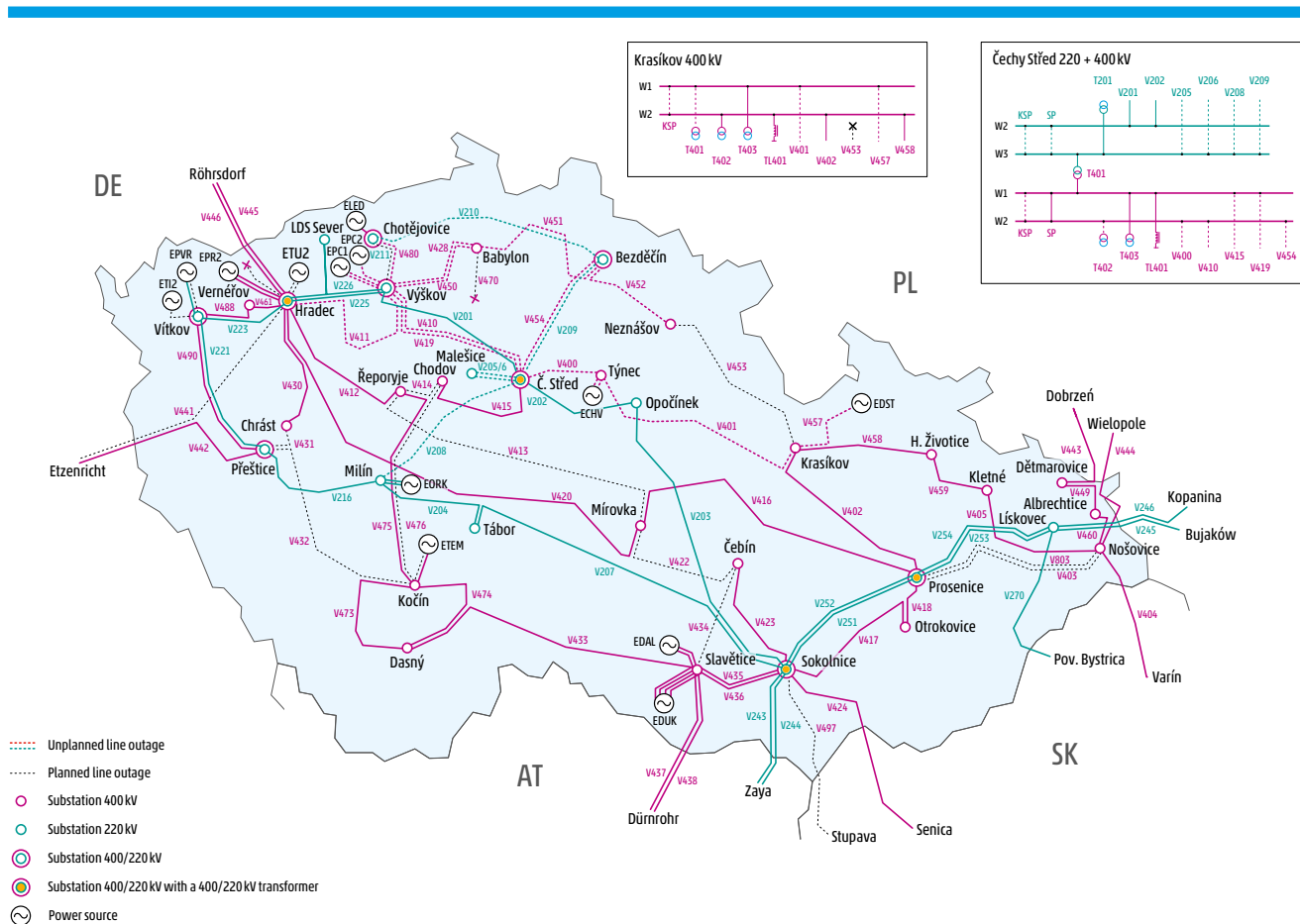


Figure 4.1: Situation of the Czech Republic transmission system on 4 July 2025 at 12:00

Immediately after the incident, dispatchers initiated the top-down restoration strategy. They gathered information on the condition of the Počerady and Chvaletice power plants in the affected area, which remained in the house-load operation mode, with the aim of exploring all possible restoration options.

During the restoration process, the dispatcher is obliged to follow the internal procedure that has been created with respect to the possible physical phenomenon called ferroresonance. This means that dispatchers strictly follow the top-down restoration strategy: whenever

they energise a busbar in a substation by reconnecting an OHL, they must switch a transformer and request the connection of a load of approximately 15 MW at a 400 kV substation and 10 MW at a 220 kV substation.

At 12:19, the dispatcher reconnected the 400 kV OHL (Krasíkov–Týnec) V401 to restore voltage at the Týnec 400 kV substation, mainly to continue energising the rest of the affected substations. With the voltage on the busbars at the Týnec 400 kV substation, the dispatcher synchronised the Chvaletice unit 4 powerplant and energised other blocks' house load at 12:41.

At 12:21, ČEPS operators received information about the instability of the house-load operation of the Počerady power plant. The power plant requested energising at least one 110 kV line to feed their consumption. The ČEPS operator ordered the operator of the 110 kV grid to set up a path from the Verněřov 110 kV substation to the 110 kV substation of the Počerady power plant to secure the household load operation.

Simultaneously, dispatchers were restoring the voltage of the 220 kV grid. First, they coupled two main busbars in the Čechy Střed 220 kV substation, closing the busbar coupler that had been open after the reconfiguration implemented before the incident. Subsequently, the dispatcher reconnected the Milín–Čechy Střed 220 kV OHL V208. At 12:30, two 220 kV parallel OHLs V205/V206 (Čechy Střed–Malešice) were reconnected together with both 220 kV transformers in the 220 kV Malešice substation to energise the Malešice 110 kV substation to restore the load in Prague. Once the Čechy Střed 220 kV substation was energised, the dispatcher reconnected the Čechy Střed–Bezděčín 220 kV OHL V209 and then the Bezděčín–Chotějovice 220 kV OHL V210 to restore the load in this area.

At 12:51:22, the dispatcher reconnected the Týnec–Čechy Střed 400 kV OHL V400 and then switched on the 400 kV/110 kV T403 transformer to restore the load. At that time, the dispatchers had to decide whether it was better to have two isolated paths (first: Milín 220 kV substation – Milín–Čechy Střed 220 kV OHL V208 – Čechy Střed 220 kV substation – Čechy Střed–Malešice 220 kV parallel OHLs V205/V206 – Malešice 220 kV substation; second: Krasíkov 400 kV substation – Krasíkov–Týnec 400 kV

OHL V401 – Týnec–Čechy Střed 400 kV OHL V400 – Čechy Střed–Chodov 400 kV OHL V415) or couple them. They decided to secure the restoration of the load in Prague by coupling the two paths. Therefore, at 12:57, dispatchers reconnected the 400 kV/220 kV transformer, connecting the Čechy Střed 400 and 220 kV substation.

At 13:01, the dispatcher reconnected the Čechy Střed–Chodov 400 OHL V415 to energise the busbars in the Chodov GIS 400 kV substation. Subsequently, in cooperation with the DSO, they energised two 400 kV/110 kV transformers (T401 and T403) to restore the load in Prague.

At 13:11, the dispatcher reconnected the Čechy Střed–Výškov 400 kV OHL V419, and one busbar at the Výškov 400 kV substation was energised for the possibility of synchronising units 2 and 6 of the Počerady TTP, which remained in house-load operation. After a short break needed for stabilisation at the Počerady power plant, the dispatcher closed the circuit breaker on the Výškov–Počerady 400 kV line V467 and synchronised unit 2 to the grid.

At 13:24, the dispatcher reconnected the Čechy Střed–Bezděčín 400 kV OHL V454, and at 13:35, the transformer at the Bezděčín 400 kV substation to restore the load.

At 13:30, the dispatcher energised the second busbar at the Výškov 400 kV substation. At 13:38, the dispatcher energised the T401 transformer at the 400 kV Výškov substation.



At 14:20, the dispatcher obtained information that CCGT Počerady 2 would be able to synchronise around 15:00.

At 14:20, the dispatcher ordered the DSOs to stop connecting new loads until the start of CCGT Počerady 2. The reason was a very high N-1 violation (up to 180 %) on the 220 kV V208 line.

At 14:40, the dispatcher switched on the T401 transformer at the Krasíkov 400 kV substation.

At 15:00, the ČEPS crisis team commenced its meeting.

At 15:10, the DSO for the northern part of the Czech Republic fixed the technical issue with the control of the 110 kV Babylon substation, so dispatchers switched on both transformers there.

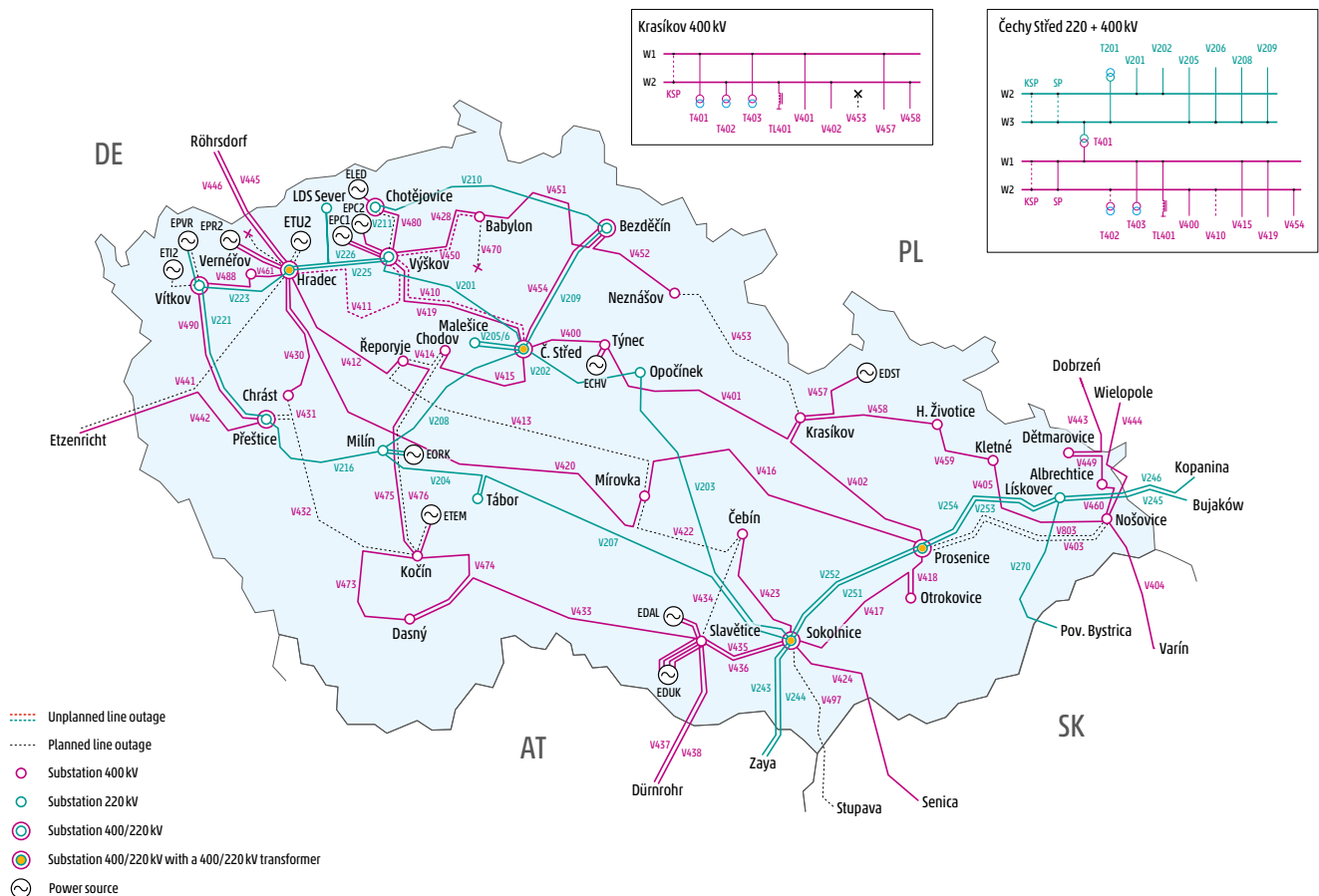


Figure 4.3: Situation in the Czech Republic transmission system on 4 July 2025 at 15:10

At 15:37, the dispatcher switched on the 400 kV/110 kV transformer T402 at the Bezděčín substation.

At 17:35, the dispatcher obtained information from DSOs that the load was fully restored.

At 23:00, the repair of the broken conductor on the OHL V411 was completed; therefore, the dispatcher could initiate its switching on.

At 23:13, the Hradec–Výchov 400 kV OHL V411) was reconnected.



4.2 Communication and coordination during the restoration process

Immediately after the outage, all area dispatchers made several phone calls to exchange and share information with DSOs and power plants. As far as they had complex knowledge of the situation, they defined the restoration strategy and set the critical situation message in EAS, together with the change to the Emergency state. Subsequently, dispatchers made more than 200 phone calls, mainly to DSOs and power plants, throughout the restoration process.

The dispatchers were regularly in touch with the synchronous area monitor Amprion, TSCNET, and neighbouring TSOs. At 12:05, Amprion contacted the ČEPS control centre regarding the significant deficit in the ČEPS control area. They received information about the incident in the grid

and the ongoing restoration process. At 12:30, the operator of TSCNET contacted the control centre of ČEPS with a question about the change of system state to emergency. He was informed about the significant outage in the Czech transmission system.

At 13:22 and 14:23, Amprion received updates on the status of restoration, the cause of the incident, and the status of the unaffected part of the system, including the supply to the NPP's house load. The NPP's house load supply was not affected by the incident. At 17:50, the ČEPS operator informed TSCNET of the completed grid restoration and preparedness for the DACF process. He explained that the V411 line would be operational in the next few hours.

4.3 Generation recovery actions

At 12:21, ČEPS operators received information about instability in the house-load operation of the Počeradý power plant. They requested energising of at least one 110 kV line to feed their consumption. The ČEPS operator ordered the operator of the 110 kV grid to establish a path from the Vernéřov 110 kV substation to the 110 kV substation of the Počeradý power plant to secure household load operation. At 12:51, the dispatcher obtained information about the secured supply of the house load of the Počeradý power plant from the 110 kV grid (supplied from the Vernéřov 110 kV substation), resulting in a prolonged time in this house-load operation mode.

With energisation of the busbars at the Týnec 400 kV substation, the dispatcher planned to synchronise unit 4 of the Chvaletice power plant. There was a minor misunderstanding due to the interpretation of the state of this block in the dispatcher's SCADA, but after reaching a common agreement with the Chvaletice operator on the unit's actual state, the dispatcher successfully synchronised unit 4 to the grid at 12:41.

At 12:45:36, the dispatcher reconnected the 400 kV OHL (Krasíkov–Dlouhé Stráně) to energise the Dlouhé Stráně 400 kV substation and the pump storage's house load.

At 12:46:35, the dispatcher closed the circuit breaker of the 400 kV OHL V471 (Týnec–Chvaletice units 1 and 2) to energise its house load and be ready to synchronise the generator to the grid and support the restoration of load in the affected area.

At 13:01, the dispatcher inquired about the real state of unit 4 at the Chvaletice TTP, and at 13:06 ordered unit 4 to switch from droop speed control mode to power control mode and started ramping up from 5 MW to 100 MW. At 13:18, the dispatcher ordered the unit 4 operator to manually lower the generator's excitation due to a fault in the automatic voltage control signalled in SCADA. At 13:27, unit 4 reached 100 MW.

In cooperation with the operator of the Počeradý TTP, the dispatcher synchronised unit 2 to the grid at 13:26. The dispatcher was informed of technical problems with the system for transporting coal to the boiler. Therefore, unit 2's available power was limited to 120 MW at that time. The dispatcher ordered the unit 2 operator to switch the turbine controller from droop speed control to power control and the excitation controller to automatic voltage control.

At 13:29, the dispatcher inquired with the operator of TPP Chvaletice about the time required for starting and ramping another unit. The operator of TPP Chvaletice replied that it takes at least 4 h, so Unit 2 and Unit 1 could be synchronised at 17:30. He promised that they would try to speed it up.

At 13:37, the operator of the ČEZ generation control centre requested synchronisation of the pumped storages at Dlouhé Stráně and Dalešice. The ČEPS dispatcher rejected the Dlouhé Stráně power plant's pumping mode because it would have affected the affected area.



At 14:14, TPP Počerady units 2 and 6 reached 120 MW each.

At 16:58, the dispatcher cancelled the ban on pumping at the Dlouhé Stráně power plant. At 17:07, Dlouhé Stráně started pumping.

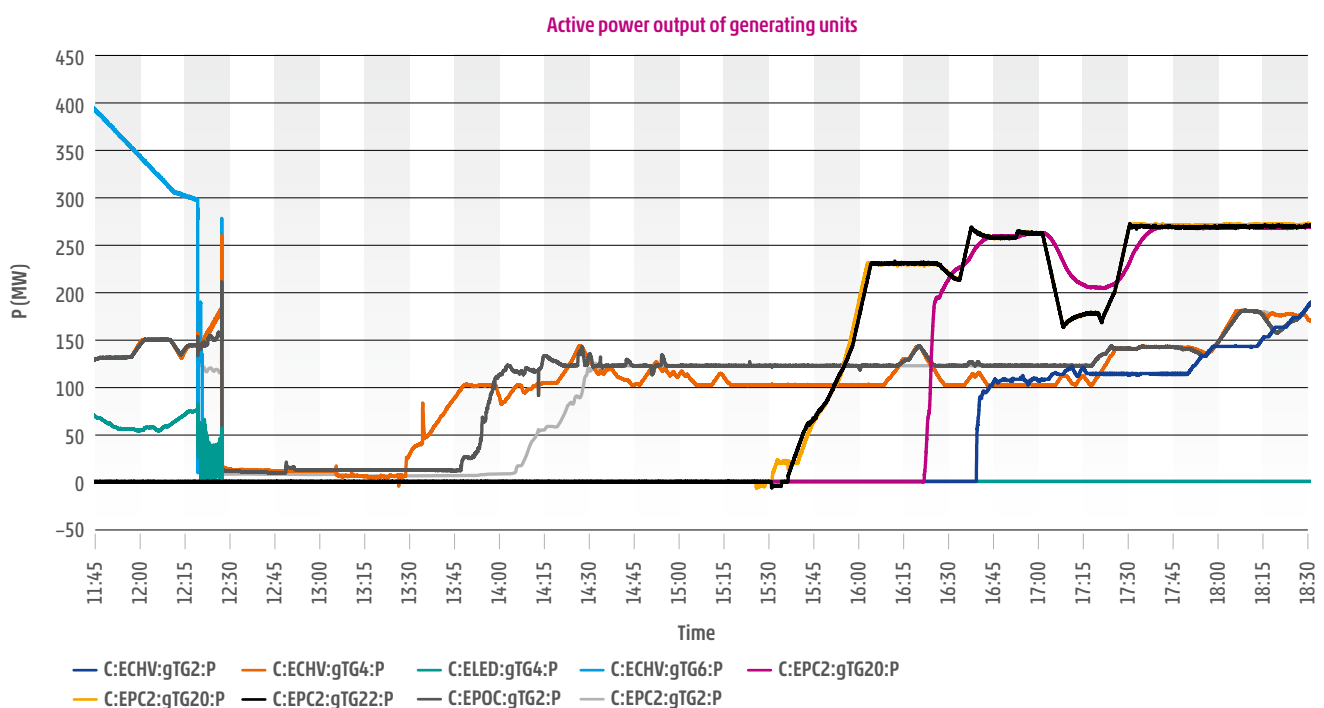


Figure 4.4: Active power output of generating units

4.4 Load recovery actions

The restoration of the load began in a DSO-TSO cooperative effort immediately after the incident.

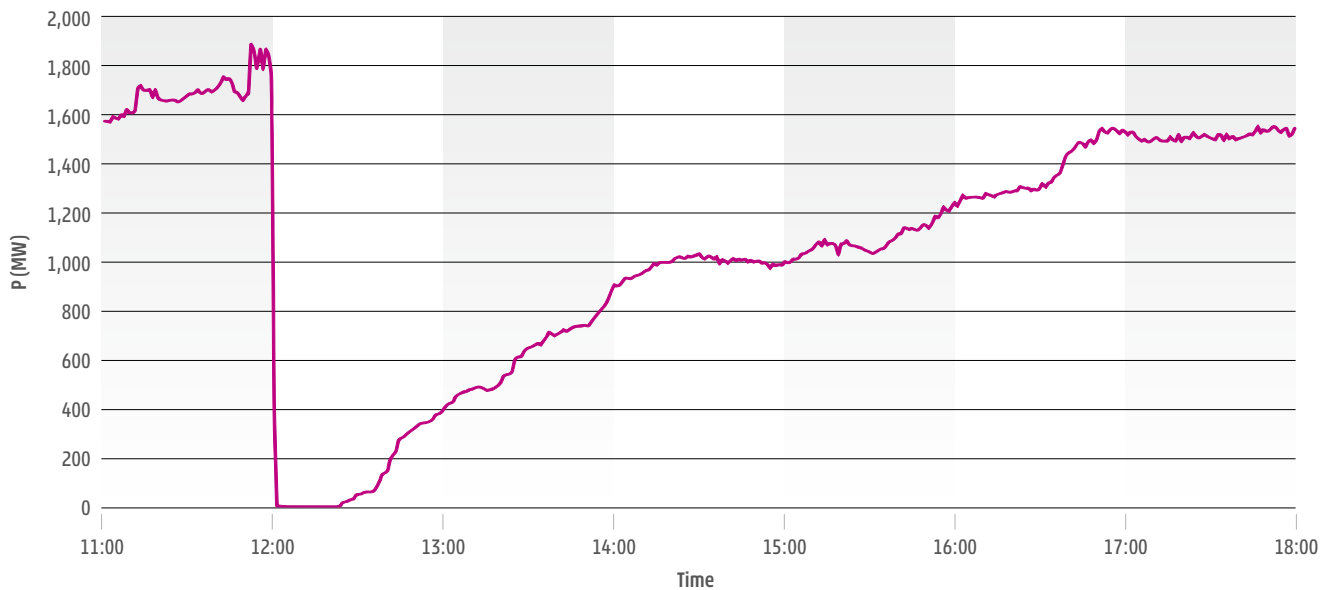


Figure 4.5: Load restoration

Krásíkov

The T402 and T403 400 kV/110 kV transformers were not affected by the incident since they were connected to the unaffected busbar at the Krásíkov 400 kV substation.

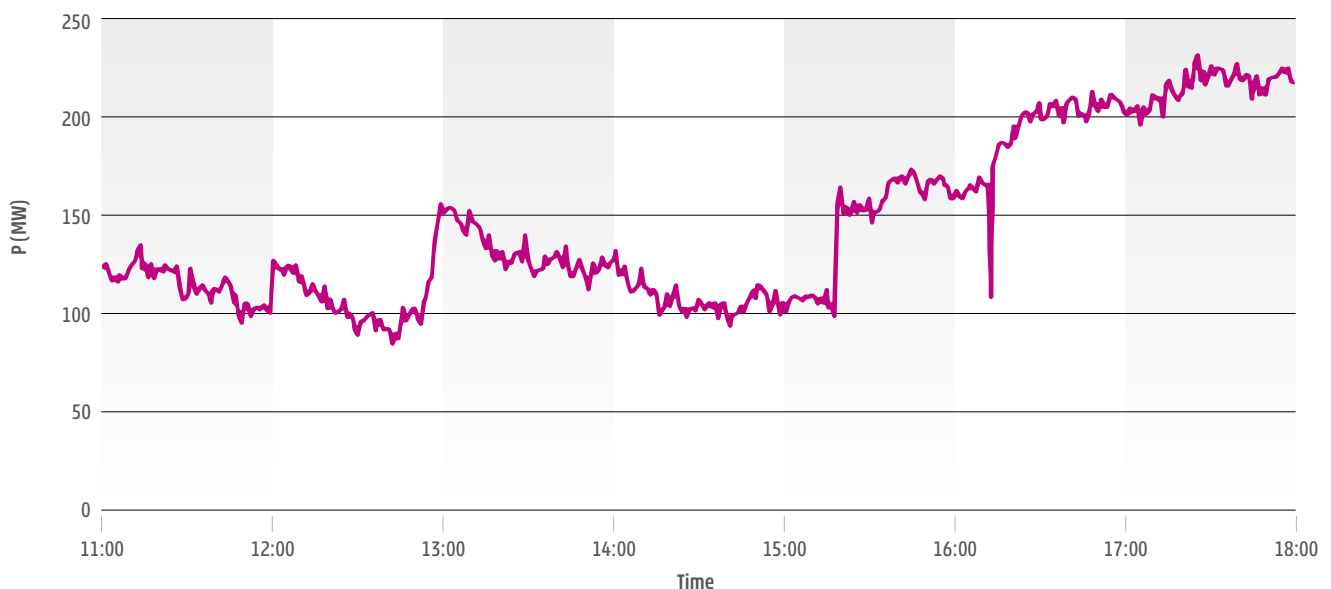


Figure 4.6: Load restoration of the T402KRA and T403KRA 400 kV/110 kV transformers



The T403 400 kV/110 kV transformer was connected to the affected busbar of the Krasíkov 400 kV substation. Therefore, the 110 kV area connected to this transformer was without voltage after the incident.

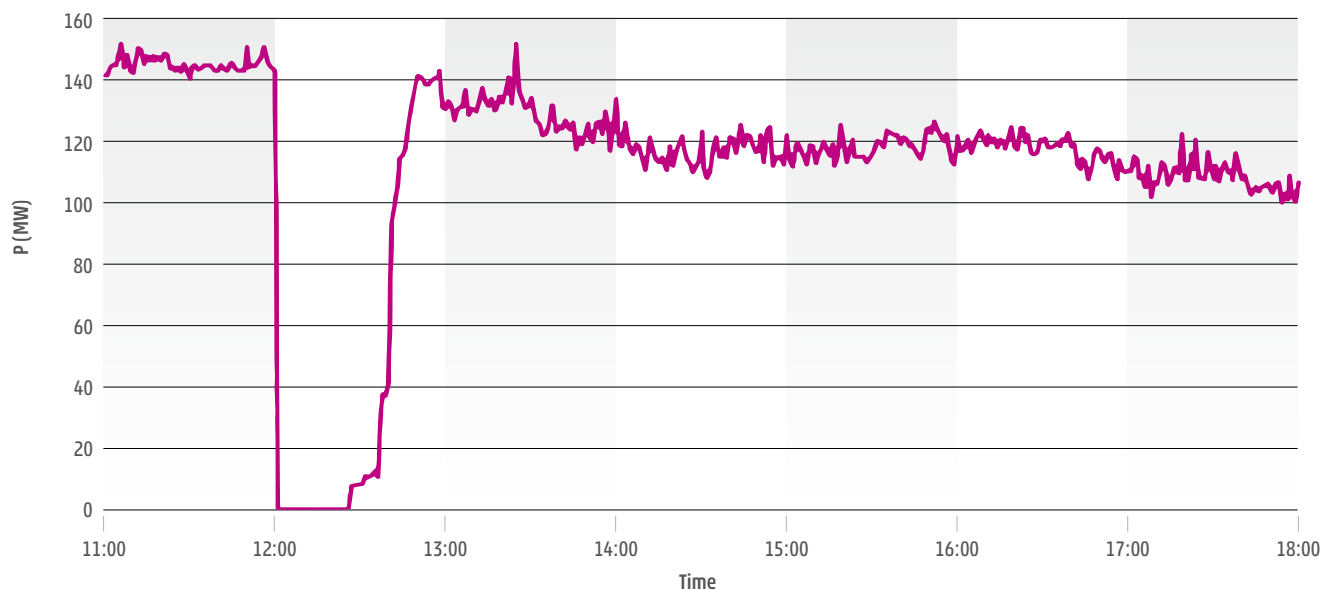


Figure 4.7: Load restoration of the T403KRA 400 kV/110 kV transformer

Týnec

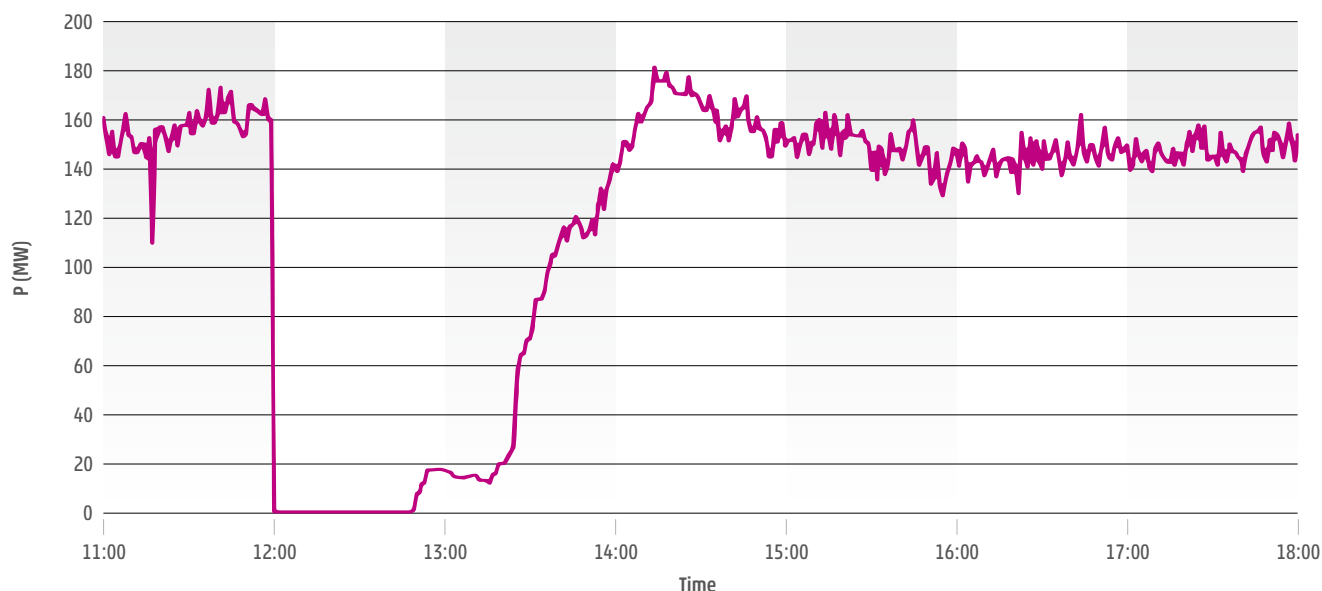


Figure 4.8: Load restoration of the T401TYN and T403TYN 400 kV/110 kV transformers



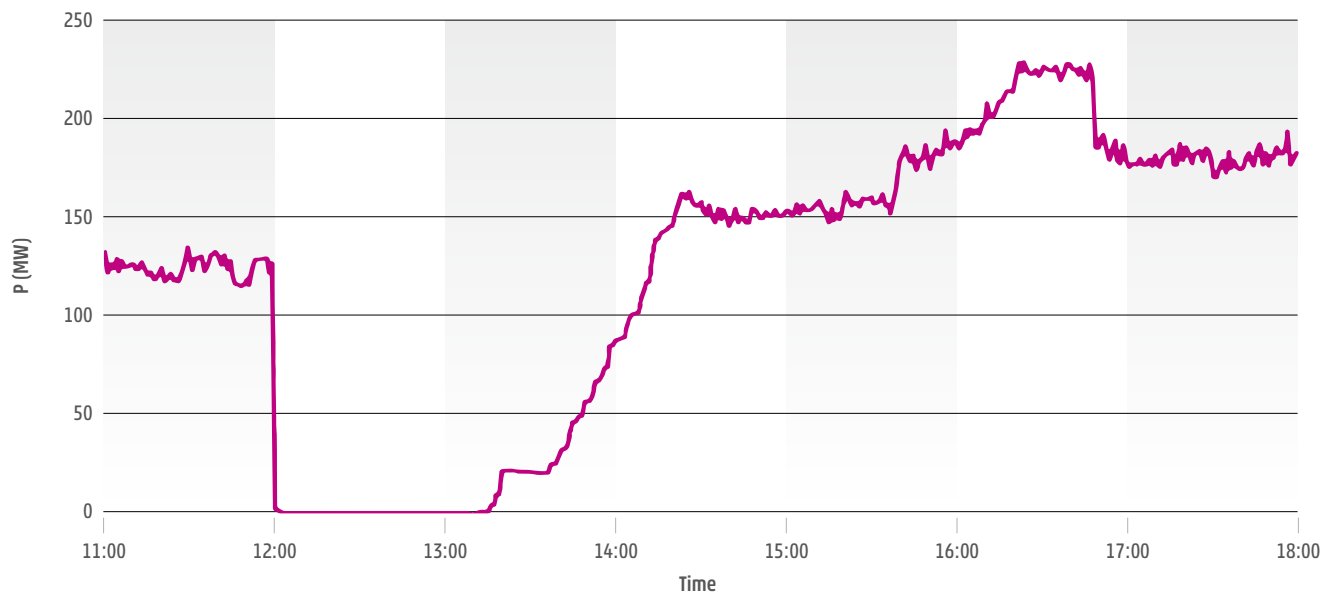


Figure 4.9: Load restoration of the T403CST 400 kV/110 kV transformer

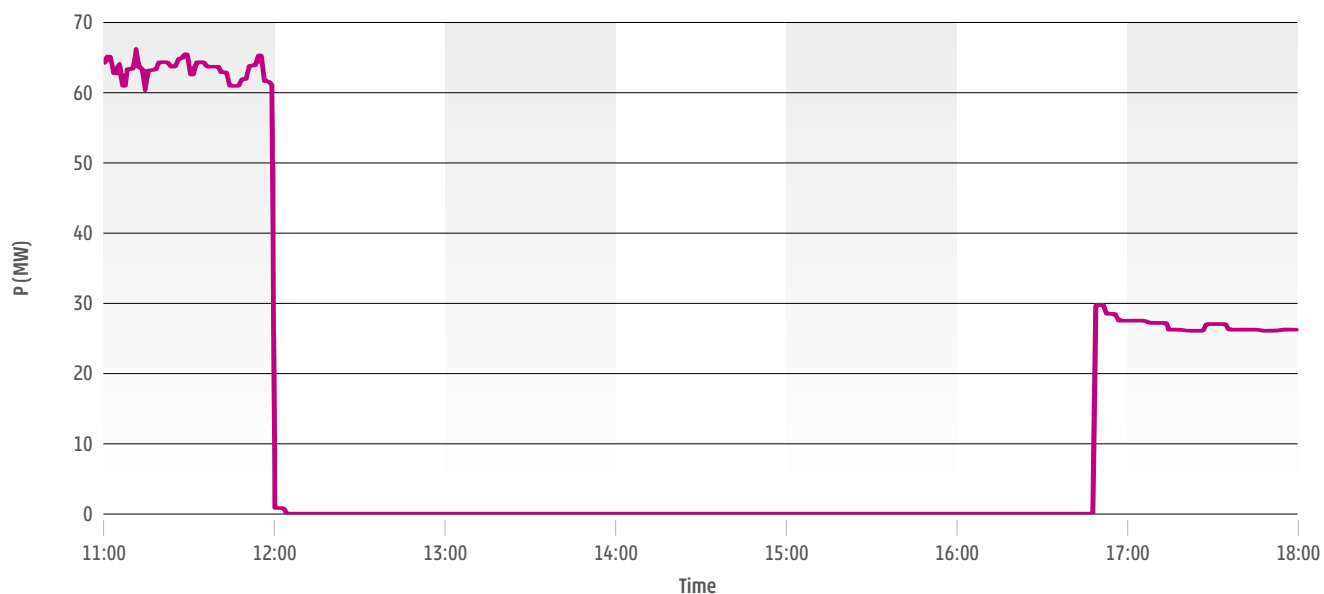


Figure 4.10: Load restoration of the T201CST 220 kV/110 kV transformer



Malešice

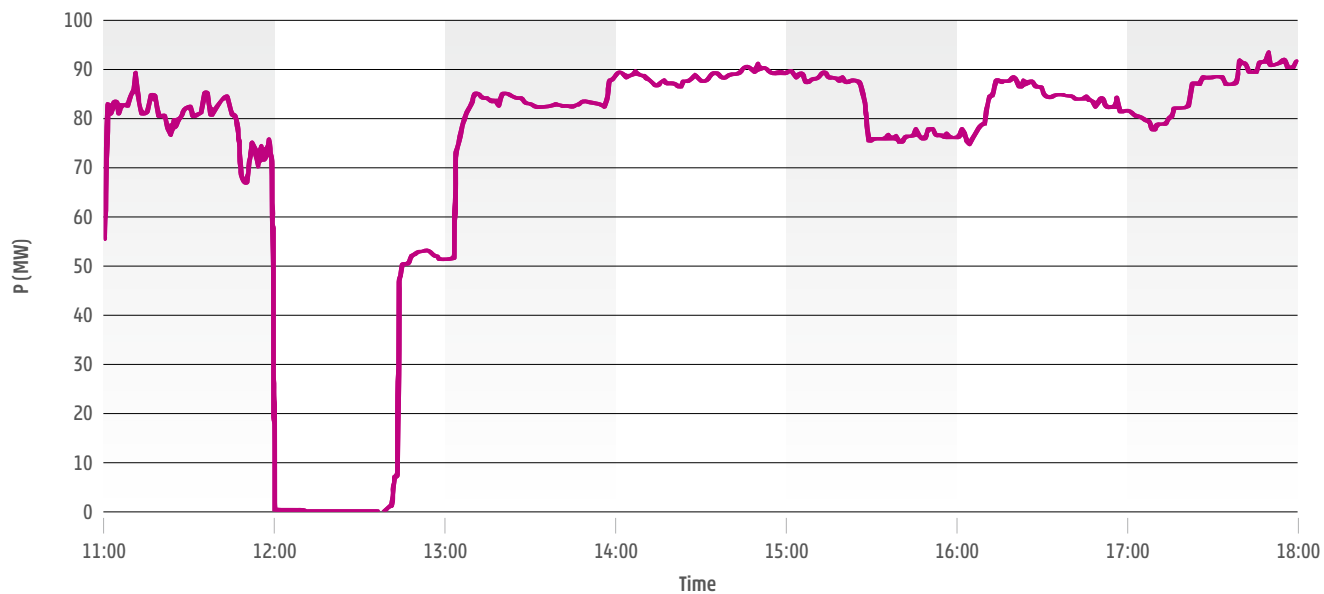


Figure 4.11: Load restoration of the T201MAL and T202MAL 220 kV/110 kV transformers

Chodov

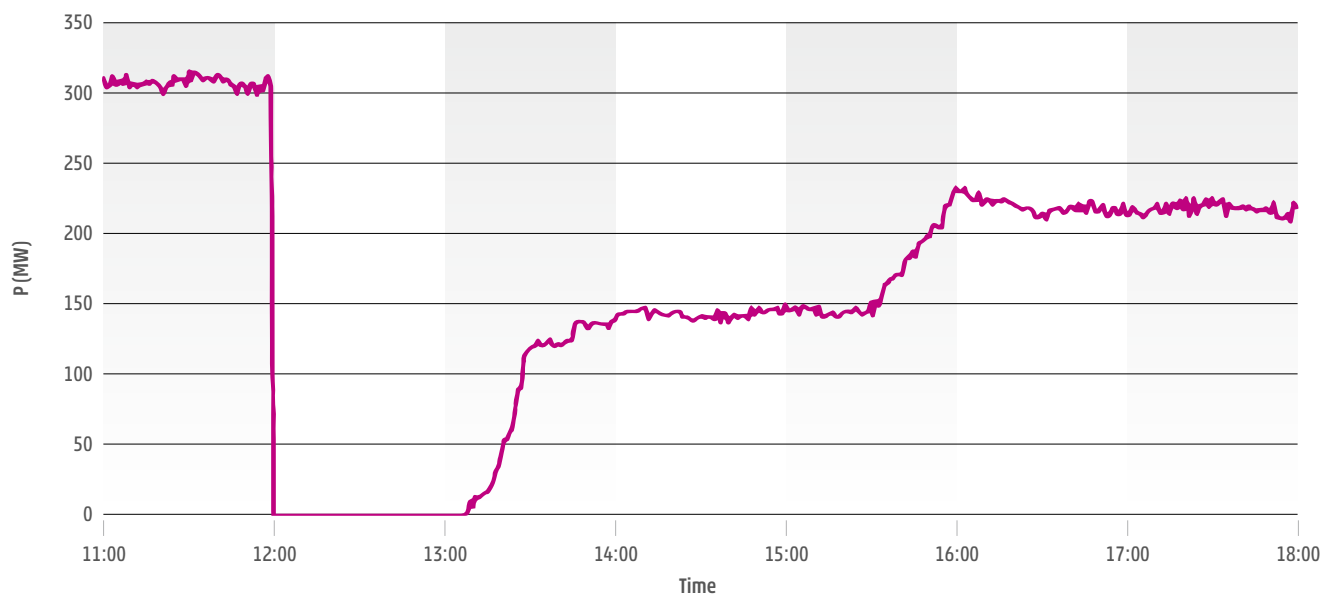


Figure 4.12: Load restoration of the T401CHD and T403CHD 400 kV/110 kV transformers



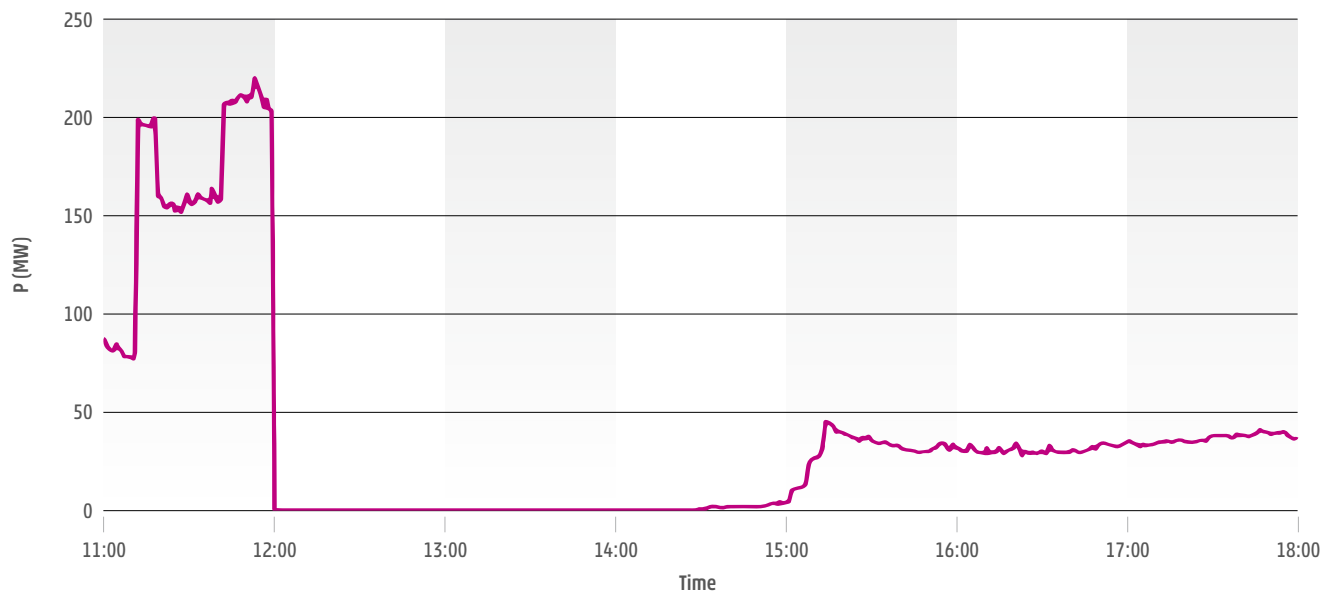


Figure 4.13: Load restoration of the T401VYS 400 kV/110 kV transformer

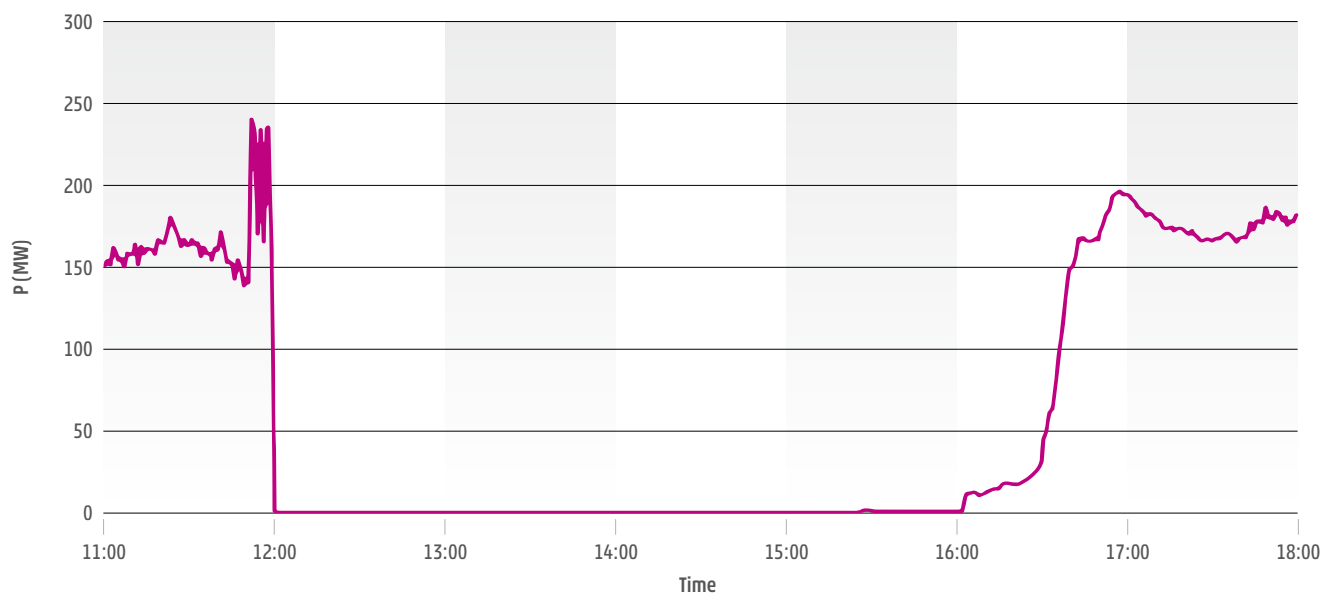


Figure 4.14: Load restoration of the T402CHT 400 kV/110 kV transformer



Babylon

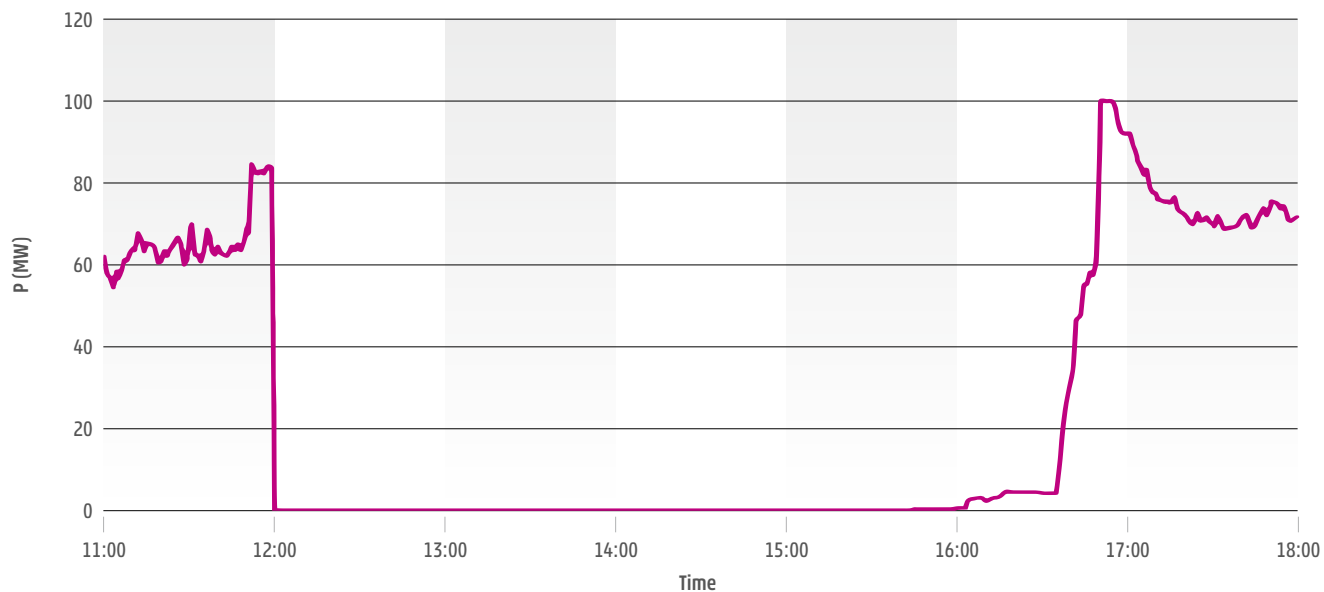


Figure 4.15: Load restoration of the T402BAB and T403BAB 400 kV/110 kV transformers

Bezděčín

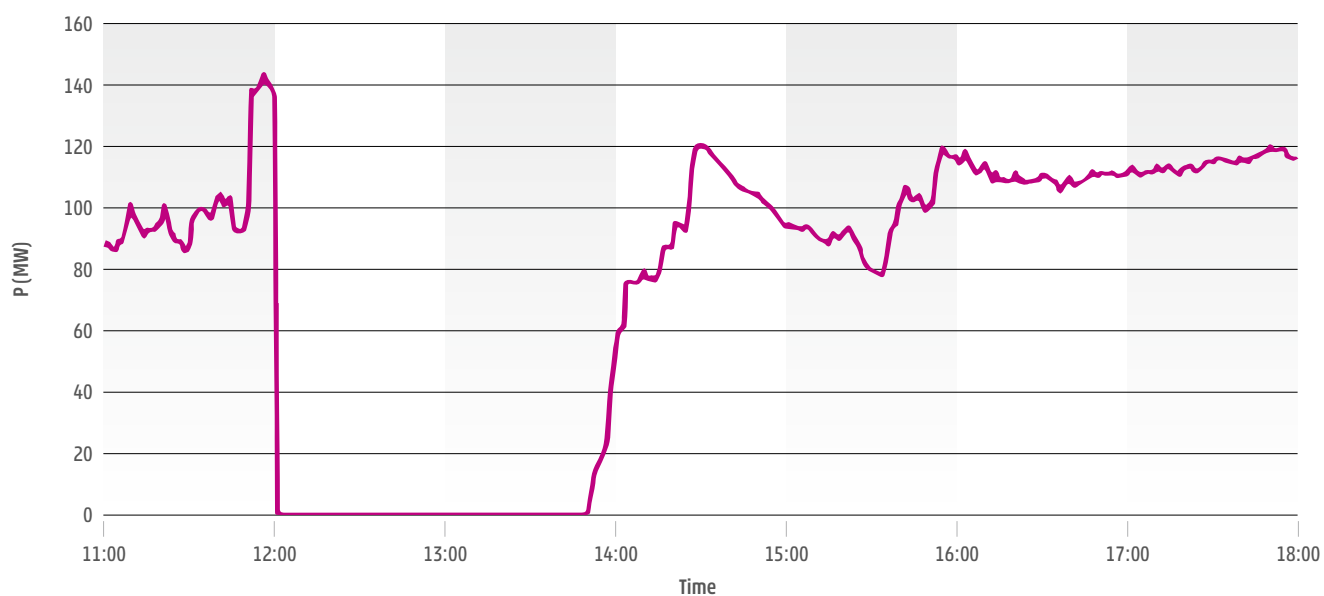


Figure 4.16: Load restoration of the T401BEZ 400 kV/110 kV transformer



Řeporyje

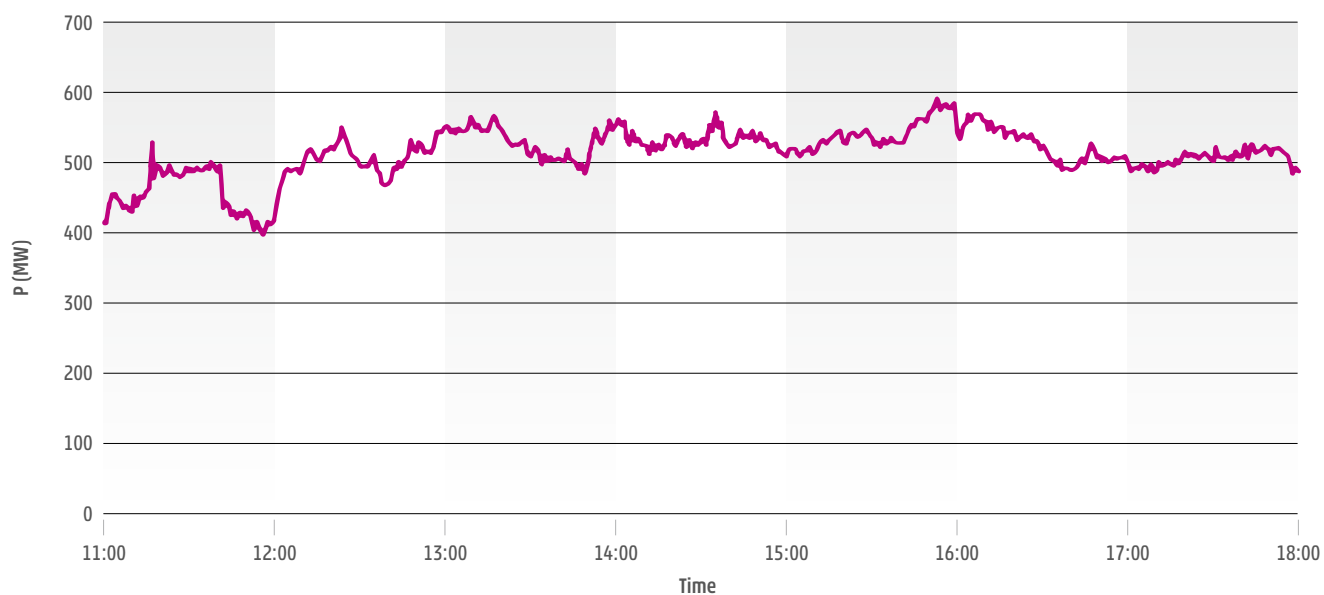


Figure 4.17: Load restoration of the T401REP, T403REP, and T404REP 400 kV/110 kV transformers

Vernéřov

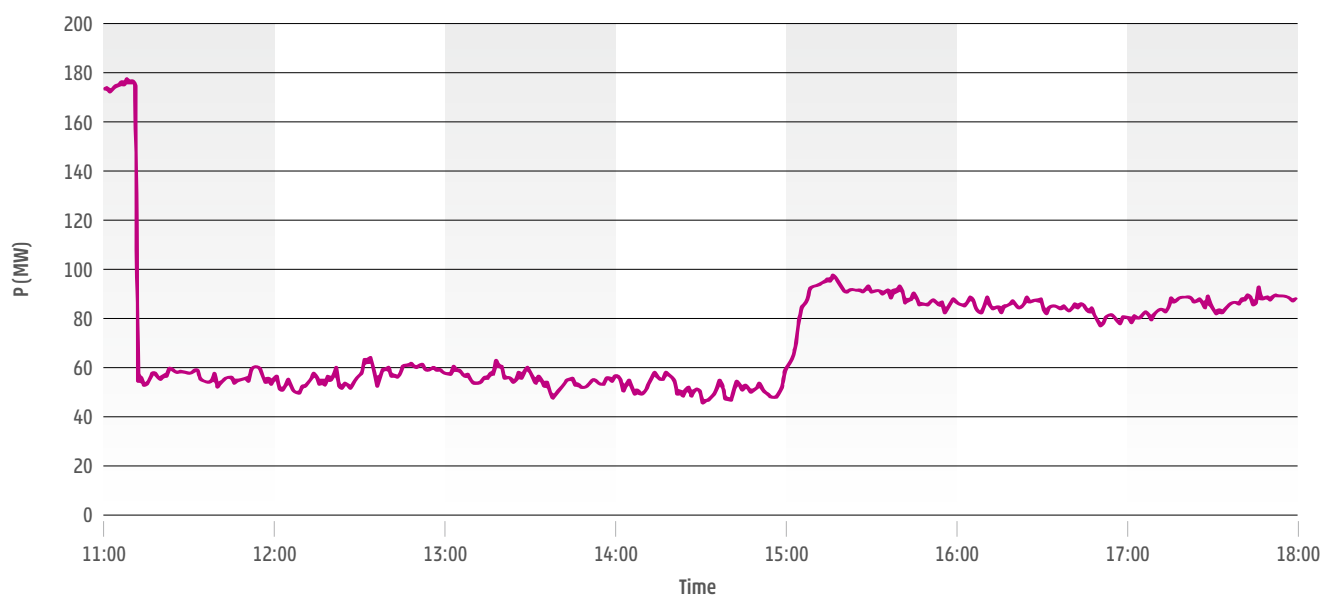


Figure 4.18: Load restoration of the T401VER 400 kV/110 kV transformer



Opočíněk

The DSO restored the load in the Neznašov area by connecting to the 220 kV/110 kV transformer at the Opočíněk substation.

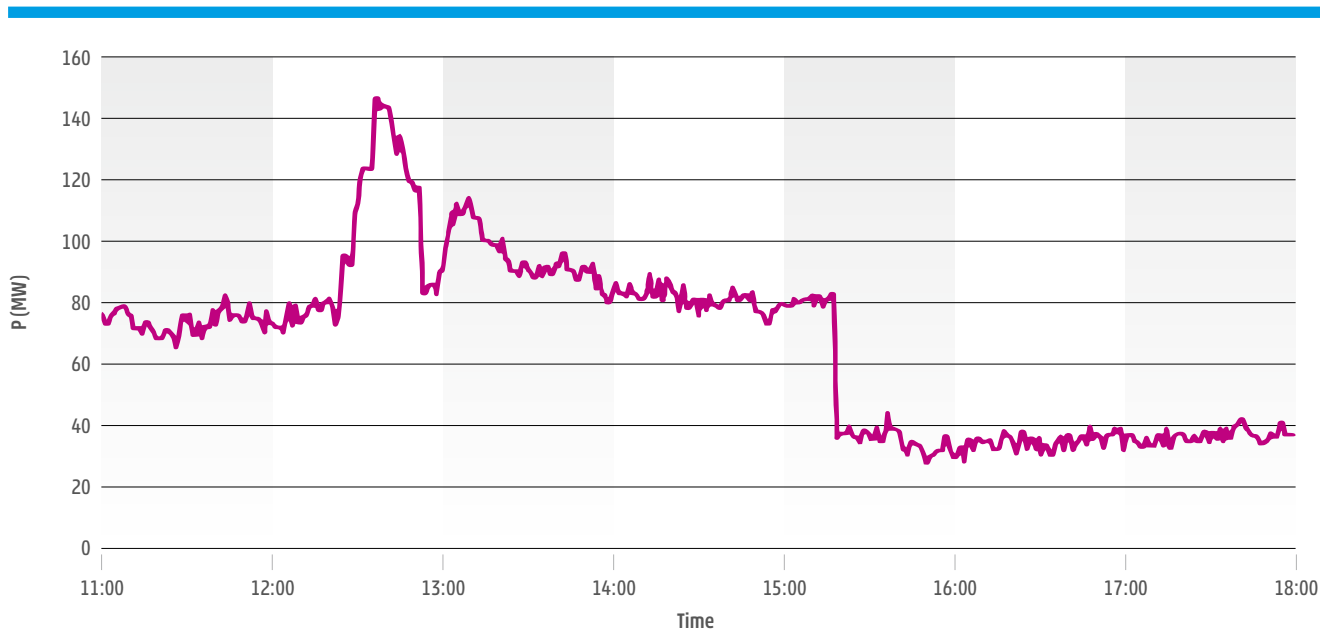


Figure 4.19: Load restoration of the T2020PO 220 kV/110 kV transformer

4.5 End of restoration

At 17:35, the dispatcher received information from DSOs about the complete restoration of the load.



4.6 Balancing during restoration

Balancing bid volumes on 4 July 2025 in the Czech Republic LFC area:

- » aFRR+: 264 MW
- » aFRR-: 236 MW
- » mFRR+: 476 MW
- » mFRR-: 78 MW
- » mFRR₅ (specific product): 203 MW

ČEPS dimensioning in the positive direction was 962 MW. Overall, ČEPS had 943 MW of available bids, reflecting a lower volume due to an outage of a unit providing mFRR5 (30 MW). The outage was not related to the incident.

In the negative direction, dimensioning was 301 MW. Available bids in the negative direction were 312 MW.

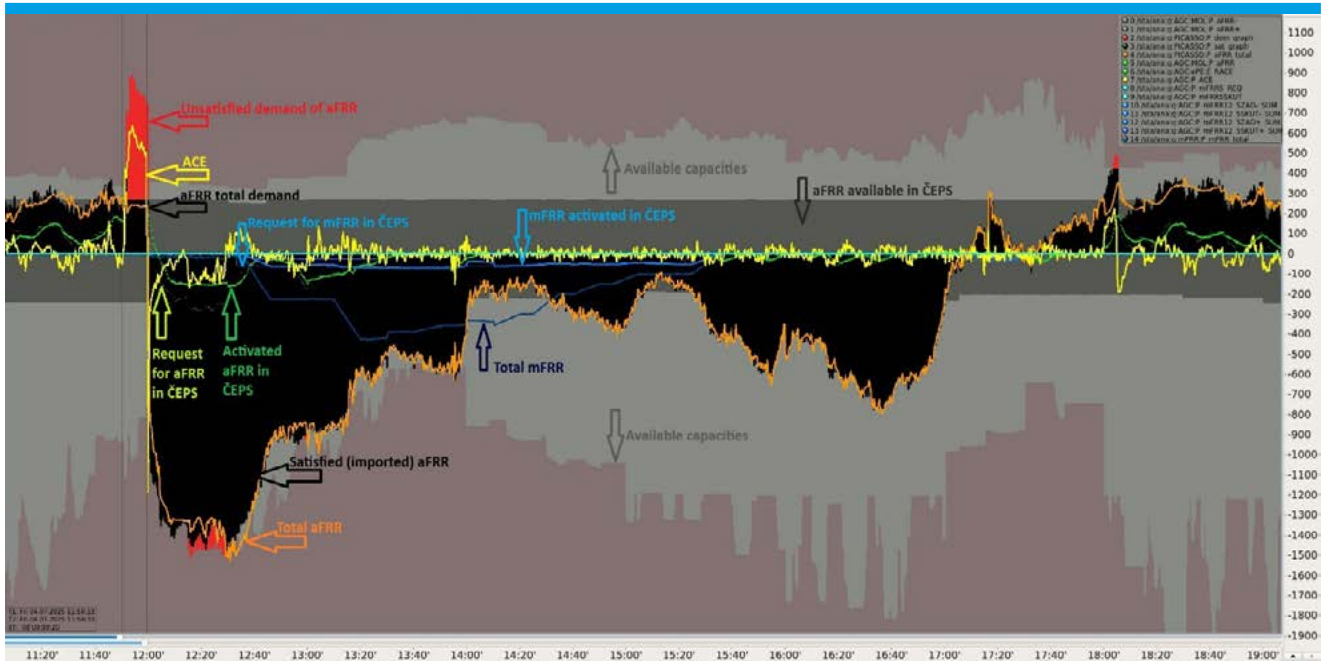


Figure 4.20: Balancing activities during the event and restoration process

- » After line V411 tripping (11:51):
 - › The Czech Republic LFC area was in deficit following the loss of generation.
 - › All aFRR+ in CZ was activated.
 - › About 500 MW aFRR+ demand was not met.
- » After the loss of the island (11:59):
 - › The Czech Republic LFC area was in surplus following the loss of demand.
 - › Peak balancing energy demand was 1,520 MW.
 - › All demand was covered by aFRR- and mFRR-.
- » LFC remained operational in normal state (P/f) and connected to MARI and PICASSO.
- » ČEPS maintained a connection to the MARI and PICASSO platforms:
 - › 2,578 MWh aFRR- imported (mainly from Germany).
 - › 556 MWh mFRR- imported (mainly from Belgium).

MTU	Reserve Type	Direction	Offered (MW)	Avg. activated in CZ (MW)[1]	Avg. imported aFRR (MW)	Average CBMP (€/MWh)
04/07/2025 11:45:00	aFRR	Up	264.00	516.83	36.67	8,646.86
04/07/2025 11:45:00	aFRR	Down	236.00	5.88	0.00	85.00
04/07/2025 12:00:00	aFRR	Up	264.00	0.00	0.00	1,992.98
04/07/2025 12:00:00	aFRR	Down	228.35	154.71	1,034.12	-1,373.17
04/07/2025 12:15:00	aFRR	Up	262.42	0.00	0.00	85.00
04/07/2025 12:15:00	aFRR	Down	193.75	251.93	1,124.74	-12,255.68
04/07/2025 12:30:00	aFRR	Up	247.09	0.00	0.00	70.00
04/07/2025 12:30:00	aFRR	Down	198.17	49.77	1,044.19	-295.04
04/07/2025 12:45:00	aFRR	Up	261.12	0.00	0.00	70.00
04/07/2025 12:45:00	aFRR	Down	190.73	86.27	791.62	-752.16
04/07/2025 13:00:00	aFRR	Up	264.00	0.00	0.00	70.00
04/07/2025 13:00:00	aFRR	Down	205.85	93.31	699.66	-552.77
04/07/2025 13:15:00	aFRR	Up	263.38	0.00	0.00	70.00
04/07/2025 13:15:00	aFRR	Down	201.62	47.51	465.21	-23.53
04/07/2025 13:30:00	aFRR	Up	261.65	0.00	0.00	125.00
04/07/2025 13:30:00	aFRR	Down	183.63	1.28	365.13	0.24
04/07/2025 13:45:00	aFRR	Up	262.63	0.03	0.00	36.50
04/07/2025 13:45:00	aFRR	Down	210.39	20.71	368.70	-27.21
04/07/2025 14:00:00	aFRR	Up	261.10	0.58	0.00	105.20
04/07/2025 14:00:00	aFRR	Down	200.68	0.00	188.66	54.37
04/07/2025 14:15:00	aFRR	Up	262.38	1.04	0.00	86.74
04/07/2025 14:15:00	aFRR	Down	209.64	0.00	156.46	37.37
04/07/2025 14:30:00	aFRR	Up	260.72	0.81	0.00	98.57
04/07/2025 14:30:00	aFRR	Down	198.07	0.00	262.78	42.91
04/07/2025 14:45:00	aFRR	Up	260.37	0.00	0.00	93.71
04/07/2025 14:45:00	aFRR	Down	195.60	0.03	340.26	34.27
04/07/2025 15:00:00	aFRR	Up	259.83	0.00	0.00	103.15
04/07/2025 15:00:00	aFRR	Down	189.75	0.04	189.18	51.05
04/07/2025 15:15:00	aFRR	Up	259.00	0.00	0.00	107.97
04/07/2025 15:15:00	aFRR	Down	186.00	0.40	178.78	55.68

Table 4.1: Aggregated aFRR results

Note. [1] Including netting.



MTU	Reserve Type	Direction	Offered (MW)	Activated in CZ (MW)	mFRR imported (MW)	CBMP (€/MWh)
04/07/2025 11:45:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 11:45:00	mFRR	Down	78.00	0.00	0.00	N/A
04/07/2025 12:00:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 12:00:00	mFRR	Down	78.00	0.00	0.00	N/A
04/07/2025 12:15:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 12:15:00	mFRR	Down	78.00	0.00	0.00	N/A
04/07/2025 12:30:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 12:30:00	mFRR	Down	78.00	0.00	0.00	N/A
04/07/2025 12:45:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 12:45:00	mFRR	Down	78.00	62.00	36.80	-424.12
04/07/2025 13:00:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 13:00:00	mFRR	Down	78.00	53.00	138.00	-250.00
04/07/2025 13:15:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 13:15:00	mFRR	Down	78.00	69.00	147.00	-916.88
04/07/2025 13:30:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 13:30:00	mFRR	Down	78.00	71.00	331.00	-2,000.00
04/07/2025 13:45:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 13:45:00	mFRR	Down	78.00	71.00	318.00	-1,999.00
04/07/2025 14:00:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 14:00:00	mFRR	Down	78.00	59.00	288.00	-934.99
04/07/2025 14:15:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 14:15:00	mFRR	Down	78.00	59.00	296.00	-450.00
04/07/2025 14:30:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 14:30:00	mFRR	Down	78.00	49.00	241.00	-427.96
04/07/2025 14:45:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 14:45:00	mFRR	Down	78.00	52.00	151.00	-250.00
04/07/2025 15:00:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 15:00:00	mFRR	Down	78.00	43.00	98.00	-350.00
04/07/2025 15:15:00	mFRR	Up	706.00	0.00	0.00	N/A
04/07/2025 15:15:00	mFRR	Down	78.00	52.00	57.00	-150.47

Table 4.2: Aggregated mFRR results



4.7 Market suspension and restoration

ČEPS suspended market activities in accordance with the Rules for Suspension and Restoration of Market Activities.²¹ During the suspension of market activities, it was not possible to allocate cross-border capacity for ID trading, thereby affecting the continuous ID cross-border trading via SIDC for the trading interval from 13:30 to 24:00 on 4 July 2025. The ČEPS control centre performed a halt of cross-border ID trading via XBID operational procedures at 12:19 on all cross-border profiles, and thus the actual affected trading intervals were from 13:30.

In the context of the suspension of market activities, ČEPS decided to stop the allocation of cross-border ID trading capacity in accordance with Article 35(2) of the NCER. ČEPS assessed that the continuation of this market activity would significantly reduce the effectiveness of the restoration process to a normal or alert state, as it was unclear whether ČEPS would be able to provide the agreed cross-border exchanges.

The suspension of market activities during the 13:30 to 24:00 trading interval on 4 July 2025 had a positive impact on the management of the Czech Republic's transmission system during the incident analysed. As a result of this measure, there was no change in the trading balance during the analysed incident, and the ČEPS control centre could thus better leverage the predictable state of the electricity system to more effectively stop the fault's propagation and restore the system faster.

The suspension of cross-border trading also affected ID trading for the following day (5 July 2025), namely by suspending cross-border trading in the SIDC continuous trading (until 22:28 on 4 July), as well as in the IDA 1 (organised on 4 July at 15:00) and IDA 2 (organised on 4 July at 22:00) for all trading slots on 5 July 2025, where zero cross-border capacity was offered for these auctions.

However, the aforementioned suspension of cross-border trading under IDA 1 and IDA 2 had only a limited impact on electricity market participants. Cross-border trading was subsequently allowed under the downstream ID continuous trading and under IDA3.

Subsequently, a state of emergency was declared for the entire territory of the Czech Republic at 15:45, with retroactive effect from 12:00, in accordance with § 54 of Act No. 458/2000 Coll. This led to the non-functionality of the marketplace and the inability to register execution diagrams, thereby implicitly suspending market activities, offering the possibility of ensuring a balanced trading position by the clearing entity and ensuring adjustments to the clearing entity's trading position. In such a case, the market operator clears imbalances for each assessment interval in a special regime pursuant to Article 31(1) of Decree No 408/2015 Coll. of the Electricity Market Rules. The agreed quantities of electricity in this regime shall be deemed to be zero pursuant to paragraph 2 of the same decree. Therefore, the impact of the suspension of market activities on market participants was non-existent, as the allocation results for the interval were assessed in accordance with Article 31(2) of the decree, regardless of the suspension.

Immediately after the suspension of market activities, ČEPS initiated the communication procedure in line with Article 38 of the NCER. As it was not possible to make the notification and other updates related to the suspension of market activities on the ČEPS website, ČEPS informed all affected entities through the Crisis Communication System (SKK) in accordance with Article 38(4) of the NCER. ČEPS sent the following message via the SKK to the affected entities by SMS and email at 15:55: "ČEPS 04.07.2025 12:00 informs about the suspension of market activities in accordance with Article 35 of Commission Regulation (EU) 2017/2196. Estimated duration is 8 hours".

21 Available from <https://www.čeps.cz/cs/nc-er>





Neighbouring TSOs and all nominated electricity market operators were informed of the suspension of the allocation of cross-border capacity for ID trading through the XBID_JOINT_OTH_02 – Internal and External Communications common communication procedure.²²

At 20:00, ČEPS informed about the postponement of the expected end of the emergency state to 22:00, thus providing an update on the transmission restoration process in accordance with Article 38(2)(d) NCER. Subsequently, at 22:28, it informed via SKK about the end of the suspension of market activities, and at 22:30, it informed about the end of the emergency state with effect from 5 July 2025 at 00:00.

Neighbouring TSOs and all nominated electricity market operators were informed about the restoration of the allocation of cross-border capacity for ID trading effective for trading intervals from 5 July 2025 at 00:00 via the XBID_JOINT_OTH_02 – Internal and External Communications common communication procedure. This was in line with Article 38(3)(f) NCER to notify the TSO that the transmission system had been returned to a normal or alert state.

22 Available from <https://www.nemo-committee.eu/continuous>



5 REGIONAL COORDINATION PROCESSES

There are five RCCs and one regional security coordinator (RSC) established in Europe. The RCCs are Baltic RCC, TSCNET, SEleNe CC, Coreso and Nordic RCC, and the RSC is SCC. They are tasked with carrying out the operational planning tasks defined in the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity. Pan-European tasks are provided jointly or on a rotational basis. Regional tasks for the Central Europe System Operation Region are provided by TSCNET or in cooperation with Coreso.

None of the RCC tasks identified a specific security risk for the Czech transmission system for the relevant hours on 4 July 2025, and the grid was considered N-1 secure:

» The STA assessment validates whether the reliably available generation capacity is sufficient to meet the expected consumption, considering both upward and downward regulation needs. The calculation is performed daily for the upcoming seven days. ČEPS participates in the cross-regional STA process, where all TSOs are required to submit input data daily. The process is executed automatically and monitored by the RCCs in rotation. In addition, a regional STA process may be triggered if the deterministic calculation indicates a potential adequacy issue for the upcoming three days. Such situations are rare.

In the days leading up to the incident, no regional STA process was triggered, and the cross-regional process did not identify any adequacy issues in the Czech Republic for the day of the incident.

» The outage planning coordination (OPC) ensures information exchange among all Central European TSOs on a yearly, monthly, and weekly basis regarding planned outages. Additionally, RCCs assess the compatibility of the different outage plans.

All ČEPS elements in coordination that were switched off on 4 July 2025 were included in the shared unavailability plans and were agreed by the partners. In addition, ČEPS also informed the partners about the outage of grid elements that are not coordinated but might hold interest to other TSOs. These disconnections are shared only with each other and are not mutually agreed upon.

» Both DA and ID coordinated capacity calculation (CCC) processes were successfully completed for the day of the incident. Required input data for CCC processes was complete and valid. The DA and ID CCC processes were completed, and the results were delivered for 4 July 2025 before the incident. Thus, the CCC processes executed for 4 July 2025 were not affected by the incident.

Despite the incident occurring concurrently with the initiation of the DACC process for 6 July 2025, the designed execution of the CCC process remained intact. The successful completion of the DA CCC process for 6 July 2025 confirms that no disruptive impact was experienced on the DA CCC process.

The processes of ID capacity calculations for 5 July 2025 at 15:00 and 22:00 were not affected by the incident. All potential risks associated with cross-zonal capacity allocation during the incident period (including auctions for 5 July 2025) were addressed by suspending ID trading for multiple MTUs in the Czech Republic bidding zone in line with the applicable requirements set out in Article 35 NCER.





- 1 // ČEPS contributes to the regional two-day-ahead, one-day-ahead and ID processes by providing IGMs in the UCTE data exchange format. All these models were submitted to RCCs on time and in the required quality, and all necessary calculations were performed including them.
- 2 // The legacy security analysis on the DACF and IDCF models was carried out successfully. At the end of the TSCNET's DACF process, the participating TSOs consider the grid N-1 secure, and the congestion-free model criterion is met if the N-1 loading is below 103 % for tie lines and below 120 % for internal elements. This was the case for all Czech lines after corrective measures were implemented. Detected congestions for the 400/220 kV transformers at the Hradec and Čechy Střed substations were either within the transitory admissible thermal limits (temporarily tolerable) and resolvable through curative measures. Hence, the Czech grid was considered N-1 secure. No unusual differences were observed between the cross-border flows in the DACF and IDCF models and the flows in real time. The results of the ČEPS local security analysis conducted in real time before the incident were fairly consistent with those from the regional processes. This, together with the detailed results, is available in Chapter 2.
- 3 // For all regional security analyses performed, the loss of line V411 with additional loss of generation was not considered as an ordinary contingency in line with CSAm Art. 7. Only the loss of line V411 alone was considered. Line V208, which was overloaded during the incident, was not considered a cross-border relevant network element (XNE) under CSAm Art. 15 and was not considered for the OPC and CCC processes. It was, however, considered during the DACF and IDCF processes, which confirmed the N-1 security even for this internal element.
- 4 // Additionally, there are other RCC tasks²³ under EU Regulation 2019/943 in operation that contribute to grid security. However, they are more long-term and less connected with the specific incident.

The coordinated security analysis based on the pan-European Common Grid Model (CGM) in the CGMES format is not yet live.

A CGM Action Plan has been in place since April 2024 to enhance CGM creation in CGMES format and data quality, building on earlier efforts to resolve persistent issues with IGM validation and inclusion.

²³ The other tasks are supporting the consistency assessment of TSOs' defence plans and restoration plans (Art. 37(1)(d)), training and certification of staff (Art. 37(1)(g)), regional incident analysis and reporting (Art. 37(1)(i)), identifying regional crisis scenarios (Art. 37(1)(m)) and calculating maximum entry capacity (Art. 37(1)(o)). More details about the RCC tasks in operation are available in the annual Central Europe SOR Report from TSCNET and Coreso.



6 ANALYSIS OF RELEVANT FACTORS

6.1 Analysis of technical reasons for the V411 disconnection

On 4 July 2025 at 11:51:07, the V411 line failed due to an unsuccessful reconnection (automatic recloser) in phase L2. The cause was a phase conductor failure, specifically a break in one of the cables between towers 35 and 36 near the village of Kličín.

Based on the dispatcher's instructions, a walk-through inspection was conducted, which precisely localised the failure and its extent. Subsequently, emergency repairs were initiated and completed on the same day at 22:23. The line was handed back to dispatcher control at 23:00.

The repair included:

- » Removal of the damaged part of the original cable (installed in 1961)
- » Addition of a new cable of the appropriate length
- » Installation of two tensile couplings
- » Replacement of damaged spacers

The cause of the wire breakage was identified as a mechanical failure. The failure occurred at the tension coupling, which was installed during an emergency repair at the beginning of December 2024.

After the repair in 2024, the dismantled wire sample was sent to the Klokner Institute of the Czech Technical University for expert examination. The test results confirmed that the tested rope met the tensile strength requirements, to the extent corresponding to a new wire; however, the results applied for the wire itself and were not necessarily applicable to the tensile coupling.

The repair in 2024 (as well as the repair in July 2025 after the incident) was carried out by renowned companies with many years of experience in the field of construction, reconstruction and restoration of lines.

After the July 2025 failure, a sample of the rope was requested and submitted to the Czech Police for examination. When ČEPS received the examined material back, specifically the ends of the broken metal conductor equipped with a tensile coupling, it submitted it for further expert examination to a certified laboratory.

The Klokner Institute of the Czech Technical University concluded that the tensile coupling showed an insufficiently tight connection. The mechanical connection of the steel core of the rope was properly tight, but the connection of the aluminium part of the conductor was insufficiently tight, resulting in higher contact resistance. The heat generated by the electrical current affected the mechanical properties of the steel core during operation, which subsequently caused the rope to break and the conductor to fall.

Following the event on 4 July 2025, an extraordinary aerial thermal imaging inspection of the V411 line was conducted. Further defects were detected and were eliminated at the nearest planned line outage.





Figure 6.1: Photo of the tensile coupling



Figure 6.2: Photo of the end of the conductor

6.2 Analysis of the impact of distributed generation

Following the tripping of line V411, a significant amount of generation was lost in the Czech system, mainly in the affected area, despite operational parameters – namely voltage and frequency – returning to normal values.

In the minutes following the tripping of V411, the decrease in generation in the affected area continued and distribution-connected generation, disconnected mostly by voltage and frequency protections.

This chapter discusses the disconnection of generation in detail. Unfortunately, the causes of some of the distributed generation disconnection remain unknown due to missing data. The same applies to a residual imbalance (i.e. imbalance after deduction of known generation loss) of the system occurring after the tripping of V411, which could not have been attributed to either generation or load behaviour.



6.2.1 Behaviour of photovoltaic generation

When analysing the behaviour of renewable resources during the fault, it was possible to trace the outage of the PV resources in connection with the one pole unsuccessful auto recloser on the V411 line.

Type	Pinst (MW)	Connection date	Time of tripping	Protection that tripped PGM	P (MW) 11:51	P (MW) 11:51:15	P (MW) 11:51:30
PV	5.997	12/27/2010	11:51:06 AM	frequency	1.015	0.891	0.891
PV	4.455	7/13/2010	11:51:06 AM	voltage	3.519	2.552	2.552
PV	4.301	12/17/2010	11:51:10 AM	voltage	0.853	0	0
PV	55.763	12/20/2010	11:51:05 AM	voltage	32.369	0	0
PV	4.387	12/22/2010	11:51:05 AM	voltage	3.412	0	0
PV	4.99536	12/2/2010	11:51:06 AM	voltage	4.544	0.003	0.003
PV	2.00304	11/2/2010	11:51:10 AM	voltage	1.019	0.354	0.354
PV	0.714	12/31/2009	11:51:06 AM	frequency	0.18	0	0
PV	3.901	12/21/2010	11:51:06 AM	frequency	3.304	2.159	2.159
PV	0.866	2/19/2010	11:51:10 AM	voltage	0.714	0	0
PV	0.829	2/19/2010	11:51:10 AM	voltage	0.677	0	0
PV	1	2/19/2010	11:51:10 AM	voltage	0.691	0	0
PV	0.987	2/19/2010	11:51:10 AM	voltage	0.815	0	0
PV	0.506	11/10/2010	11:51:06 AM	voltage	0.151	0	0
PV	1.225	7/7/2010	11:51:06 AM	voltage	0.904	0.593	0.593
PV	1.998	12/1/2010	11:51:09 AM	voltage	0.62	0	0
PV	0.245	12/17/2010	11:51:06 AM	voltage	0.083	0	0
PV	0.159	9/10/2010	11:51:06 AM	voltage	0.113	0	0
PV	0.199	10/1/2010	11:51:10 AM	voltage	0.157	0	0
PV	4.2636	9/20/2024	11:51:21 AM	voltage	2.68	0	0
PV	0.547	11/12/2010	11:51:06 AM	voltage	0.356	0	0
PV	0.1928	3/20/2025	11:51:17 AM	voltage	0.061	0	0
PV	0.55	5/12/2009	11:51:07 AM	voltage	0.444	0.276	0.276
PV	0.23	12/23/2009	11:51:08 AM	voltage	0.128	0.003	0.003
PV	1.974	12/27/2010	11:51:06 AM	voltage	1.22	0.285	0.285
PV	1.0692	9/22/2010	11:51:06 AM	frequency	0.22	0.114	0.114
PV	0.503	12/9/2009	11:51:08 AM	voltage	0.124	0.07	0.07
PV	0.2	12/9/2010	11:51:06 AM	voltage	0.159	0	0



Type	Pinst (MW)	Connection date	Time of tripping	Protection that tripped PGM	P (MW) 11:51	P (MW) 11:51:15	P (MW) 11:51:30
PV	0.772	12/23/2009	11:51:07 AM	voltage	0.627	0.092	0.092
PV	0.397	9/16/2009	11:51:08 AM	voltage	0.059	0	0
PV	0.13107	11/22/2010	11:51:06 AM	voltage	0.034	0	0
PV	2	12/23/2010	11:51:06 AM	voltage	0.564	0.077	0.077
PV	0.299	12/31/2012	11:51:07 AM	voltage	0.209	0.175	0.175
PV	0.155625	11/11/2013	11:51:07 AM	voltage	0.03	0.007	0.007
PV	0.402	12/15/2008	11:51:08 AM	voltage	0.34	0.207	0.207
PV	1.184	11/23/2010	11:51:08 AM	voltage	0.755	0.222	0.222
PV	0.845	11/18/2010	11:51:08 AM	voltage	0.538	0.014	0.014
PV	0.48	12/27/2010	11:51:09 AM	voltage	0.428	0	0
PV	0.5	12/27/2010	11:51:06 AM	voltage	0.251	0	0
PV	1.311	11/26/2010	11:51:08 AM	voltage	0.853	0.022	0.022
PV	0.135	8/10/2009	11:51:07 AM	voltage	0.089	0	0
PV	0.149	11/16/2010	11:51:06 AM	voltage	0.143	0.084	0.084
PV	0.207	12/6/2010	11:51:07 AM	voltage	0.128	0	0
PV	0.5	12/6/2010	11:51:06 AM	voltage	0.4	0.212	0.212
PV	0.5	9/16/2010	11:51:07 AM	voltage	0.086	0	0
PV	1.19784	12/6/2010	11:51:06 AM	voltage	0.557	0.005	0.005
PV	1.499	11/15/2010	11:51:08 AM	voltage	0.16	0.043	0.043
PV	0.144	11/22/2012	11:51:06 AM	voltage	0.023	0	0
PV	0.2	12/21/2010	11:51:06 AM	voltage	0.15	0	0
PV	0.108	12/6/2010	11:51:06 AM	voltage	0.098	0	0
PV	2.969	12/22/2010	11:51:06 AM	voltage	0.519	0	0
PV	1.3464	12/8/2009	11:51:07 AM	voltage	1.083	0.609	0.609
PV	0.165	11/11/2010	11:51:08 AM	voltage	0.096	0.013	0.013
PV	4.403	12/7/2010	11:51:11 AM	voltage	0.831	0.009	0.009
	126.059935				69.583	9.091	9.091

Table 6.1: Behaviour of PV after unsuccessful auto reclosure of V411



Most PV sources were put into operation at a time when **"the Rules for the Operation of Distribution Systems" from 12/2008** were in force, which state the following (translation from the Czech binding original courtesy of ČEPS):

- » The Rules for the Operation of Distribution Systems from 12/2008 were based on the German Transmission Code 2007 and were valid for
 - > for renewable generation connected to the 110 kV grid and
 - > power >15 MW
- » These rules state the following:
 - > "(5) In the event of network faults outside the protected zone of the generating plant, **disconnection from the network is not permitted. A contribution to the short-circuit current must be supplied** to the network for the duration of the fault. [...]
 - > (6) If the voltage at the connection point **drops below 85 % of the reference voltage** (e.g. $110 \text{ kV} \times 0.85 = 93.5 \text{ kV}$) **and remains so while reactive power is being drawn from the network** at the connection point (under excited operation), **the generating plant must be disconnected from the network with a time delay of 0.5 s. The voltage value refers to the largest of the three phase-to-phase voltages.**
 - > (7) When **the voltage on the lower voltage side of each source transformer drops and remains at or below 80 % of the lower limit of the voltage range** (e.g. $690 \text{ V} \times 0.8 = 525 \text{ V}$), one quarter of the generators must be disconnected from the grid in 1.5 s, the other in 1.8 s, in 2.1 s and in 2.4 s. The voltage value refers to the largest of the three phase-to-phase voltages. [...]
 - > (13) Three-pole short circuits or symmetrical voltage drops during faults must not lead to instability or disconnection of the generating plant from the network above limit 1.
 - > (14) **Inside the hatched area and above limit 2: All generating plants must overcome the fault** – pass through without disconnecting from the grid. **If a generating plant cannot, due to the concept of connection** (devices including generators) to the grid, meet this condition without disconnecting from the grid, **it is allowed in agreement with the network operator**, this limit can be shifted while simultaneously shortening the resynchronisation time and ensuring a minimum reactive current supply in the event of a fault.
 - > (15) Below limit 2, short-term disconnection of the generating plant from the grid is always permitted. [...]"

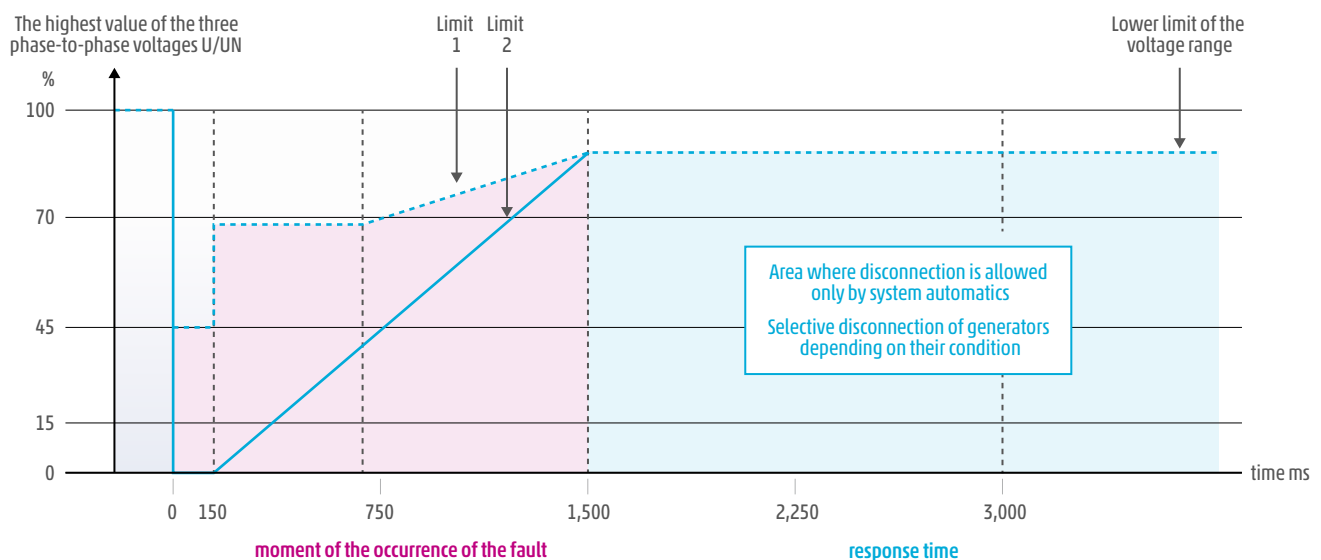


Figure 6.3: Voltage limits at the connection point for a renewable power plant during a grid fault

According to the information provided, these rules are related to single PV in the affected area.

Type	Pinst (MW)	Connection date	Time of tripping	Protection that tripped PGM	P (MW) 11:51	P (MW) 11:51:15	P (MW) 11:51:30
PV	55.763	12/20/2010	11:51:05 AM	voltage	32.369	0	0

Table 6.2: PV unit subject to "the Rules for the Operation of Distribution Systems" from 12/2008

During the initial incident, this PV was connected to the substation 110 kV which was supplied by transformer TS/110 kV T401BEZ.

ČEPS does not have sufficiently accurate measurements from the 110 kV substations, however accurate measurements from the quality meters on the 110 kV side of the T401BEZ transformer were used.

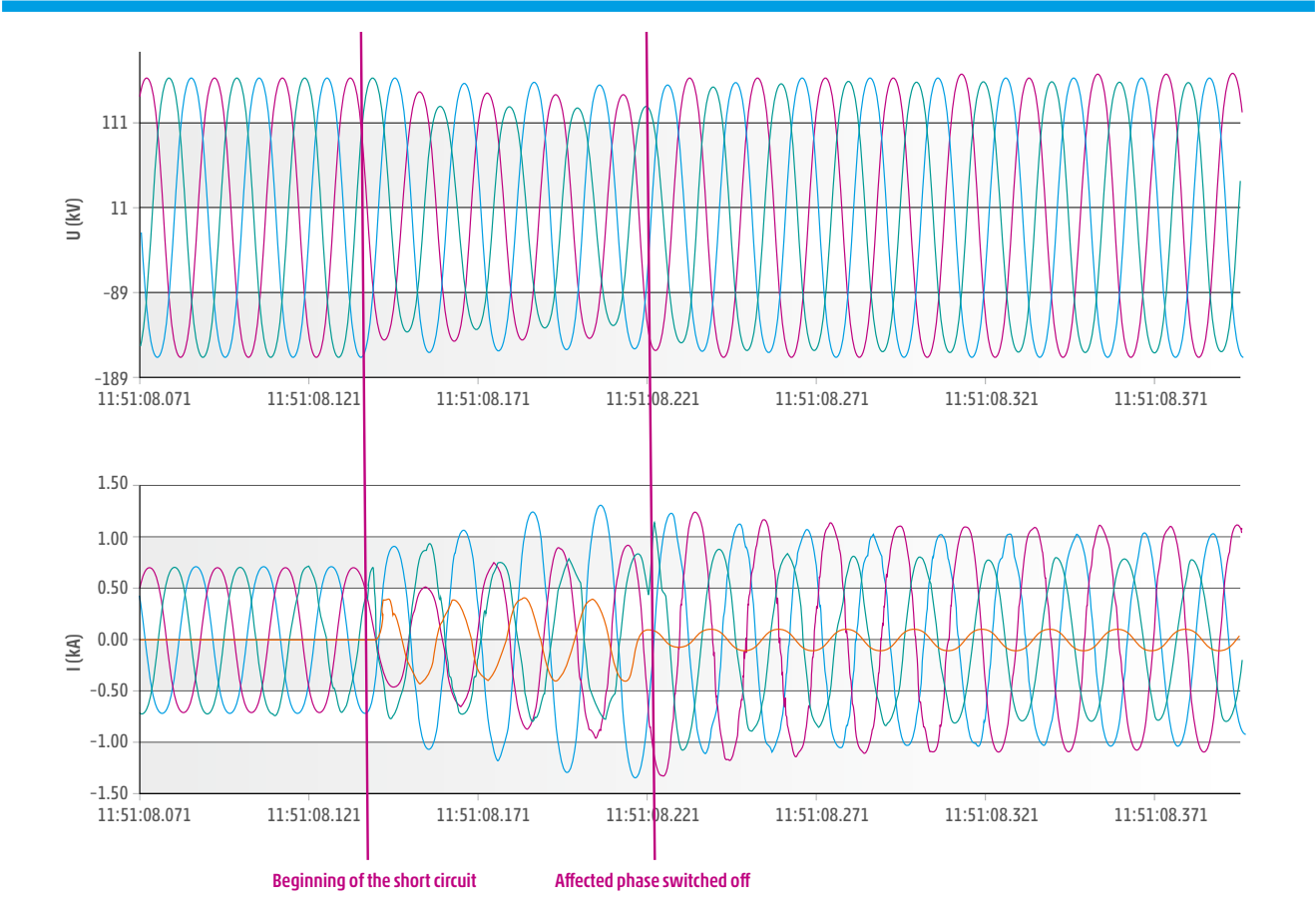


Figure 6.4: Measurements from the quality meters on the 110 kV side of the T401BEZ transformer at the beginning of the short circuit



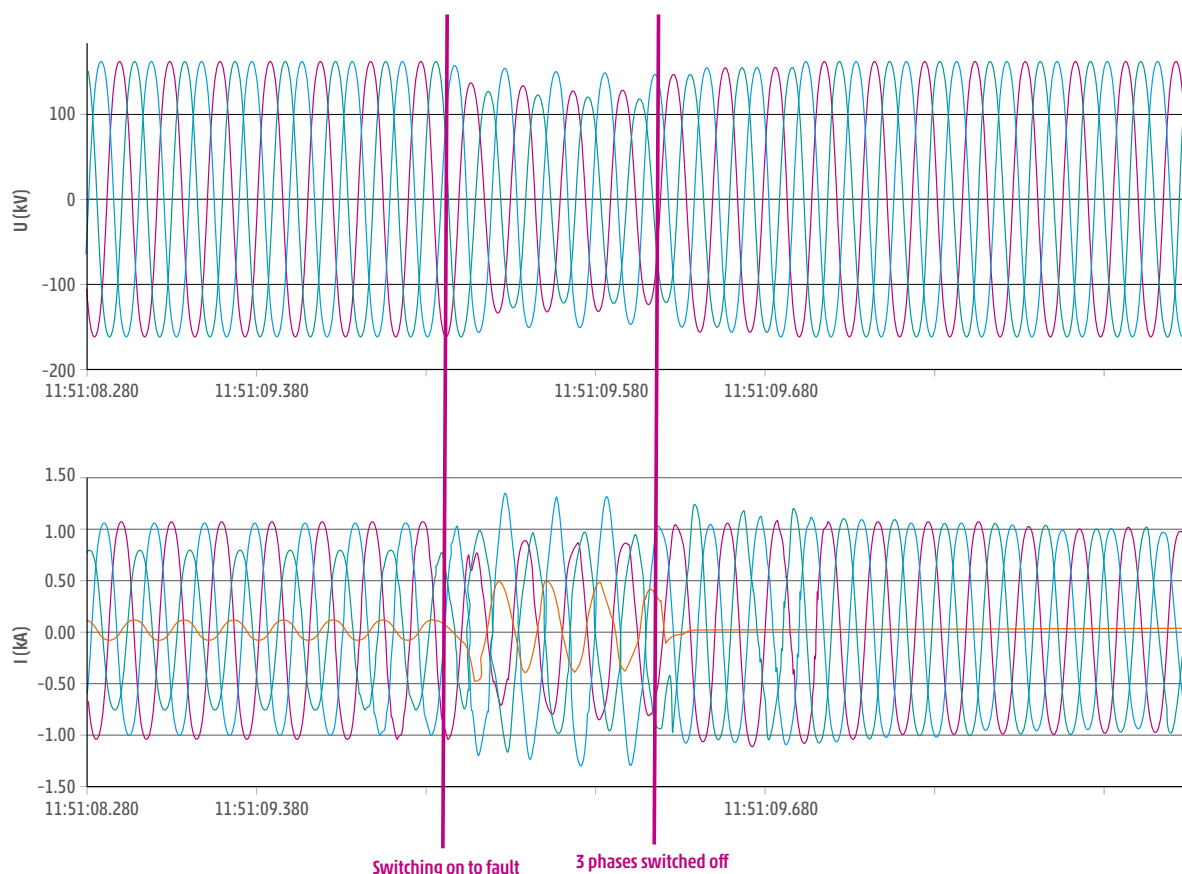


Figure 6.5: Measurements from the quality meters on the 110 kV side of the T401BEZ transformer until 3 phase tripped

This measurement shows that on the 110 kV side of the T401BEZ transformer, the voltage in none of the three phases dropped below 100 kV during the entire fault period (i.e. during the initial one pole short circuit, during the single-pole auto-recloser or during the switch to the fault).

Since the measurement location is physically closer to the location of the initial fault itself, it can be evaluated that the voltage drop observed at the connection point of the PV did not exceed FRT limits.

As far as PV resources fall under the RfG rules, only 4.4564 MW of the total installed capacity of the PV resources fall under this category (according to the date of commissioning).

Specifically, the following ones:

ID	Type	Pinst (MW)	Category	Connection date	Time of tripping	Protection that tripped PGM	P (MW) 11:51	P (MW) 11:51:15	P (MW) 11:51:30
A	PV	4.2636	B2	9/20/2024	11:51:21 AM	voltage	2.68	0	0
B	PV	0.1928	B1	3/20/2025	11:51:17 AM	voltage	0.061	0	0

Table 6.3: PV units subject to RfG requirements



According to the date of commissioning, the PV power plant A falls under **the rules for operating distribution systems from 2/2022**, which state the following about the ability to overcome a fault:

t[s]	U[p.u.]
0-0.15	0.05
3	0.85

Table 6.4: Fault-ride-through capability parameters for PV unit A

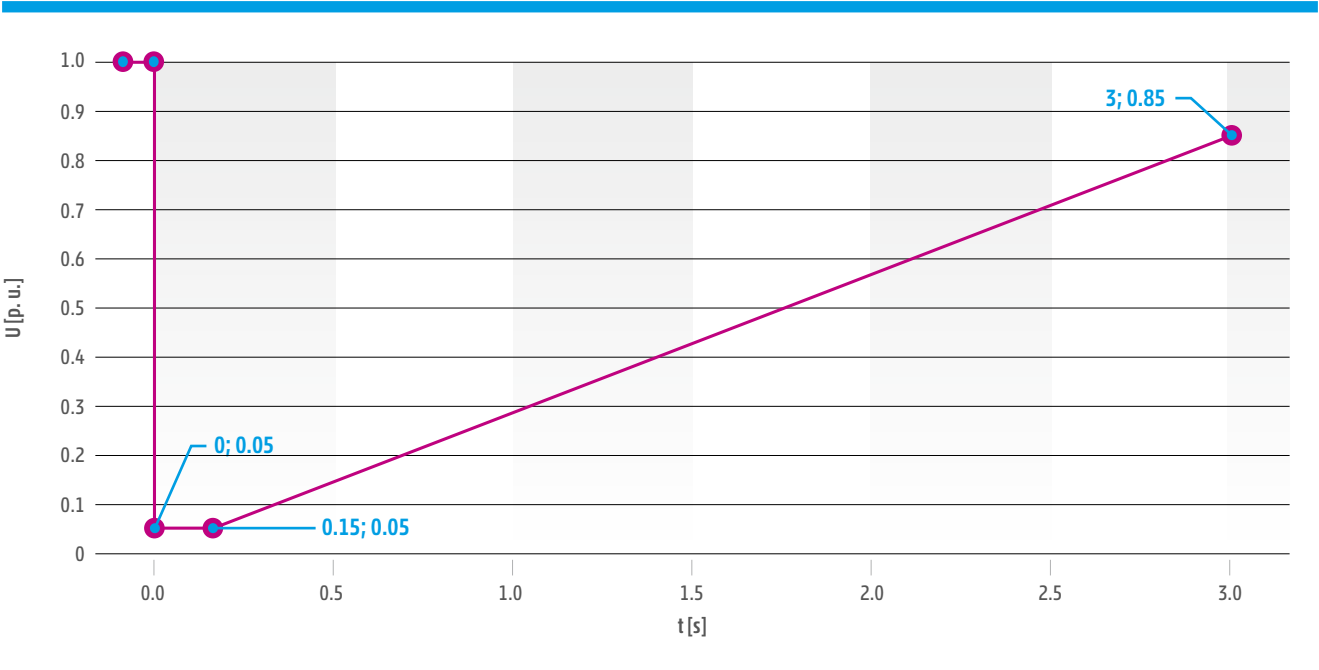


Figure 6.6: through capability requirements for PV unit A, B and C

During the initial incident, this PV was connected to the substation 110 kV which was supplied from transformer TS/110 kV T401BEZ during the incident.

The accurate measurements from the quality meters on the 110 kV side of the T401BEZ transformer, same as for above mentioned PV power plant A, shows that on the 110 kV side of the T401BEZ transformer, the voltage in none of the three phases dropped below 100 kV during the entire fault period (i.e. during the initial one pole short circuit, during the single-pole auto-recloser or during the switch to the fault).

Since the measurement location is physically closer to the location of the initial fault itself, it can be evaluated that the voltage drop observed at the connection point of PVA did not exceed FRT limits.

According to the date of commissioning, the PV power plant B falls under **the rules for operating distribution systems from 2025**, which state the following about the ability to overcome a fault:

t[s]	U[p.u.]
0-0.15	0.05
3	0.85

Table 6.5: Fault-ride-through capability parameters for PV unit B

During the initial incident, this PV was connected to the substation 110 kV which was probably supplied by transformer TS/110 kV T403CST during the incident.

The accurate measurements from the quality meters on the 110 kV side of the T403CST transformer show that, on

the 110 kV side of the T403CST transformer, the voltage in none of the three phases dropped below 100 kV during the entire fault period (i.e. during the initial one pole short circuit, during the single-pole auto-recloser, or during the switch to the fault).

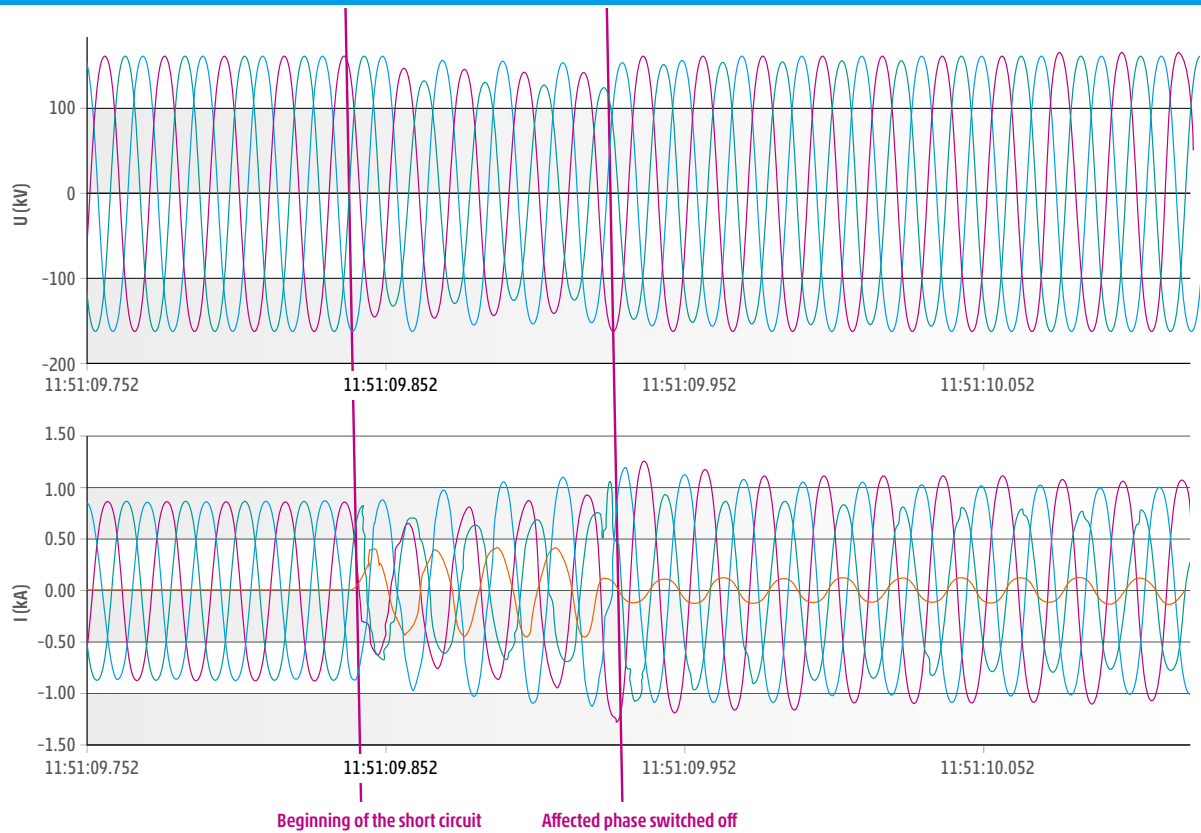


Figure 6.8: Measurements from the quality meters on the 110 kV side of the T403CST transformer at the beginning of the short circuit



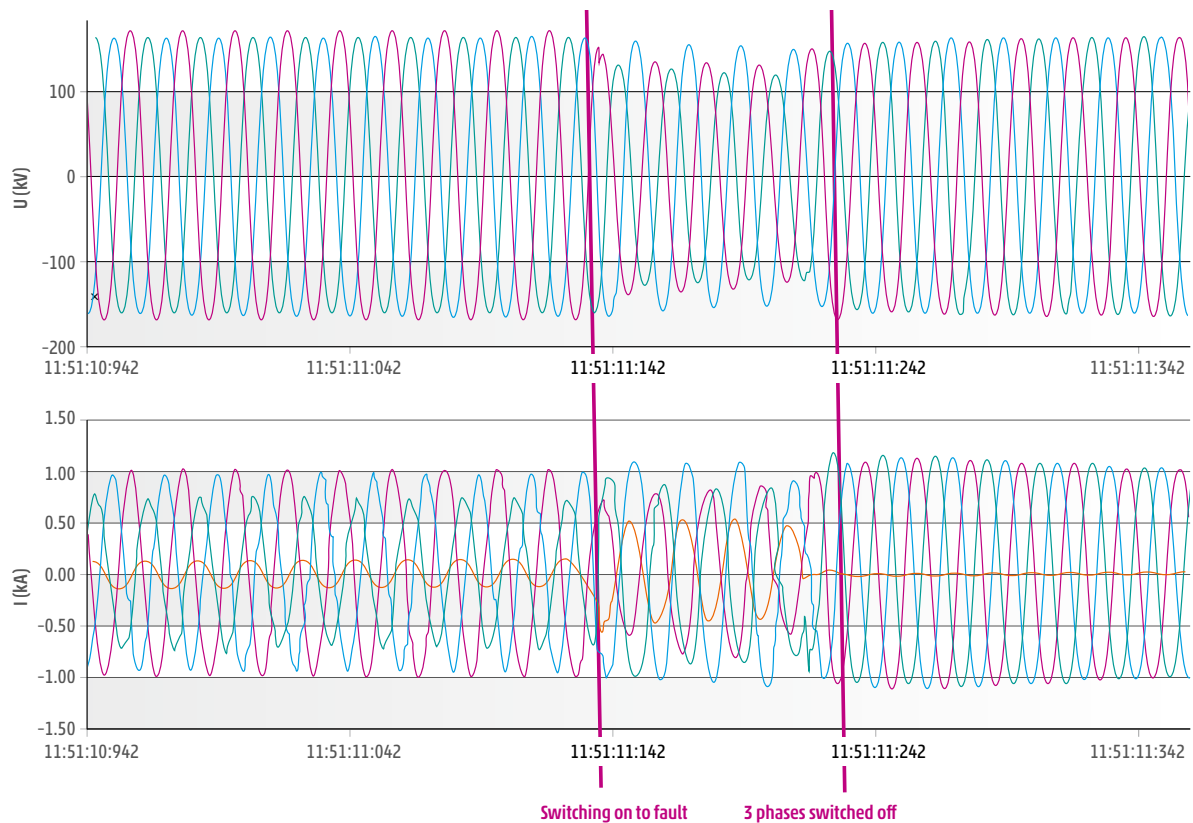


Figure 6.9: Measurements from the quality meters on the 110 kV side of the T403CST transformer until 3 phases tripped

Since the measurement location is physically closer to the location of the initial fault itself, it can be evaluated that the voltage drop observed at the connection point of PV B did not exceed FRT limits.

From the above analyses, the Expert Panel concluded that the disconnection of 35 MW PV power plants diverged from the applicable requirements at the time of their commissioning – specifically, these plants, subject to the FRT requirement did not ride through the fault as intended.

Regarding the disconnections of 95 MW RES with no requirement for fault-ride through capability the Expert Panel did not conclude whether or not the disconnections diverged from the applicable requirements. There was no requirement that they ride through a fault. While

an assessment per individual plant was not performed, it is to note that based on measurements on the secondary side of three transmission-distribution transformers, the voltage in the 110 kV side did not exceed the voltage range for continuous operation $110 \text{ kV} \pm 10\%$ in these points of the grid.

With regards to the 5 MW of RES that disconnected due to frequency protections, the Expert Panel concluded that these disconnections did not diverge from the applicable requirements.

All in all, around 135 MW of distributed RES generation disconnected in the affected area and added to its generation deficit.



6.3 Island operation capability as the ancillary service

This chapter provides a more detailed description of the IOCM of the units.

6.3.1 Definition and purpose of the service

The IO capability provides support during emergency or critical system conditions in the power system. Its primary goal is to ensure that selected grid areas remain operational even when disconnected from the rest of the transmission system.

By enabling autonomous operation of an isolated section, the service helps maintain supply to essential loads, supports system restoration procedures and enhances overall grid resilience. Since the service is based on transitioning to proportional (droop) speed control mode, it allows the unit to operate even in a parallel-connected area regardless of whether a true topological island is formed.

6.3.2 Technical and operational requirements for IO capability

The requirements for providing IO capability are divided into four principal areas:

- | | |
|---|---|
| A // Transition to IOCM (droop speed control mode) | C // Reconnection of the island to the rest of the grid (transition from IOCM back to normal control mode) |
| B // Operation in IOCM (droop speed control mode) | D // Availability and verification of the service |

A // Transition to IOCM

The transition from normal parallel operation to IOCM involves a sudden change in system frequency and an imbalance of active and reactive power. The generating unit must be capable of ensuring a stable and automatic transition according to the following conditions:

- » The unit's control system shall automatically switch to droop speed control mode suitable for IO conditions.
- » Any participation in the automatic frequency restoration reserve (aFRR) or other remote active power control must be temporarily disconnected.
- » The unit must also allow remote control via the ČEPS regulator designed for IO, which controls units operating in droop speed control mode.
- » The generating unit must ensure stable adjustment of rotational speed to the new island frequency.
- » In the case of significant system separation, the unit must be capable of self-supply operation (operation on house-load) or complete disconnection from the external grid if frequency deviations exceed the allowed limits.
- » The transition is to be automatically detected by a frequency relay, following the prescribed frequency plan (below 49.8 Hz or above 50.2 Hz). The transition from normal operation to IOCM must be carried out with a maximum delay of 1 s (including frequency deviation evaluation by the frequency relay and switching of the unit's control scheme). No minimum delay is specified.



B // Operation in IOCM

During IO, the generating unit must ensure stable, coordinated operation within the isolated system segment and autonomously regulate active and reactive power output in response to system frequency and voltage variations.

Key functional requirements include the following:

- » The unit shall be capable of stable parallel cooperation with other generating units forming the island.
- » The response of active and reactive power to changes in frequency and voltage must remain adequate and stable, even under non-nominal conditions.
- » The unit's active power output in steady-state conditions shall follow the idealised dependency of turbine power P_{id} on frequency deviation Δf , as given by:

$$P_{id} = P_0 - \frac{100}{S} \frac{P_n}{f_n} \Delta f$$

where:

- » S – governor droop (recommended range: 4–8 %, allowed range: 4–10 %);
- » P_0 – power output of the generating module prior to transition to island mode, or the value corresponding to the base position of the regulating elements (e.g. control valves for steam turbines, fuel controller for gas turbines or guide vanes/runner blades for hydro turbines), provided that the operator has adjusted the output upon TSO dispatcher request.

The unit must be capable of autonomous regulation of frequency, voltage and load changes, without relying on external control loops, unlike during regular interconnected operation.

C // Reconnection of the island to the transmission system

For safe synchronisation and reintegration of the island with the rest of the grid, the generating unit must meet the following operational criteria:

- » Maintain stable IO for at least 2 h.
- » Smoothly adjust and regulate the island frequency as instructed by the TSO dispatcher to achieve synchronous conditions.
- » If synchronisation occurs at a transmission substation, the generating unit must be capable of energising the busbar and maintaining stable voltage control during synchronisation.

D // Availability and service monitoring

The IO service provider must ensure continuous readiness and compliance with certification requirements:

- » Periodic certification tests must be conducted to demonstrate the unit's capability to perform IO in accordance with the prescribed parameters.
- » The provider must allow on-site inspections by the TSO to verify technical preparedness and control system configuration.
- » During operation, the following parameters shall be continuously monitored and recorded:
 - › Switching of control modes (transition to/from IOCM)
 - › IOCM status
 - › Frequency measurements
 - › Confirmation of remote-control commands
 - › Other relevant telemetry signals required by the TSO



6.3.3 Testing and verification of IO capability

The generating unit operator must demonstrate both technical and control system readiness for IO operation through a set of prescribed verification tests. Certification measurements are conducted once every five years (for units providing black start capability simultaneously, this period can be shortened to three years).

The certification test comprises the IO- Δn test (by simulating rotational speed) and IO-transition to house-load operation (the so-called shutdown test).

IO- Δn test

This test is carried out on a generating unit synchronised with the power system. The frequency entering the IO controller from the power system essentially does not differ from the standard 50 Hz frequency. The rotational speed simulation test consists of several partial measurements and sub-tests. These are used to verify the generating unit's response to various types of fluctuations in real IO, as well as the correct functionality of the designed IO system.

1 // Transition to IOCM

The purpose of the test is to verify the unit's behaviour during the transition to IOCM. Since the frequency of the power system at the moment of transition to IO is practically nominal (50 Hz), the switch to IO should occur with no power impact. Any current deviation of the ES frequency from the nominal value might result in a corresponding power jump of the unit.

Depending on the unit's current capabilities, the transition to IO should be tested at least at two different power levels of the generating unit using a simulated islanding signal. It is recommended that one of the tested levels be the generating unit's nominal power level.

2 // Simulated step changes in rotational speed

The purpose of the test is to verify the behaviour of the generating unit during step changes in the droop speed controller's setpoint frequency (rotational speed). In this mode, the generating unit does not operate in closed-loop power control. Changes in the rotational speed setpoint result in adjustments to the opening of the unit control valves. The unit output is influenced not only by changes in the speed setpoint but also by other external factors (e.g. instantaneous steam inlet conditions, power system frequency fluctuations, etc.).

The generating unit is typically loaded with step signals for rotational speed changes at the upper, middle and lower values of the agreed power range for testing the unit's IO to make the test as representative as possible.

3 // Simulated continuous changes in rotational speed

The purpose of the test is to verify the correct behaviour of the unit's bypass stations, the available reserve for instantaneous active power changes across the entire IO control range and the correctness and functionality of the applied IOCM algorithm.

This test represents a comprehensive examination of the generating unit's behaviour across its full power range. It begins with a step change in rotational speed, followed by a linear continuous change until the upper or lower active power limit of the generating unit is reached.

4 // Switching the generating unit to the normal control structure

The purpose of the test is to verify the unit's behaviour during the transition from IOCM to the generating unit's normal operating mode.

The transition from IOCM is tested at least at two different power levels of the generating unit. The transition should be smooth and stable, without significant or abrupt changes in the unit's active power output.



IO-transition to house-load operation test

This is a disconnection test (or so-called shutdown test) in which the generating unit, previously automatically switched to droop speed control mode during the test, is shut down from its nominal active power level and transitions to the minimum load level defined by the unit's house load. The test itself comprises several sub-measurements:

- 1 // Disconnection test from nominal active power to the unit's house-load level.
- 2 // Operation at house-load level and variation of load caused by switching a large motor on and off.
- 3 // Synchronisation of the unit operating in IOCM with the power system at the transmission system substation.
- 4 // Transition of the unit to normal operating mode.

During the test, the unit does not receive information about the status of the unit evacuation line circuit breaker at the substation. As a result, it transitions to house-load operation mode based on the record from the run-over protection system.



6.4 Assessment of change in the IOCM band

In 2016, ČEPS requested several studies assessing the impact of changing the IOCM activation band from 200 MHz to 500 MHz. It is necessary to emphasise that, given their date of preparation, the studies were carried out from the perspective prior to RfG entering into force.

The studies were conducted by certification authorities specialising in the certification of non-frequency ancillary services, including the IO capability. A total of three mutually independent studies were produced by three companies. At that time, the main motivation for conducting the studies was the deteriorating frequency profiles in Continental Europe Synchronous Area and the higher probability of reaching ± 200 MHz thresholds.

The studies will be referenced in the text as follows.

» Study 1

» Study 2

» Study 3

The main objective of the studies were to assess the consequences of this change. Results of the studies was then presented to ČEPS. The conclusion from studies and companies' presentations was not to change the IOCM band from 200 MHz to 500 MHz, as the advantages were significantly smaller than disadvantages, costs and risks.

6.4.1 Study 1

The study contained a description of the IOCM for conventional thermal and hydro power plants. It also included the basic structure of the IOCM for selected TTPs. The study focused on evaluating the impact on conventional TTPs.

The study stated that it would be necessary to modify the parameters of frequency protection, the IOCM algorithm, and overspeed protection. Due to these changes, it would be necessary to perform tests and obtain new certification, which would result in increased economic costs and greater stress on the technology.

The study analysed the impact on frequency behaviour and boiler pressure. The activation threshold of frequency itself did not result in increased stress on the technology; however, a longer transition into IOCM and larger frequency deviations led to greater changes in boiler pressure, which in turn imposed additional stress on the boiler.

If the IOCM band was changed to ± 500 MHz while keeping the primary control reserve at ± 200 MHz, it created a 200–500 MHz band in which no primary control reserve was available.

This had a negative impact on the transition into IOCM and on frequency regulation within the 200–500 MHz band (for example, when the grid collapsed into multiple parts). Alternatively, a new control algorithm would have had to be implemented to handle the frequency response within this band.

The financial analysis consisted of the development and implementation of the algorithm, as well as performing tests on the unit and the cost of non-delivery of power caused by these tests. The financial costs were estimated at 1,400,000 CZK (approximately € 58,000) per unit, assuming that the tests were successful on the first attempt. The study assumed, for the purposes of the financial analysis, a reference 200 MW coal-fired unit. The stated costs corresponded to the 2016 prices.

The main risks associated with these changes concerned the modification of overspeed protection and the parameters in the IOCM. It was necessary to verify whether the power plant was capable of these modifications. Exceeding the configured overspeed protection limits would have resulted in a unit shutdown.



6.4.2 Study 2

The study contained a description of the IOCM in the Dukovany and Temelin NPPs. It also focused on evaluating the impact of the change on the Dukovany and Temelin NPPs.

The study described changes in the IOCM algorithm as well as in other parts of the power plant control system. It also noted changes in how NPPs reacted to a “large/small island”. Adjustments to the frequency relay limits were also necessary.

No significant changes were expected in the process of switching into IOCM. The study also supported this claim with a simulation of the Dukovany power plant switching into IOCM.

In the Dukovany power plant, the study expected greater overspeed in the event of a “small island”. In the Temelin power plant, the study expected that a larger frequency drop could have led to an outage of the main coolant pump.

The financial analysis consisted of modifications to the documentation, frequency protection, and the power plant control system. The cost of these changes was estimated to exceed 500,000 CZK (approximately € 21,000) per unit at that time. This study, unlike Study 1, did not include the costs of the change testing itself.

The study did not recommend changing the IOCM band from 200 MHz to 500 MHz for the Dukovany and Temelin NPPs.

6.4.3 Study 3

The study contained a description of the current implementation of the IOCM and how it was applied in coal-fired, nuclear, hydro, and CCGT power plants.

The study assessed the impact from two perspectives. The first perspective considered the power plant’s extended stay in normal operation (power control mode) up to ± 500 MHz. The frequency remained within the normal operating band, and no issues occurred in this case, meaning that it stayed within limits considered normal from the power plant’s technological perspective and did not impose any operational time constraints on the units.

The second perspective examined the longer transient states that occurred when the power plant switched into IOCM. This could have led to overspeed or a larger frequency drop, depending on the initial power imbalance. It also affected the certification tests, where a large surplus of power typically occurred during the switch-off test.

The study presented a similar view to Study 1. Changing the IOCM band would have resulted in a 200–500 MHz band in which no primary control reserve was available.

The frequency relay would have needed adjustment on all units capable of IOCM, and it would have been necessary to verify that no conflict arose with the new frequency limit. It would also have been necessary to modify the description of the frequency-relay signal, the basic valve-opening algorithm, and the algorithm for transitioning from IOCM back to normal operation (power control mode).

The cost depended heavily on the number of vendors and the extent of the modifications within the power plant. The study estimated that the cost per power plant would have been 600,000 CZK + 200,000 CZK multiplied by the number of units in the power plant (approximately € 25,000 + € 8,000 × units). This study also did not include the costs of the testing itself.

6.4.4 Conclusion

The conclusions of the studies showed that shifting the IOCM activation band from 200 MHz to 500 MHz would have more disadvantages than advantages. However, based also on experience from the incident on 4 July 2025, it appears that dynamic transient phenomena may occur in the power system that can result in a rapid and temporary deviation of the measured frequency beyond the ± 200 MHz limits, without the frequency deviating at the global level (i.e. at the level of the synchronous zone).

Based on this fact, Expert panel recommends to introduce a certain delay in the operation of frequency protections. This delay should ensure sufficiently fast operation in cases of a genuine global frequency deviation or a system split, while at the same time filtering out fast local transient phenomena in order to prevent unnecessary operation.



6.5 Analysis of system defence measures

The Expert Panel analysed the relevant legislation and the internal ČEPS procedures to understand dispatchers' actions during the incident.

At the beginning of the situation, with the tripping of line V411, dispatchers proceeded in accordance with the joint operational instructions 020-8 and 028-1, which define responsibility and competencies between all the subjects participating in dispatch control of the Czech grid.

When the line V411 tripped, followed by the outage of generation, dispatchers were notified by many visual and sound alarms, especially:

- » About the trip of the line (due to activation of the protection device)
- » Unsatisfied aFRR demand (due to the high area control error)
- » Very high aFRR price
- » Overloading of the line V208, transformer T402 in substation Hradec and busbar coupler in substation Krasíkov

Dispatchers were well informed about the tripping of line V411. They initiated their action according to operational procedure 620-12.

The rapid change in balancing was not considered as relevant in the first minute due to their inability to analyse the primary cause of deviation. Based on internal operational procedure 320-6 and practical training, dispatchers should find the root cause of the balancing incident for their next decision on how to balance the system.

With the overloading of the V208, T402 in substation Hradec and of the busbar coupler in substation Krasíkov dispatchers checked the maximum ampacity of these elements. The line V208 is not overloadable at all since it is equipped with the dynamic rating, the transformer T402 in substation Hradec can be overloaded up to 120 % for 3 hours. The maximum ampacity of the busbar coupler in substation Krasíkov alarmed in control system is set on 2,000 A (the maximum set ampacity for disconnectors), set point for the overcurrent protection is 2,880 A.

To decrease the overloading especially of the line V208 dispatchers were trying to find either the topological measure or the redispatch measure according of the operational procedure 620-15. They presumed the redispatch as not efficient enough due to the slow activation.

After concluding that remedial actions were not sufficient to solve the overloading, they proceeded to the evaluation of the system defence plan. Specifically, they considered the following measures (as described in the operating instructions):

- » Activation of the change of generated power by SGU (Art. 20 NCER)
- » Manual disconnection of the overloaded element (if the fault does not propagate to another location, especially across the border)
- » Limitation plan (Oper. Instr. 827-1)
- » Load shedding

Under the circumstances of the strong overloading (142.9 %) and balancing problem and from "dispatchers" point of view of the non-standard behaviour of the control system due to the rapid changes in the grid - the divergent cases in contingency analysis, a limitation on metering transformer in the 220 kV substation Milín and the respective visualisation of the metered values on the line V208 in the control system, dispatchers were aiming at finding a suitable and efficient topological non-costly measures and costly measures as the change of generated power and even the load shedding in the affected area. The activation of load shedding would require a declaration of a state of emergency or prevention of a state of emergency according to Czech law, which would take tens of minutes during which the situation would further worsen. None of the other measures were fast enough either. Increasing active power output of distributed generation is technically not possible at all.



6.6 Analysis of manual disconnection of the overloaded line

The dispatchers considered that the line V208 passes through a densely populated area of Prague and its overloading poses a risk to the inhabitants. The dispatchers conducted an online load flow analysis and N-1 calculation of the impact of switching off V208, and concluded at that time that the results meant that the disconnection would have no further consequences of the grid. However, the disconnection resulted in an overloading of the busbar coupler in Krasikov, its disconnection, and the collapse of the island.

The ex-post analysis of the Expert Panel shows that the analyses in fact correctly predicted that the V208 disconnection would result in overloading of the busbar coupler in the 400 kV substation Krasíkov to the protection limit; however, this effect was not identified at the time.

The Expert Panel issues a related recommendation R5 on decision support for control room operators and R9 on storing the results of online N-1 calculations.



7 INCIDENT CLASSIFICATION BASED ON ICS METHODOLOGY

The ICS methodology was originally developed in accordance with Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009, as repealed by the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast), and updated to fulfil the objectives and the security indicator requirements laid out in Article 15 of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SOGI). The definitions and concepts in this methodology are in line with Articles 15 and 18 of the SOGI and further extended to describe the real-time situation of the TSO's system.

Scale 0 Noteworthy incident		Scale 1 Significant incident		Scale 2 Extensive incident		Scale 3 Major incident / TSO	
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)		

Table 7.1: Incident classification scale

Table 7.1 shows the ICS criteria from the methodology and the corresponding scale, ordered by descending priority. An incident can comprise multiple events and meet various ICS criteria. In this case, the highest criterion decides the scale of the incidents.

In the case of a scale 2 or 3 incident, an investigation is conducted by an Expert Panel. While only the highest-priority criterion is relevant for determining the scale, the other criteria are also assessed.



7.1 RCC investigation threshold

The RCC post-operation and post-disturbances analysis and reporting (RIAR) methodology has been developed to define the respective 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 TSO has moved from a normal or alert system state to an emergency system state as a result of actions taken by another TSO being in emergency, blackout or restoration system state; and
- » The incident has been confirmed as at least scale 2, as defined by the ICS methodology.

Post-analysis confirmed that no other TSO in the area entered the emergency system state as a result of this incident.

7.2 Scale of incident

The highest-violated ICS criterion during this incident was a scale 2 incident on load (L2). This criterion is met if more than 10 % but less than 50 % of the load is lost (compared to the pre-incident load). In this incident, 2,300 MW of load was lost, which is 28 % of the demand before the incident (8,200 MW) in the ČEPS control area. In addition to the lost load, there were several other criteria violations as listed in Table 7.2.

At 11:51:06 CEST, a T1 incident occurred, resulting in the loss of the 400 kV V411 line. Within seconds, there was a below scale G violation with a loss of 340–440 MW of generation. This resulted in ON1 as there was a deviation from operational security limits due to the thermal overload of the 220 kV V208 line.

After the manual disconnection of the 220 kV V208 line at 11:59:44, another T1 occurred when a 400 kV busbar coupler and a 400 kV/110 kV transformer in substation Krasíkov tripped, resulting in a scale 1 separation from the grid (RS1). The subsequent loss of all remaining generation on the separated island violated the G1 criteria, and the loss of load resulted in a scale 2 loss of load (L2) violation. Neither scale 2 threshold for the T2 or the ON2 criteria were met as no ICS scale 1, 2, or 3 violation propagated to a neighbouring TSO due to the incident. The voltage collapse in the separated area during the incident was too fast to be registered in the existing ICS criteria for OV. No frequency degradation was measured in Continental Europe due to the incident.



Criterion	Scale	ČEPS
OB	3	Not Violated
L	2	×
	1	
	0	
F	2	Not Violated
	1	
	0	
	BS	
T	2	
	1	×
	0	
G	2	
	1	×
	0	
	BS	
ON	2	
	1	×
RS	2	
	1	×
	0	
OV	2	Not violated
	1	
	0	
	BS	
RRC	2	Not violated
	1	
	0	
LT	2	Not violated

Table 7.2: ICS criteria violations by TSO

Note. Each violated ICS criterion has an X in the cell. The scales shown are 0–3 and below-scale (BS).



8 ROOT CAUSES

The **Root Cause Tree** shown on the next page outlines the key events leading to the collapse of the affected area. These events are described in detail in Chapter 3.

The graph below shows the decomposition of the loading of the line V208 and the busbar coupler at the Krasíkov 400 kV substation. From that it can be concluded that only the disconnection of V411 would kept the loading of V208 below 100% and the incident would not propagate. Subsequent events following the trip of V411

led to a severe overload of V208, reaching up to 142%. After that, the line V208 was disconnected, marking the point of no return (as described in the fault tree).

For a detailed time series of the loading of affected elements please refer to Figure 3.4 and Figure 3.5

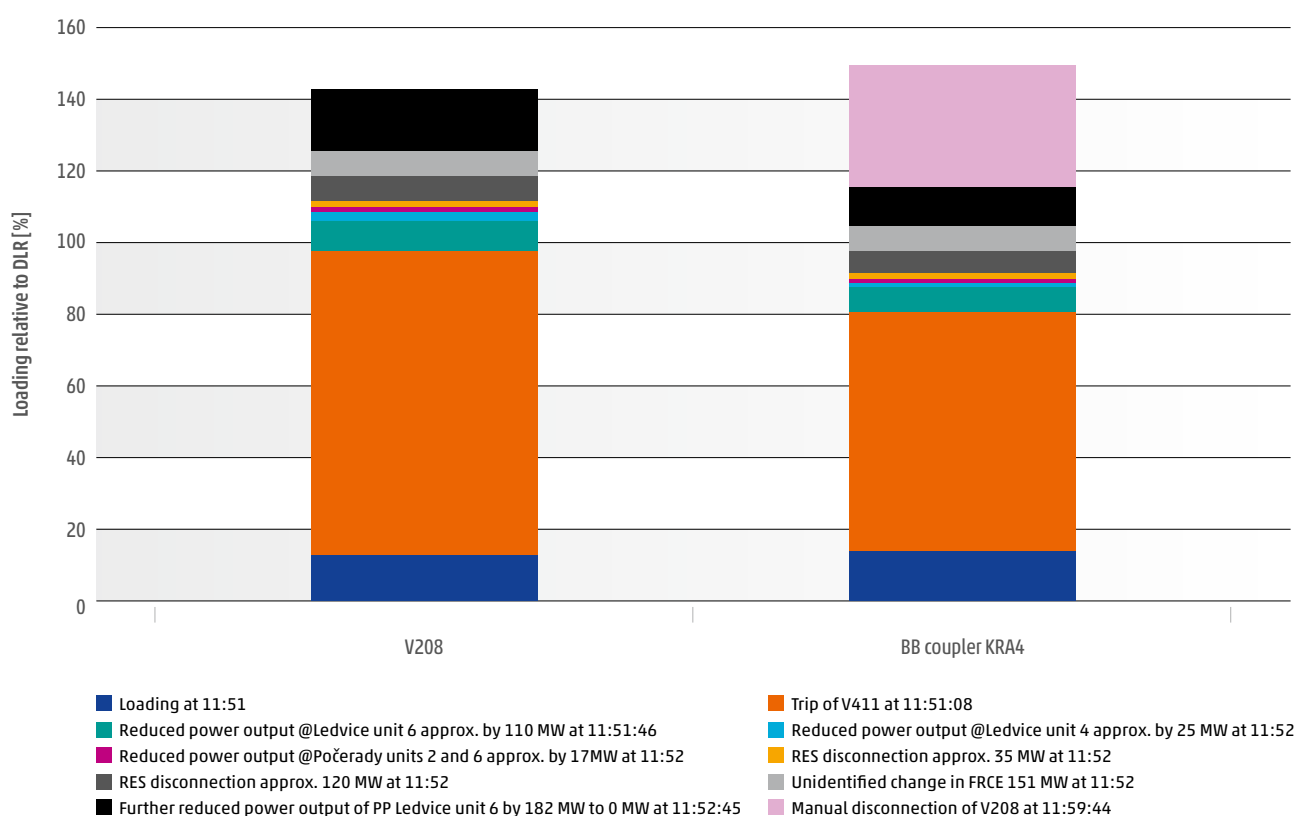


Figure 8.1: Decomposition of the loading of the line V208 and the busbar coupler at Krasíkov

The numbers at selected events refer to recommendations addressing these events. Those are described in Chapter 9.



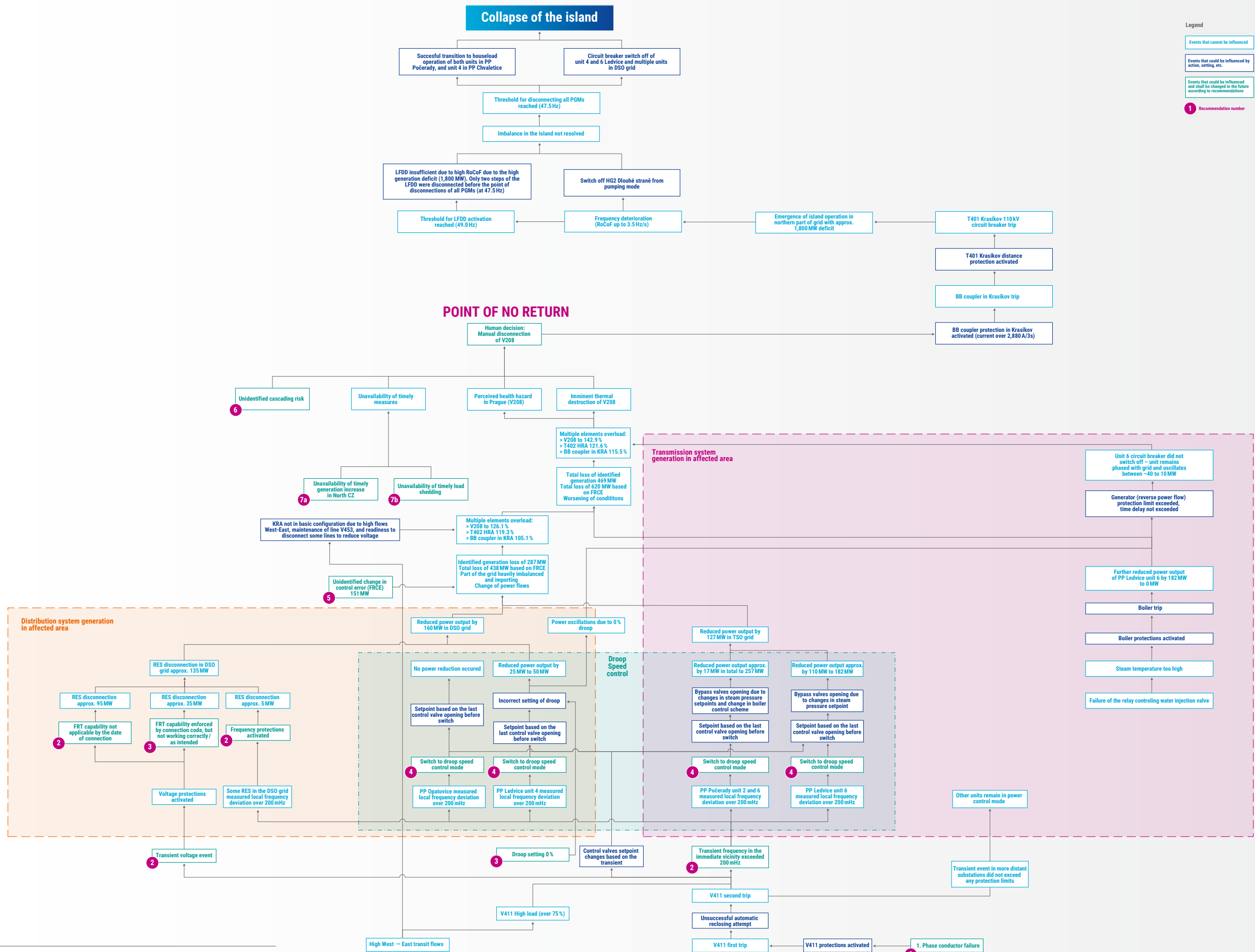


Figure 8.2: Root Cause Tree

9 RECOMMENDATIONS

R250704-1	Strengthen verification and quality assurance for work on the transmission network, with a particular focus on emergency repairs and work affecting the mechanical integrity of primary equipment.
Description	Review verification and quality assurance for maintenance works in the transmission network (TSOs), with particular focus on emergency repairs and works affecting mechanical integrity of primary equipment. Assess and, where needed, increase the level of supervision and documentation for emergency works (TSOs) (e.g., photographic evidence of critical assembly steps and torque/installation records where applicable). TSOs should ensure that the installation/maintenance teams use appropriate (and certified, where relevant) tools when performing works on the primary equipment. Assess feasibility to apply thermal diagnostics/inspection after emergency works (TSOs) (performed as soon as practicable and under suitable conditions) to detect abnormal heating indicative of poor contacts or assembly issues.
Justification	In the incident, the tensile coupling after an emergency repair of the line had an insufficiently tight connection. The investigation did not identify the cause. Additional verification, quality assurance procedure and also possible thermal diagnostics could reduce the failure of equipment after repair or maintenance works.
Delivery owners	TSOs
Priority	Medium

R250704-2	Assess and mitigate the risk of distributed generation disconnection after transient events.
Description	a // ENTSO-E should prepare a list of plausible scenarios for which the risks of widespread distributed generation disconnections should be assessed. b // TSOs should assess the risk of widespread distributed generation disconnection following transient processes (TSOs and DSOs) (e.g. faults cleared under N-1 conditions). This risk may be assessed by performing ex-post analysis after incidents on the system and proportionate mitigation measures should be proposed (TSOs). Each TSO, in coordination with the relevant DSO, should evaluate the criteria for when distributed generation disconnection risk shall be explicitly considered in operational security assessments. Where justified by the risk assessment, TSOs may propose for the approval of NRA or Member States, to update the requirements for distributed generation, in particular for voltage and power protection settings for relevant power generating units, including consideration of applying Article 4 RfG to relevant existing power generating units.
Justification	During the incident, some distribution-connected generation unexpectedly disconnected following a voltage transient after a transmission line trip. Identification of such risk and application of possible measures could reduce the risk of unexpected behaviour of the power system during transient processes.
Delivery owners	ENTSO-E, TSOs, DSOs, and national competent authorities
Priority	High



R3 R250428_8	Change needed (in magenta) for recommendation 8 from the grid incident in Spain and Portugal on 28 April 2025. Validated control and protection settings for generation and storage units and generation and storage evacuation grid connected to the TSO and DSO.
Description	TSOs and DSOs should assess the adequacy and consistency of the protection settings for generation and storage units and evacuation grid elements (e.g., transformers below which several power-generating and storage modules are connected, including distribution-connected and distributed energy resources). This verification should ensure that withstand capabilities (high/low voltage, RoCoF) are aligned with the highest capabilities of grid users connected downstream, with explicit checks on over/undervoltage thresholds, and minimum time delays (commensurate with system dynamics and measurement uncertainties, e.g., ≥ 100 ms or even > 1 s where applicable), alignment with the minimum timing requirements and voltage thresholds established by the applicable regulations and ensuring a sufficient margin in the adjusted thresholds to prevent potential measurement inaccuracies from causing unintended disconnections remains critically important. If this is not the case, appropriate corrective actions to achieve compliant protection settings should be identified and implemented. Protection settings and control settings of power generating modules and storage modules (e.g., droop setting) should be consistent with applicable connection requirements and/or bilateral agreements and should be periodically assessed. If necessary, TSOs should assess, in coordination with national competent authorities, the possibility of applying the relevant requirements (e.g. Art. 4 RfG), where justified by system security needs.
Justification	The analysis and expert inputs point to sensitivity to local protection settings (e.g., overvoltage thresholds measured away from the point of connection, instantaneous trips without delay, or droop setting) that can unnecessarily disconnect generation when voltages oscillate or rise transiently. In some cases, the protection appears to diverge from the applicable requirements. During the incident, the droop at one of the thermal generating units was set at 0 %, meaning an infinite gain and triggering oscillations. Inappropriate control settings or protection settings can contribute to unstable behaviour or loss of generation during disturbances. While droop settings and behaviour of storage units was not assessed in the investigation, the addition is made by analogy.
Delivery owners	TSOs, DSOs, and national competent authorities.
Priority	Medium

R250704-4	Review transition to droop speed control mode (IO mode) logic and frequency protection delay, where applicable.
Description	To avoid triggering on fast local transients while maintaining protection of genuine system separations, TSOs should review the settings and operational logic related to transition of turbine governors to droop speed control mode (IO mode) or LFSM, where such capability exists, and associated frequency protection actions, including the potential need for introducing an intentional time delay before transitioning, where justified to improve selectivity.
Justification	The investigation highlighted that fast local phenomena could lead to the significant short-term frequency deviations. Instantaneous protection action without a defined minimum time delay may itself contribute to worsening system behaviour during fast transients. Improved selectivity reduces unnecessary transitions/actions. In this incident, there was no time delay setting (i.e. $t = 0$ s) for the transition of generators to droop control mode, meaning they transitioned immediately when the frequency transient reached 49.8 Hz.
Delivery owners	TSOs
Priority	Low



R5 R250428_14	Change needed (in magenta) for recommendation 14 from the grid incident in Spain and Portugal on 28 April 2025. Streamlined cross TSO/DSO/PGM investigation data governance.
Description	Establish a permanent, standardised framework for data provision during incident investigations or for broader system analyses to improve understanding of overall system behaviour. This framework should ensure fast, complete and uniform access to all required datasets from TSOs, DSOs (including distribution-connected generation data available to DSOs), SGUs operating power-generating facilities, SGUs operating large demand facilities, and SGUs operating HVDC or other inverter-based installations and other parties capable of providing relevant data on small-scale generation or storage facilities. The framework should be jointly developed by TSOs and DSOs, coordinated at the European level, and subject to oversight from the national competent authority. This framework should define: » the exact data types and formats (event logs, dynamic recordings, high-resolution PMU/SCADA, DER status, protection activations); » latency and completeness requirements, including defined escalation mechanisms; » authorised data-sharing; » predefined legal/contractual provisions removing the need for ad hoc negotiations. This process should allow investigations to fully and reliably compare oscillation behaviour, disconnection patterns, and defence plan performance across all voltage levels, taking into account applicable SO GL Article 40(5) provisions and national RfG banding thresholds. Where relevant for incident investigation purposes, the framework should define conditions under which selected operational data already available in real-time is preserved and made accessible for post-event analysis, without introducing additional real-time operational obligations. In addition, regular data-provision readiness exercises should be conducted to verify and benchmark all partners' ability to deliver the required datasets within the specified timeframes and formats. This recommendation should apply to all installations (existing, new, restored or modified), ensuring uniform obligations and avoiding gaps in data availability. This framework is intended to support incident investigation, system learning and analytical consistency and does not replace or modify existing regulatory compliance or enforcement processes.
Justification	The investigation faced delays and analytical limitations due to gaps in the available data, particularly from SGUs operating power-generating facilities and from DSOs. This reduced the ability to reconstruct dynamic behaviour, identify oscillation sources, quantify DER disconnections, and understand protection responses. In future events, a structured, pre-agreed data governance framework would help ensure timely, consistent data provision and thereby enhance both the speed and the quality of incident analysis. In the investigation of the incident on 4 July 2025, datasets with detailed measurement and protection activation data for distributed generation remained unavailable. In fact, the active power lost in the distribution system which could be identified (160 MW) is almost equal to the active power deviation the cause of which could not have been identified (151 MW). Data gaps hinder root-cause identification and can lead to incorrect assumptions in operational planning and dynamic studies.
Delivery owners	TSOs, DSOs, SGUs operating generation, demand or HVDC/inverter-based installations and national competent authorities, and other parties capable of providing relevant data on small-scale generation or storage facilities.
Priority	Medium



R250704-6	Enhance the decision support for control room operators with real-time assessment and visualisation tools to identify the cascading risk.
Description	To enable sound dispatcher decision making under high stress, TSOs should review the real-time assessments and visualisation capabilities during critical real-time situations. The improved visualisation should enable operators to evaluate the system impact of remedial actions (including possible disconnections of overloaded elements) and to identify potential cascading effects. Where necessary, proportionate improvements should be implemented to visualisation tools to clearly visually distinguish N-1/switching action resulting in acceptable overloads from the ones potentially triggering a cascade of disconnections (i.e. non-permissible and unacceptable violations). Furthermore, TSOs can consider tools and approaches to enhance and facilitate operators' situational awareness, and may also review training, procedures and coordination practices in critical real-time situations.
Justification	During fast developing events decisions must be made under time pressure. Enhanced situational awareness and fast impact assessment reduce the risk that remedial actions inadvertently trigger cascading effect. In this incident, the control room operators manually disconnected line V208 expecting no consequences of the grid, while the regular N-1 analyses correctly indicated the disconnection of this line would in fact lead to further trips.
Delivery owners	TSO
Priority	High

R250704-7	Review and operationalise the system defence plan procedures for preventing the escalation of the incident, and ensure they include all technically possible measures, and that the measures are executable in practice where relevant.
Description	TSOs should consider reviewing emergency procedures enabling timely activation of technical measures to prevent escalation of overloads and reduce the likelihood of cascading effect (TSOs together with relevant DSOs and SGU). TSOs should review whether various measures in the emergency situation to prevent escalation of the incident can be implemented in practice. Examples of such measures: - a // Procedure with relevant power generation and storage modules to change active power set point, particularly for storage units consuming energy, and including distribution-connected modules. - b // Procedure to disconnect or reduce consumption in transmission network (including manual load shedding) and distribution networks where relevant. Where the TSO identifies procedural or legal obstacles impeding an efficient activation of emergency measures (e.g. significant time or regulation limitations), the TSOs should consider proposing the relevant regulatory amendments to NRAs or, if applicable, legislative amendments to the applicable entity.
Justification	During the event, measures that would have relieved the deficit of the affected area (like manual load shedding of distribution load, reduction of the consumption of the pumped-storage units, or generation activation) were not undertaken as they would have necessitated the process of formally declaring a state of emergency or were considered to be insufficiently fast. Clear emergency procedures and pre-agreed timely measures increase response speed and consistency, reducing the probability of escalation.
Delivery owners	TSOs, DSOs, NRAs.
Priority	High



R250704-8	Review the thresholds and technologies providing automatic response to frequency deviations
Description	a // TSOs should review, and if necessary, adjust, the thresholds and time delays for underfrequency disconnections of storage facilities in electricity consumption mode. Particularly, the TSOs should ensure that storage consuming electricity switches to generation mode or disconnects at appropriate frequency thresholds and time delays, prior to the activation of the LFDD scheme. In CESA, the setting should be in accordance with SAFA Annex on Emergency and Restoration policy C-5. b // Analogously, TSOs should review the thresholds and time delays for overfrequency disconnections of storage facilities in generation mode. When performing the review mentioned in points a) and b), the TSO should assess whether storage technologies other than pump storage are appropriately considered - in particular, inverter-based battery storage. If relevant, TSOs should consider whether different thresholds for different technologies might be applicable.
Justification	While not relevant for the incident due to the high RoCoF (up to 3.5 Hz/s), the current setting of underfrequency protections of pumped-storage units in pumping mode may not ensure their full disconnection before the activation of LFDD in all foreseeable situations.
Delivery owners	TSOs
Priority	Medium

R250704-9	Storing the data of online N-1 calculations
Description	TSOs should ensure the results (and all other relevant data, which may include incl. input data) of ad-hoc online/study mode N-1 security assessments performed in the control room are available for assessing the results in ex-post event investigations, but also in regular feedback processes where relevant. As an example, in case of N-1 calculations, both the results and the model used shall be available. The storage should be performed automatically for the appropriate amount of time (e.g. one week), with the possibility to permanently store any results of particular interest (e.g. related to an incident).
Justification	While the results of the regular N-1 calculations, automatically performed every two minutes, were stored, this was not the case for the results of the ad-hoc online/study mode N-1 assessments. Having these latter inputs and results available during the investigation would have offered more clarity on an aspect of this incident, and would enable a more accurate conclusion of where possible improvements lie.
Delivery owners	TSOs
Priority	Medium



LIST OF ABBREVIATIONS

aFRR	automatic frequency restoration reserve
CCT	critical clearing time
CCC	coordinated capacity calculation
CBMP	Cross border marginal price
DA	day-ahead
DACF	day-ahead congestion forecast
DFRs	disturbance fault recordings
DLR	dynamic line rating
DSA	dynamic stability assessment
DSO	distribution system operator
EAS	ENTSO-E Awareness System
FRCE	frequency restoration control error
ICS	Incident Classification Scale
ID	intraday
IDA	intraday auction
IO	island operation
IOCM	island operation control mode
LFDD	low-frequency demand disconnection
NCER	Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration
NPP	nuclear power plant
NRA	National regulatory authorities
OPC	outage planning coordination
PGM	power-generating module
RCC	regional coordination centre
RfG	Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators
RoCoF	rate of change of frequency
SGU	significant grid user
SOGL	Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation
STA	Short-term adequacy
TSO	Transmission system operator
TPP	Thermal power plant
XNE	cross-border relevant network element



EXPERT PANEL MEMBERS

Donatas Matelionis	Litgrid (Expert Panel Convenor)
Ana Cigarán Romero	50Hertz
Rafał Kuczynski	ENTSO-E (RG CE convenor – PSE)
Gamze Dogan	ENTSO-E
Martin Pistora	ČEPS
Radim Chrapek	ČEPS
Uros Gabrijel	ACER
Georgios Antonopoulos	ACER
Domen Kodric	ACER
Jan Kostevc	ACER
Nicolas Krieger	BNETZA
Jochen Gerlach	BNETZA
Thomas Hoelzer	BNETZA
Martín Colchón	CNMC
Pavel Šimončík	ERÚ
Jan Metzl	ERÚ
Jørn Schaug-Pettersen	Statnett
Jonas Häusler	TSCNET



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info@entsoe.eu
info@acer.europa.eu

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