# » Local Grid Incident in Rogowiec (Poland) substation on 17 May 2021

ICS Investigation Expert Panel » Final Report » 18 March 2022

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# Expert Panel Members

This Final Report was produced by the Expert Panel on the Local Grid Incident in Rogowiec (Poland) on 17 May 2021:

| | |
|---|---|
| **Laurent Rosseel** | RTE/Expert Panel Convener |
| **Marek Kornicki** | PSE |
| **Uros Gabrijel** | ACER |
| **Aleksander Glapiak** | ACER |
| **Tahir Kapetanovic** | APG |
| **Mohamed El Jafoufi** | ELIA/ICS Convener |
| **Tomasz Barlik** | PSE |
| **Rafał Kuczyński** | PSE |
| **Nicolas Krieger** | BNetzA |
| **Jochen Gerlach** | BNetzA |
| **Witold Zuchowski** | URE |
| **Piotr Owczarczak** | URE |
| **Lukasz Makos** | URE |
| **Ioannis Theologitis** | ENTSO-E |
| **Kacper Kepka** | ENTSO-E |

# Report Drafting Team

| | |
|---|---|
| **Laurent Rosseel** | RTE / Expert Panel Convener |
| **Marek Kornicki** | PSE |
| **Tahir Kapetanovic** | APG |
| **Mohamed El Jafoufi** | ELIA / ICS Convener |
| **Tomasz Barlik** | PSE |
| **Rafał Kuczyński** | PSE |
| **Ioannis Theologitis** | ENTSO-E |
| **Kacper Kepka** | ENTSO-E |
| **Bernard Malfliet** | Elia |
| **Olivier Arrive** | RTE |
| **Albino Marques** | REN |
| **Nikola Obradovic** | EMS |
| **Giorgio Giannuzzi** | Terna |
| **Walter Sattinger** | Swissgrid |

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# EXECUTIVE SUMMARY

On Monday 17 May 2021 at 16:34 CET an incident occured in Poland's Rogowiec substation which led to the tripping of ten generation units of the Bełchatów power plant and a loss of 3,322 MW of generation capacity. The initiating cause of the incident was a human error. Incorrect manipulation of the line earthing switch led to a short circuit in the 400 kV Rogowiec switchyard.

No consumer was disconnected. There was no negative impact on the operation of the synchronously interconnected power system of Continental Europe (CE). Thanks to the swift remedial actions taken by PSE, the Polish Transmission System Operator (TSO), as well as the emergency support from neighbouring TSOs and cooperation with the coordination centre, the power system was operating within the security limits approximately 20 minutes after the incident. The Rogowiec substation returned to normal operation about an hour after the incident and the tripped generation units of the Bełchatów power plant were re-connected to the power system as soon as technically possible.

The incident did not have a direct impact on the functioning of the market. The unavailability of Power Generation Modules (PGMs) caused by a grid constraint (i. e. inability to generate power by those PGMs due to grid constraints) does not impact the balancing price formation. The market continued to function according to the agreed procedures in all times.

In light of the legal provisions set forth by the System Operation Guideline (Article 15 SO GL), a mandatory classification of the incident in accordance with the Incident Classification Scale (ICS) methodology has to be investigated.

The Polish Investigation Commission was therefore established. The Commission examined the causes and circumstances related to the incident and examined the actions leading to the restoration. Based on the analysis of the incident, improvements have been derived and introduced internally by PSE. Based on the collected facts, the Expert Panel presents general recommendations and internal actions for TSOs.

# 1 INTRODUCTION

The analysis presented in this Report is based on the information provided by PSE (Polish TSO), as well as the information provided by Coordination Centre North operated by Amprion in Brauweiler (Germany). Additional relevant sources of data were measurements from transient recorders or digital protection devices with precise GPS time stamps from substations in Poland and Wide Area Monitoring Systems (WAMs) across the Continental Europe synchronous area (CE SA).

**The final report is structured as follows:**

- The second chapter presents the facts that have been gathered regarding the evolution of system conditions during the event – it includes the system conditions before the separation, the impact on the market and the sequence of events. The chapter is complemented by an overview of system status and automatic defence actions as well as the manual countermeasures and system stabilisation.
- The third chapter focuses on the recovery process and taken countermeasures.
- The fourth chapter reflects the communication between the TSOs.
- The assessment of the incident based on the ICS Methodology is given in the fifth chapter.
- The overall analysis of the incident, recommendations and internal actions are concluded on in the final, sixth chapter.

# 2 EVOLUTION OF THE SYSTEM CONDITIONS DURING THE EVENT

## 2.1 System conditions before the event

### 2.1.1 System conditions in Poland

Prior to the incident, the Polish Power System (PPS) was operating within security limits and with the required level of reserves (SO GL requirements were fulfilled). The active power reserve amounted to 3,379 MW, whereas the required minimum amounted to 1,748 MW and was available on thermal and hydro Centrally Dispatched Power Generating Modules (PGM). RES generation amounted to 330 MW in wind farms and 800 MW in photovoltaics (PV).

**The scheduled exchange at the cross-border interconnections of the PPS was as follows:**

- +1,173 MW (import) on synchronous interconnections (Germany, the Czech Republic and Slovakia);
- +600 MW (import) on the Poland–Sweden DC interconnection;
- +190 MW (import) on the interconnection with Ukraine (radial operation of the PGMs from the Dobrotvir Power Plant (PP).

The Poland–Lithuania DC (B2B) interconnection was out of operation due to maintenance. The total scheduled exchange of PPS amounted to +1,963 MW (import). The area control error (ACE) of the PL control block was 30 MW in the export direction. The frequency immediately prior to the incident was equal to 49.984 Hz. The voltage levels did not exceed the limits for the normal system state.

Based on the version 62 of the Continuously Updated Balancing Plan (as of 16:26:03), the PPS balance was consistent with the values presented in Table 1 below.

| Time | PPS demand (gross) | Generation in Poland (gross) | Scheduled Exchange | Available FCR | Available aFRR |
|---|---|---|---|---|---|
| **16:30** | 21,054 MW | 19,054 MW | 2,000 MW | 170 MW | 563 MW |
| **16:45** | 21,057 MW | 19,057 MW | 2,000 MW | 170 MW | 563 MW |
| **17:00** | 20,925 MW | 18,925 MW | 2,000 MW | 170 MW | 563 MW |

Table 1: PPS balance according to the Continuously Updated Balancing Plan (version 62 as of 16:26:03)

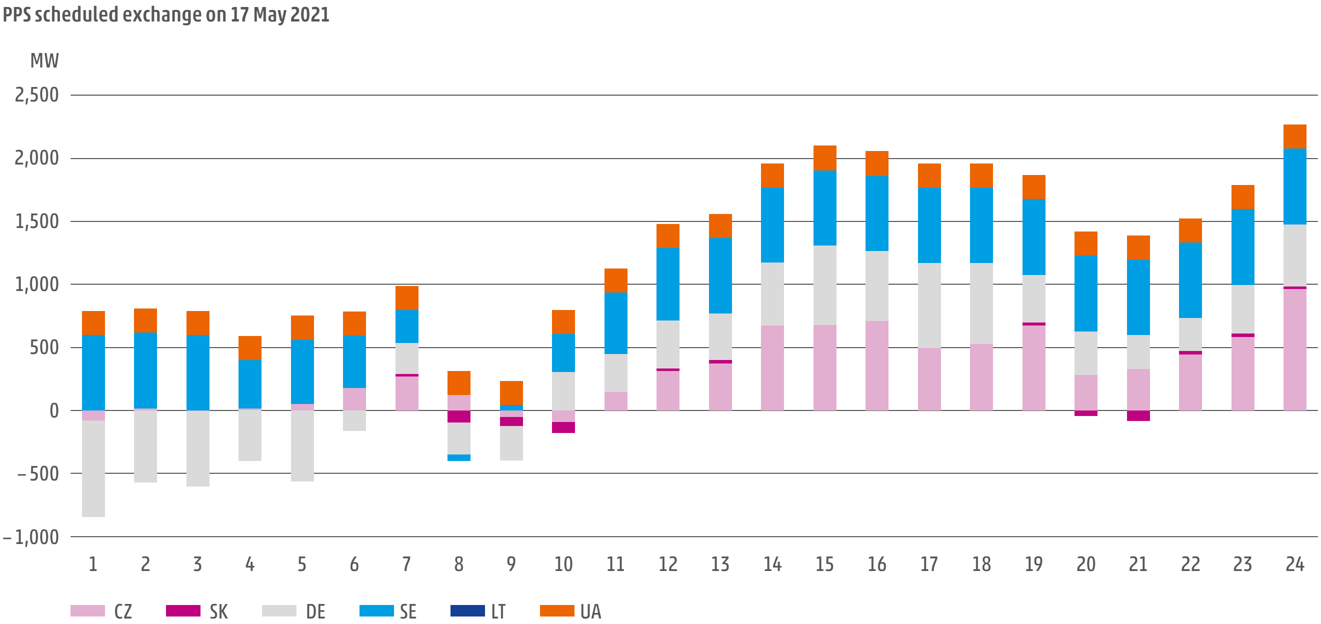



Figure 1: PPS scheduled exchange on 17 May 2021.

## 2.1.2 Rogowiec Substation configuration

On 17 May 2021 only scheduled outages took place. There were no forced outages. Substation Rogowiec operated in the standard configuration. Directly before the incident, the R-400 kV Rogowiec switchyard operated as one electrical node, whereas the R-220 kV Rogowiec switchyard operated as two separate electrical nodes.

Substation R-400 kV Rogowiec consists of 2 main busbars and an additional bypass busbar. Each main busbar can be separated by section busbar coupler. Directly before the incident, the substation R-400 kV Rogowiec operated in the following configuration:

- » system 1: closed busbar section's coupler of system 1 (1A-1B). Lines: Trębaczew (TRE4), Płock (PLO4) and Tucznawa (TCN4); 400/220 kV autotransformer AT1; PGM lines: PGM BEL_4-07, PGM BEL_4-10 and PGM BEL_4-11;
- » system 2: closed busbar section's coupler of system 2 (2A-2B). Lines: Ostrów (OSR4), Ołtarzew (OLT4) and Joachimów line circuit 3 (JOA4); 400/220 kV autotransformer AT2; PGM lines: PGM BEL_4-06, PGM BEL_4-08, PGM BEL_4-09 and PGM BEL_4-12;
- » busbar coupler SP-B closed (1–2);
- » busbar coupler SP-A opened.

Substation R-220 kV Rogowiec consists of 3 main busbars. Directly before the incident, the substation R-220 kV Rogowiec operated in the following configuration:

- » system 1: de-energised;
- » system 2: Lines: Bełchatów Kopalnia line circuit 1 (BEK21), Pabianice line circuit 1 (PAB21), Janów line (JAN2) and Joachimów line circuit 1 (JOA21); 400/220 kV autotransformer AT2; PGM lines: PGM line BEL_2-02 and PGM line BEL_2-04; PP's auxiliary transformers TR1 & TR2;
- » system 3: Lines: Piotrków (PIO2), Joachimów circuit 2 (JOA22), Pabianice line circuit 2 (PAB22) and Bełchatów Kopalnia circuit 2 (BEK22); 400/220 kV autotransformer AT1; PGM lines: PGM BEL_2-03 and PGM BEL_2-05;
- » busbars coupler A and B opened.

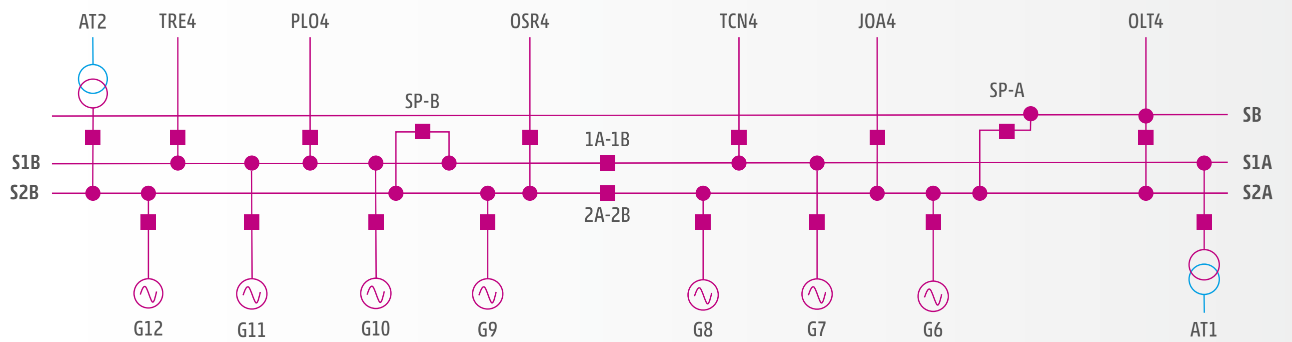



Figure 2: Line diagram of R-400 kV substation Rogowiec.

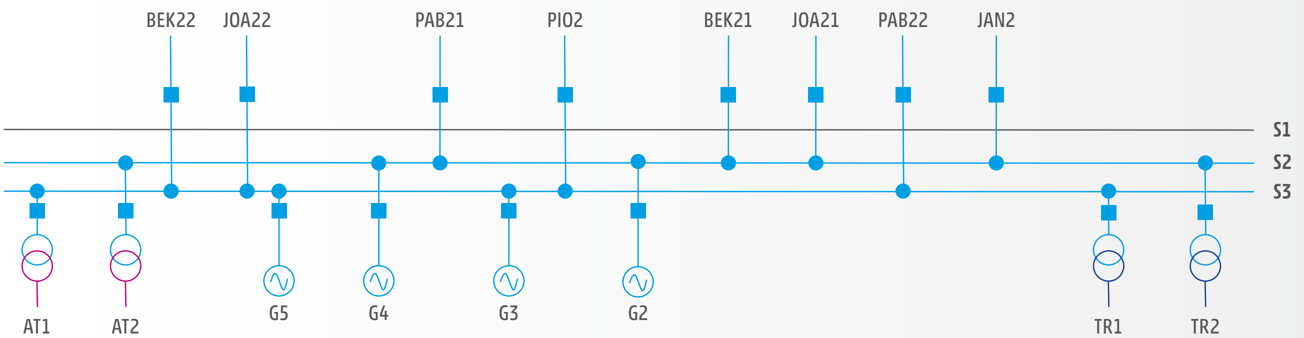



Figure 3: Line diagram of R-220 kV substation Rogowiec.

At 16:34:10, i. e. at the moment of the incident, the total generation of all PGMs of Bełchatów PP in Rogowiec Substation (R-400 kV Rogowiec and R-220 kV Rogowiec) amounted to 3,556 MW (gross values). The generation of individual PGMs is shown in Table 2.

| PGM | Switchyard voltage | Active Power (gross) P [MW] | Reactive Power (gross) Q [MVAr] |
|---|---|---|---|
| BEL_2-02 | 220 kV | 361 | 11 |
| BEL_2-03 | | 359 | 41 |
| BEL_2-04 | | 343 | 8 |
| BEL_2-05 | | 356 | 44 |
| BEL_4-06 | 400 kV | 361 | 15 |
| BEL_4-07 | | 356 | 22 |
| BEL_4-08 | | 349 | 24 |
| BEL_4-09 | | 366 | 22 |
| BEL_4-10 | | 357 | 22 |
| BEL_4-11 | | 348 | 23 |
| BEL_4-12 | | 0 | 0 |
| Sum 2-11 | | 3,556 | 232 |

Table 2: Generation of PGMs of the Bełchatów PP at 16.34:10 on 17 May 2021.

## 2.1.3 Maintenance works and switching operations in Rogowiec

### 2.1.3.1 Rules of planning maintenances in PSE

Planning of maintenance work is carried out according to PSE's internal maintenance procedure. Maintenance work is scheduled for the whole year in a yearly maintenance plan. Modernisations and extensive maintenance work is planned and updated in five-year rolling plans.

The basis for creating maintenance plans are (i) the "Instrukcja organizacji i wykonywania prac eksploatacyjnych na liniach i stacjach NN" (eng.: "Instruction for the organisation and performance of maintenance works on transmission network lines and substations"), (ii) the results of the assessment and inspections of the technical conditions of network transmission elements, (iii) recommendations from the assessment of disturbance analyses of network elements. The Instruction is an internal regulation of PSE, which defines, inter alia, the scope, time periods and criteria for assessing the performance of inspections and diagnostics of network elements, based on the requirements of Polish law, including The Energy Law, the Construction Law, the Technical Inspection Act, the Environmental Protection Law and executive regulations to the aforementioned acts, as well as operating guidelines from manufacturers of network elements and also operational experience.

The disconnector in the Ołtarzew bay (OLT4) and the earthing switch passed the last scheduled inspection in December 2017 with a positive result.

Currently, there is no standard and there is no practice in the CE SA to assess the resilience of the grounding net to a short circuit current, including identification of the material deterioration that could arise since the commissioning.

Diagnostics of the condition of the grounding net are performed as part of the verification of the shock voltage values on the substation equipment. It is performed based on the standard PN-EN 50522:2011. Relatively low currents are used for that type of diagnostics and the outcomes do not verify the resilience of the grounding net to the possible-to-reach values of short circuit current in the network node. Moreover, the diagnostics performed within this standard are not aimed at identifying, and do not identify, invisible workmanship defects and any material deterioration of the grounding net that has arisen since the commissioning. Shock voltage measurements are performed every 5 years. The last verification in Rogowiec substation was performed in June 2017 with a positive result.

### 2.1.3.2 Rules of performing switching operations in PSE

The requirements that must be met by personnel performing, among others, switching operations are regulated by the "Health and Safety at Work at Power Equipment and Installations" (Polish acronym: IOBP). IOBP is an internal document of PSE SA, which was elaborated on based on the requirements of Polish law.

In accordance with the aforementioned Instruction, the switching operation shall be performed by a team of at least two employees, one of whom is (i) certified to work with transmission network elements and (ii) mandated to perform switching operations at the bay level, whereas the second employee is required to be certified to work with transmission network elements.

The switching operations on energised disconnectors and circuit breakers may only be performed on the command of the National/Regional Control Centre operator. Similarly, the switching operations on the earthing switch from the bay level are performed only on the command of the National/Regional Maintenance Centre operator.

It is forbidden by the operational rules to bypass the physical, mechanical and electrical blockades during switching operations on earthing switches.

### 2.1.3.3 Switching operations in Rogowiec on 17 May 2021

The National Control Centre (NCC) approved scheduled switching operation in Rogowiec substation in the bay Ołtarzew. Following that, the Regional Control Centre (RCC) ordered the personnel at the Rogowiec substation to perform switching operations. There were three workers present at the substation.

All three of them were certified; two of them were mandated and one was on a training period to be mandated to perform switching operations at the bay level (see description above). No remote control from NCC/RCC is available at Rogowiec substation, as it was constructed in 1980s and this control has not been upgraded since then. Switching operation can be performed only from the control building at the substation or from the local drive cabinets at the bays.

During the switching of the 400 kV Rogowiec (ROG4) – Ołtarzew (OLT4) line into a bypass busbar, the disconnector did not successfully close in phase L2. An attempt was made to fully close phase L2 of this disconnector manually, using the local drive cabinet. To perform this operation, the blockade was manually bypassed. As a result of a human error, this switching operation was performed from an incorrect local drive cabinet, which operates the earthing switch instead of the disconnector. Consequently, instead of closing the disconnector in phase L2 – the earthing switch of phase L2 was mistakenly closed. The local drive cabinets of the disconnector and the earthing switch are back-to-back to each other. Bay description, phase number of the disconnector and line earthing switch are fixed to the cabinet door as well as above the cabinet.

Manual switching operation from the bay's drive cabinet was performed by two certified workers, one of whom was mandated to perform switching operations at the bay level (see description above).

## 2.2 Impact on market

The 17 May 2021 incident was caused by the faulty operation of the TSO personnel (as described in chapter 2.1.), that led to a malfunction of TSO protection equipment and the unavailability of grid elements (lines, part of the substations). Hence, this incident was classified as a network problem.

Considering the zonal market model applied in Poland, grid constraints within the bidding zone should not affect market functioning as internal congestion caused by network unavailability is not visible for market participants. According to the "Polish Grid Code – Terms and Conditions for Balancing" ("Instrukcja ruchu i eksploatacji sieci przesyłowej. Bilansowanie systemu i zarządzanie ograniczeniami systemowymi", the unavailability of PGMs caused by a grid constraint (i. e. the inability of those PGMs to inject the power to the network due to grid constraints) does not impact the balancing price formation.

Due to the above, the incident did not have a direct impact on the functioning of the market.

In the figure below, the forecast (in magenta) and actual (in blue) balancing price formation is illustrated. Initially, when the cause of the incident was not verified, based on preliminary classification as unavailability on Power Generating Facility, the balancing prices were predicted to be quite high. However, after verification of the cause of the PGMs unavailability, this classification was corrected and, hence, the actual balancing prices for evening of that day were lower.

The incident led to additional costs on the TSO side – these costs were related to the congestion management costs, emergency supportive power costs and start-up costs for the units that had to be (re)-started. In total, this operational cost is estimated at ca. 6.359 million PLN (ca. 1.4 M€).

Balancing market prices in Poland

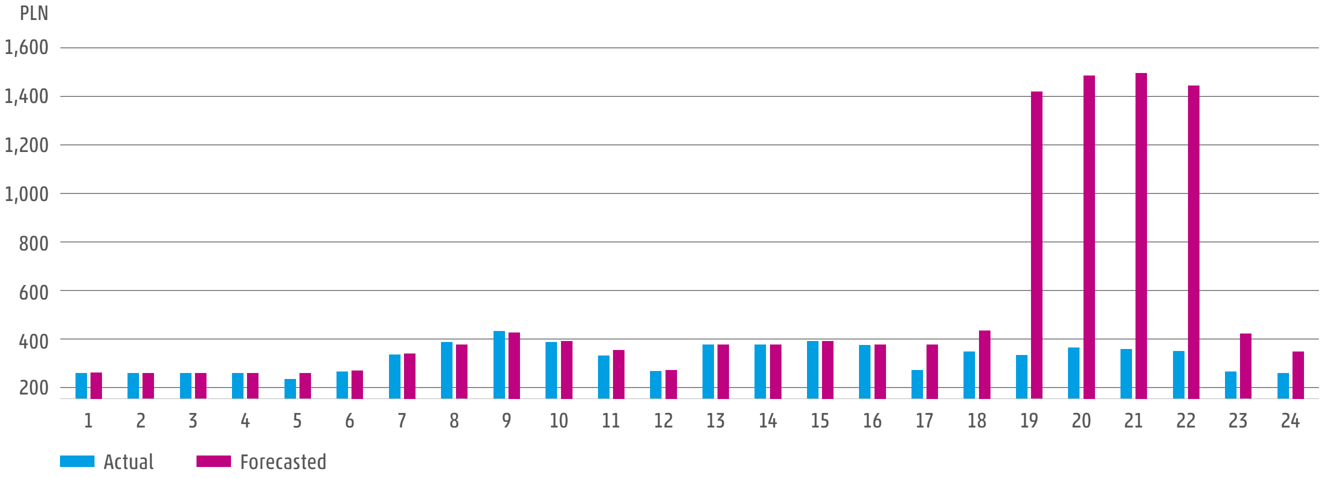



Figure 4. Balancing market prices on 17 May 2021.

## 2.3 Sequence of events

### 2.3.1 Sequence of events from the perspective of Bełchatów Power Plant

At 16:34:10, the PP Bełchatów PGMs lines' bays at the Rogowiec substation automatically tripped. At that time, a total of 10 PGMs were connected to the R-400 kV, i. e. BEL_4-06, BEL_4-07, BEL_4-08, BEL_4-09, BEL_4-10 and BEL_4-11 and R-220 kV switchyards, i. e. BEL_2-02, BEL_2-03, BEL_2-04 and BEL_2-05.

Two PGMs connected to the R-220 kV Rogowiec switchyard switched to house load operation. PGM BEL 2-04 operated on house load for approx. 1 min., whereas PGM BEL 2-05 for approx. 5 min. Their generator's circuit breakers remained closed. Eight remaining PGMs (BEL_4-06, BEL_4-07, BEL_4-08, BEL_4-09, BEL_4-10, BEL 4-11, BEL_2-02, BEL_2-03) were unable to operate on house load because all the generator's circuit breakers – between the generator and unit transformer – tripped as well.

All PGMs of the Bełchatów PP are capable of house load operation. The reasons for PGM BEL_2-04 and PGM BEL_2-05 not maintaining this mode of operation are a subject of investigation that is ongoing, and which involves Bełchatów PP representatives.

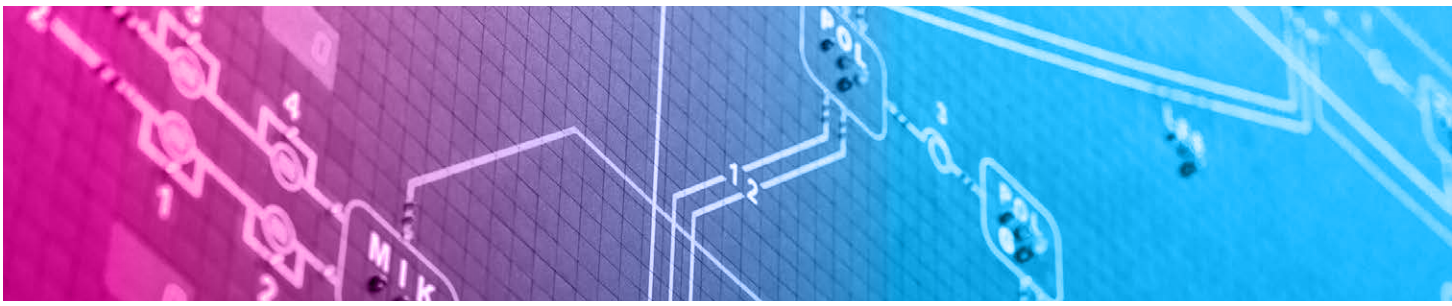
The PGM BEL_4-14 of Bełchatów PP, connected to the R-400 kV Trębaczew switchyard (TRE4), remained in operation.

## 2.3.2 Sequence of events from the perspective of Rogowiec Substation (R-400 ROG and R-220 ROG)

The sequence of events was reconstructed based on measurements and with protection device recordings which both possess precise GPS time stamps. The sequence of events is detailed in table 3.

| Time | Bay | Event |
|---|---|---|
| 15:45 | R-400 kV ROG, line OLT4 | The regional dispatcher, after receiving consent from national dispatcher to initiate switching operations, instructed the Rogowiec Substation personnel to switch the Ołtarzew line to operate via a bypass busbar. During the remote closing of the bypass busbar disconnector, phase L2 did not fully close. An attempt was made to fully close phase L2 of the disconnector manually, using the local drive cabinet. |
| 16:34:09 | R-400 kV ROG, line OLT4 | Closure of phase L2 of the line earthing switch, caused by human error. |
| 16:34:09 | R-400 kV ROG, line OLT4 | Tripping phase L2 circuit breaker by the protection devices, responding to a 1-phase short-circuit, which was followed by activation of auto-reclose. |
| 16:34:10 | R-400 kV ROG, line OLT4 | Reclosure of the circuit breaker (result of the auto-reclosure) and (repeated) detection of a short-circuit in the L2 phase. No final tripping of this line. |
| 16:34:10 | R-400 kV ROG, line OLT4 | Final tripping of the circuit breaker. |
| 16:34:10 | R-220 kV ROG, 400/220 kV AT1 | Final tripping of the autotransformer AT1 circuit breaker on the 220 kV side. |
| 16:34:10 | R-400 kV ROG, bay BEL_4-10 | Final tripping of the BEL_4-10 PGM line circuit breaker. |
| 16:34:10 | R-220 kV ROG, bay BEL_2-02 | Final tripping of the BEL_2-02 PGM line circuit breaker. |
| 16:34:10 | R-400 kV ROG, bay BEL_4-07 | Final tripping of the BEL_4-07 PGM line circuit breaker. |
| 16:34:10 | R-400 kV ROG, bay BEL_4-06 | Final tripping of the BEL_4-06 PGM line circuit breaker. |
| 16:34:10 | R-400 kV ROG, bay BEL_4-11 | Final tripping of the BEL_4-11 PGM line circuit breaker. |
| 16:34:10 | R-220 kV ROG, 400/220 kV AT2 | Final tripping of the autotransformer AT2 circuit breaker on the 220 kV side. |
| 16:34:10 | R-220 kV ROG, bay BEL_2-04 | Final tripping of the BEL_2-04 PGM line circuit breaker. |
| 16:34:10 | R-220 kV ROG, bay BEL_2-05 | Final tripping of the BEL_2-05 PGM line circuit breaker. |
| 16:34:10 | R-220 kV ROG, line JOA21 | Final tripping of the 220 kV Joachimów line circuit 1 (JOA21) circuit breaker. |
| 16:34:10 | R-400 kV ROG, bay BEL_4-12 | Final tripping of the BEL_4-12 PGM line circuit breaker. |
| 16:34:10 | R-400 kV JOA, line ROG43 | Final tripping of the 400 kV Rogowiec line circuit 3 in the Joachimów substation. |
| 16:34:10 | R-220 kV ROG, line JAN2 | Final tripping of the 220 kV Janów line (JAN2) circuit breaker. |
| 16:34:10 | R-220 kV ROG, bay TR2 | Final tripping of the 220 kV/MV TR2 transformer. |
| 16:34:11 | R-400 kV ROG, bay BEL_4-09 | Final tripping of the BEL_4-09 PGM line circuit breaker. |
| 16:34:11 | R-220 kV ROG, BEL_2-03 | Final tripping of the BEL_2-03 PGM line circuit breaker. |
| 16:34:11 | R-400 kV ROG, bay BEL_4-08 | Final tripping of the BEL_4-08 PGM line circuit breaker. |
| 16:34:11 | R-400 kV ROG, bay SP2 | Final tripping of the busbar section's coupler of system 2 circuit breaker. |
| 16:34:11 | R-400 kV ROG, bay SPOB | Final tripping of busbar coupler B (SPOB) circuit breaker. |
| 16:34:12 | R-220 kV ROG, line PIO2 | Tripping and reclosure, in a successful auto-reclosure cycle, of the 220 kV Piotrków line (PIO2) circuit breaker. |
| 16:34:13 | R-220 kV ROG, line PAB21 | Final tripping of the 220 kV line Pabianice circuit 1 (PAB21) circuit breaker. |
| 16:34:13 | R-220 kV ROG, line PAB22 | Final tripping of the 220 kV Pabianice line circuit 2 (PAB22) circuit breaker. |
| 16:34:13 | R-220 kV ROG, bay TR1 | Final tripping of the 220 kV/MV TR1 transformer. |

Table 3: Sequence of events in Rogowiec Substation



## 2.3.3 Configuration of the R-400 kV Rogowiec switchyard after tripping of the lines and PGMs

As a result of the tripping of the circuit breakers of the busbar section's coupler of system 2 (2A–2B) and the busbar coupler B (1B–2B), the R-400 kV Rogowiec switchyard was divided into three electrical nodes:

- system 1: remained loaded – closed busbar section's coupler of system 1 (1A-1B). Lines that remained connected (loaded): Trębaczew (TRE4), Płock (PLO4) and Tucznawa (TCN4). 400/220 kV autotransformer AT1 tripped from one side in the R-220 kV Rogowiec switchyard. Tripped lines: PGM BEL_4-07, PGM BEL_4-10 and PGM BEL_4-11;
- system 2A: de-energised. Tripped lines: PGM BEL_4-06 and PGM BEL_4-08, 400 kV Rogowiec (ROG4) – Ołtarzew (OLT4) and Rogowiec (ROG) – Joachimów line circuit 3 (JOA4) tripped on one side, respectively at the R-400 kV Ołtarzew and R-400 kV Joachimów switchyards;
- system 2B: remained energised. Ostrów line remained connected (OSR4). 400/220 kV autotransformer AT2 tripped from one side in the R-220 kV Rogowiec switchyard. Tripped lines: PGM BEL_4-09 and PGM BEL_4-12.

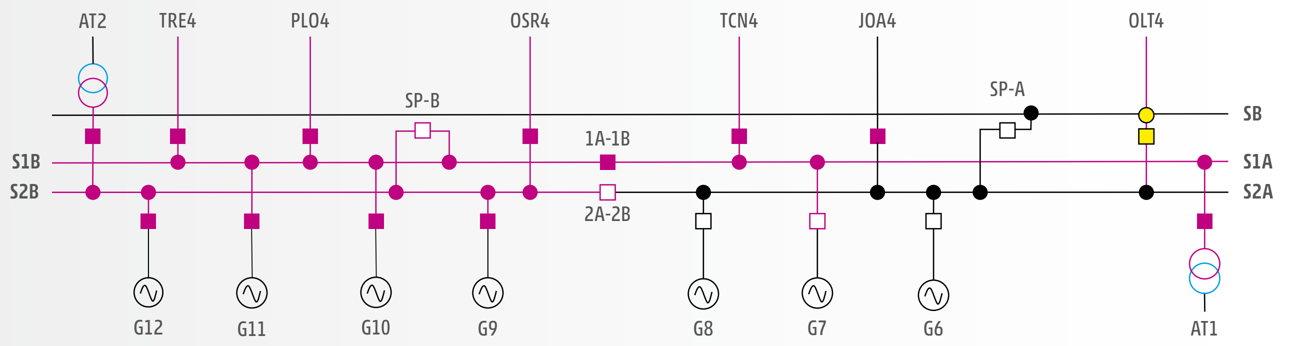



Figure 5: Line diagram of R-400 kV substation Rogowiec after the incident (black - no voltage).

## 2.3.4 Configuration of the R-220 kV Rogowiec switchyard after tripping of the lines and power units

The R-220 kV Rogowiec switchyard still operated as two separate electrical nodes.

- system1: de-energised.
- system 2: remained energised. The Bełchatów Kopalnia line circuit 1 (BEK21) remained connected. Tripped elements: PGM line BEL_2-02, PGM line BEL_2-04, PP's auxiliary transformer TR2, 400/220 kV autotransformer AT2, Pabianice line circuit 1 (PAB21), Janów line (JAN2) and Joachimów line circuit 1 (JOA21);
- system 3: remained energised. Lines that remained connected: Piotrków (PIO2), Joachimów circuit 2 (JOA22) and Bełchatów Kopalnia circuit 2 (BEK22). Tripped elements: Pabianice line circuit 2 (PAB22), PGM line BEL_2-03, PGM line BEL_2-05, PP's auxiliary transformer TR1 and 400/220 kV autotransformer AT1.

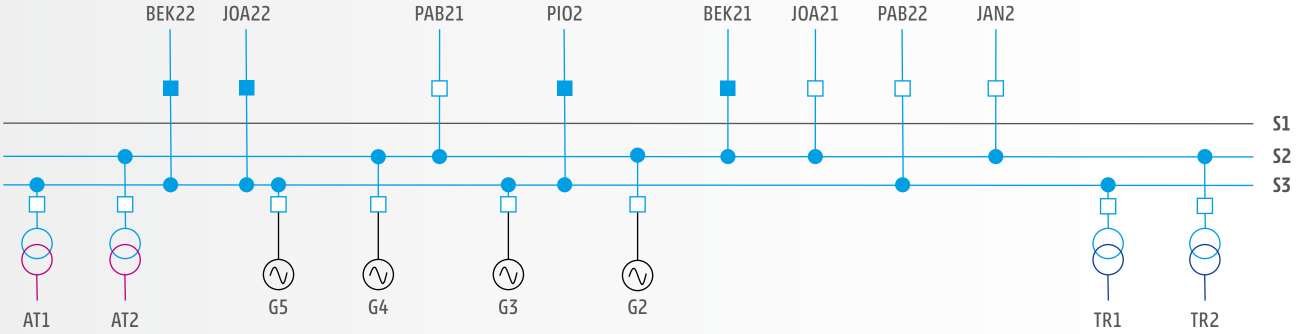



Figure 6: Line diagram of R-220 kV substation Rogowiec after the incident (black - no voltage).

### 2.3.5 Performance of the protection devices in Rogowiec

Due to a damaged grounding net, the short-circuit current flew not only to the ground, but also to secondary circuits. The short-circuit current resulted in numerous induced undesirable impulses. Protection devices, unaffected by undesirable impulses, correctly separated the affected busbar section of the substation, reacting properly.

Post disturbance analyses confirmed no need to change the protection's settings in Rogowiec substation. The function directly responsible for switching off the circuit breakers on both ends of the PGMs' lines and, in the final outcome, the tripping of these PGMs, was Switch On The Fault (SOTF), which is a standard function of long-distance protections in transmission substations, if available. Although the SOTF function was activated by the undesirable impulses, the disconnection of the PGMs' lines being the result of this activation is assessed as a proper operation of this function.

## 2.4 System parameters during the incident

Due to the incident, a dynamic frequency deviation of −158 mHz was recorded in CE SA (frequency drop to 49.842 Hz). Before the incident, the actual exchange balance on the synchronous profile of the PL control block amounted to approx. +1,260 MW (import). After the incident (16:34:25) its value amounted to +4,443 MW (import). The value of the power loss (net) as a result of the incident amounted to 3,322 MW (i. e. 3,556 MW gross generation of disconnected Bełchatów PP PGMs minus the auxiliary load).

### 2.4.1 PPS frequency

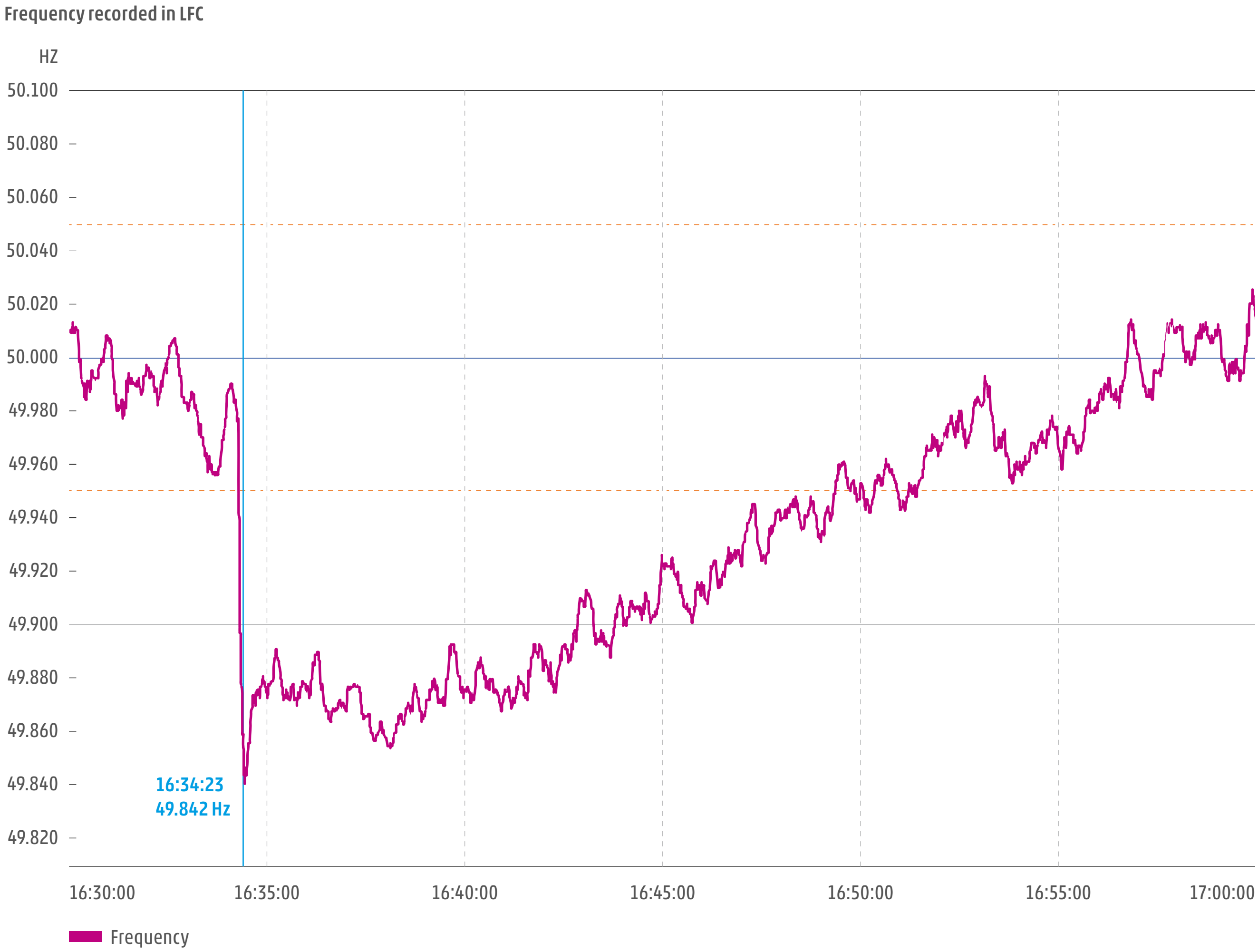



Figure 7: Frequency recorded in Polish LFC.

### 2.4.2 Continental Europe SA frequency

Frequency deviation of CE SA was restored to the level below 100 mHz at 16:43, and to the level below 50 mHz at 16:49. The nominal value of frequency was reached at 16:56.

Frequency deviation 17 May 2021, 16:30 – 17:00

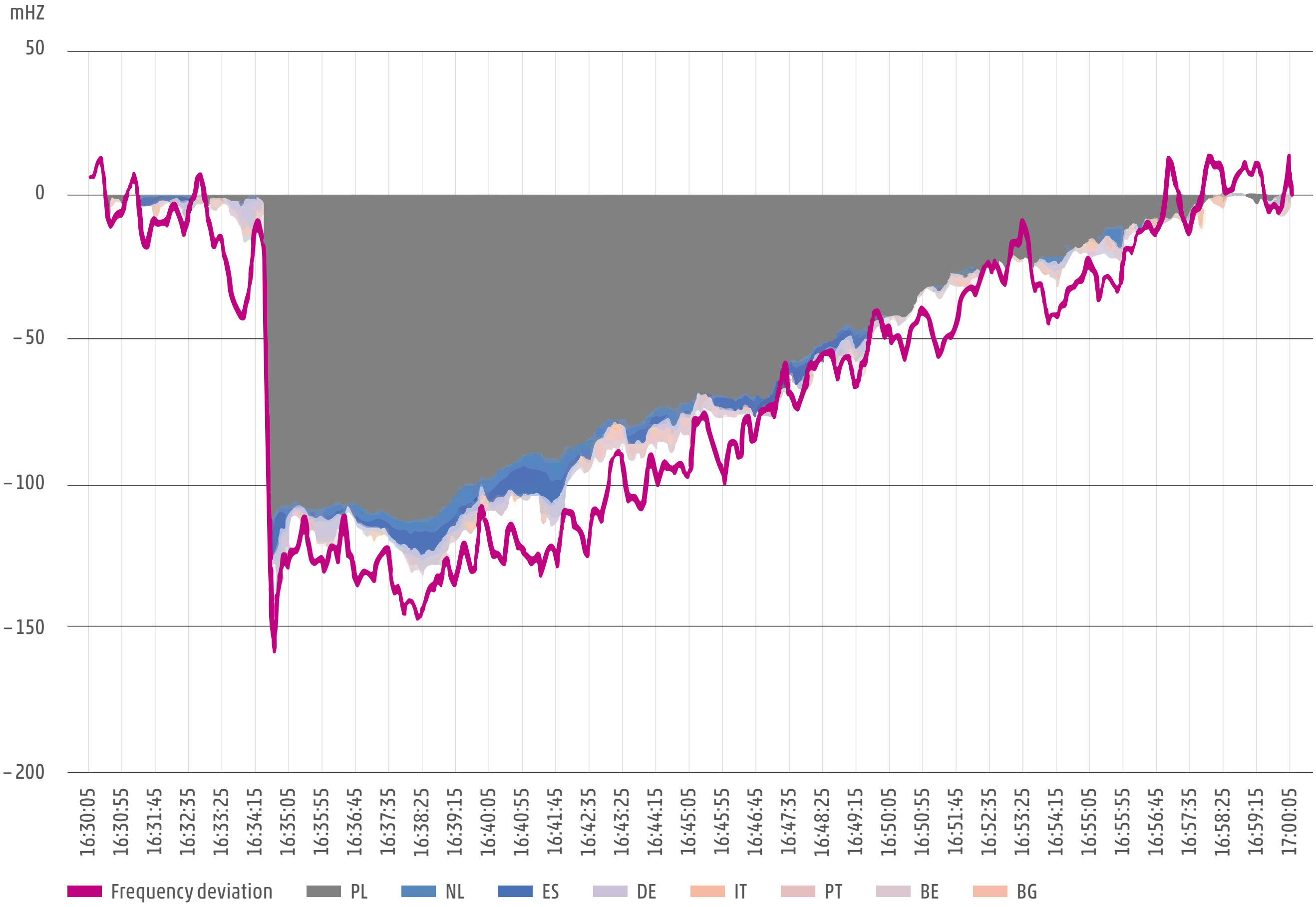



Figure 8: Contribution of selected control blocks in frequency deviation on 17 May 2021.

### 2.4.3 Selected data from fault recorders

The following figures present selected voltage graphs illustrating the course of the events. The diagrams illustrate the following information: the first fault (L2 phase), which was cleared by the protection systems, and the second fault leading to the trippings of the 10 PGMs of Bełchatów PP and other equipment in the R-400 kV and R-220 kV Rogowiec switchyards.

At 16:34:09, the 400 kV busbar coupler SP-B detected one phase (L2 phase) voltage drop which was caused by a short circuit current generated by the mistaken closure of phase L2 of the line earthing switch at 400 kV Line Rogowiec – Ołtarzew. The disturbance was correctly cleared by tripping phase L2 circuit breaker by the protection devices at line, responding to a 1-phase short-circuit, which was followed by the activation of auto-reclose. The second voltage drop (after 1.8 s) detected by SP-B was caused by the reclosure of the circuit breaker of 400 kV Line Rogowiec – Ołtarzew (result of the auto-reclosure). Busbar coupler SP-B switched off and divided substation into 2 nodes – both nodes have the nominal voltage.

At 16:34:09 TPP Bełchatów (Figure 10, PGM BEL_4-10 as example) noticed one phase L2 short circuit voltage drop cleared by protection devices. Approximately 2 seconds later all 10 PGMs in Bełchatów noticed a loss of voltage at all 3 phases at line bays.

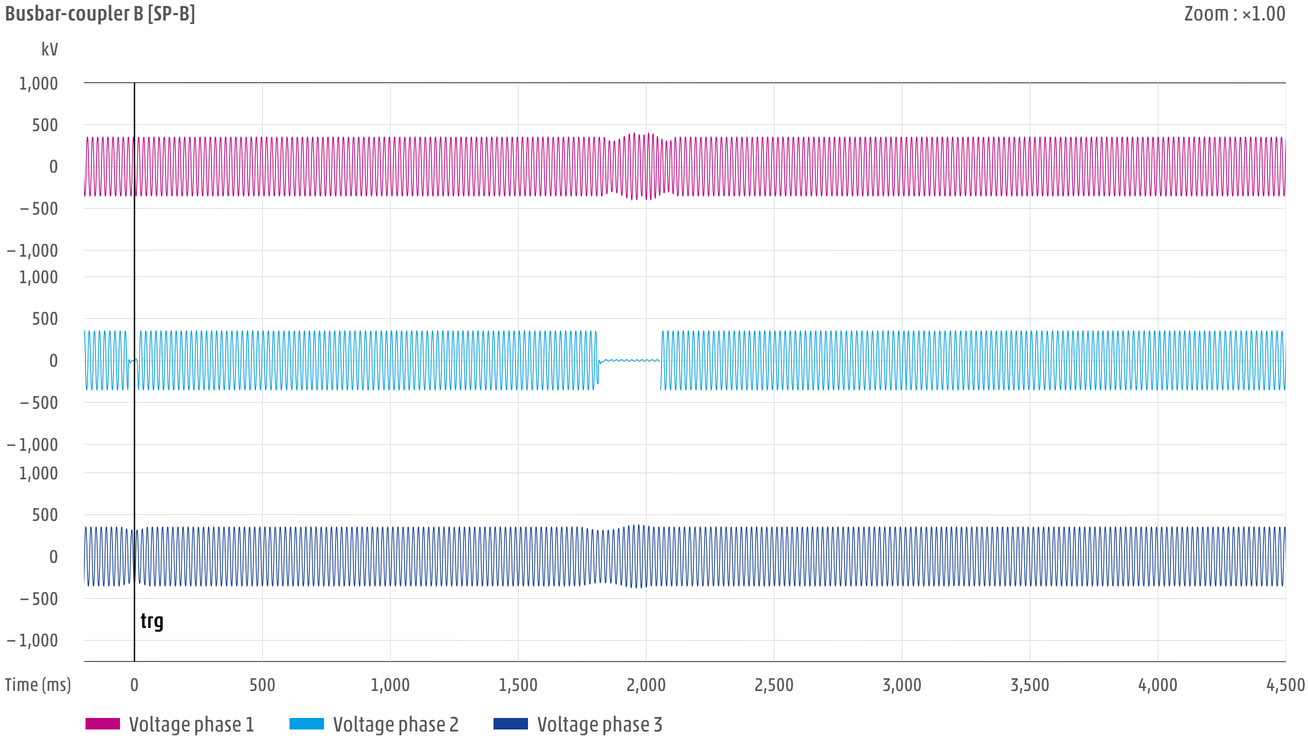



Figure 9: Voltage diagram in the R-400 kV Rogowiec substation – SP-B busbar coupler.

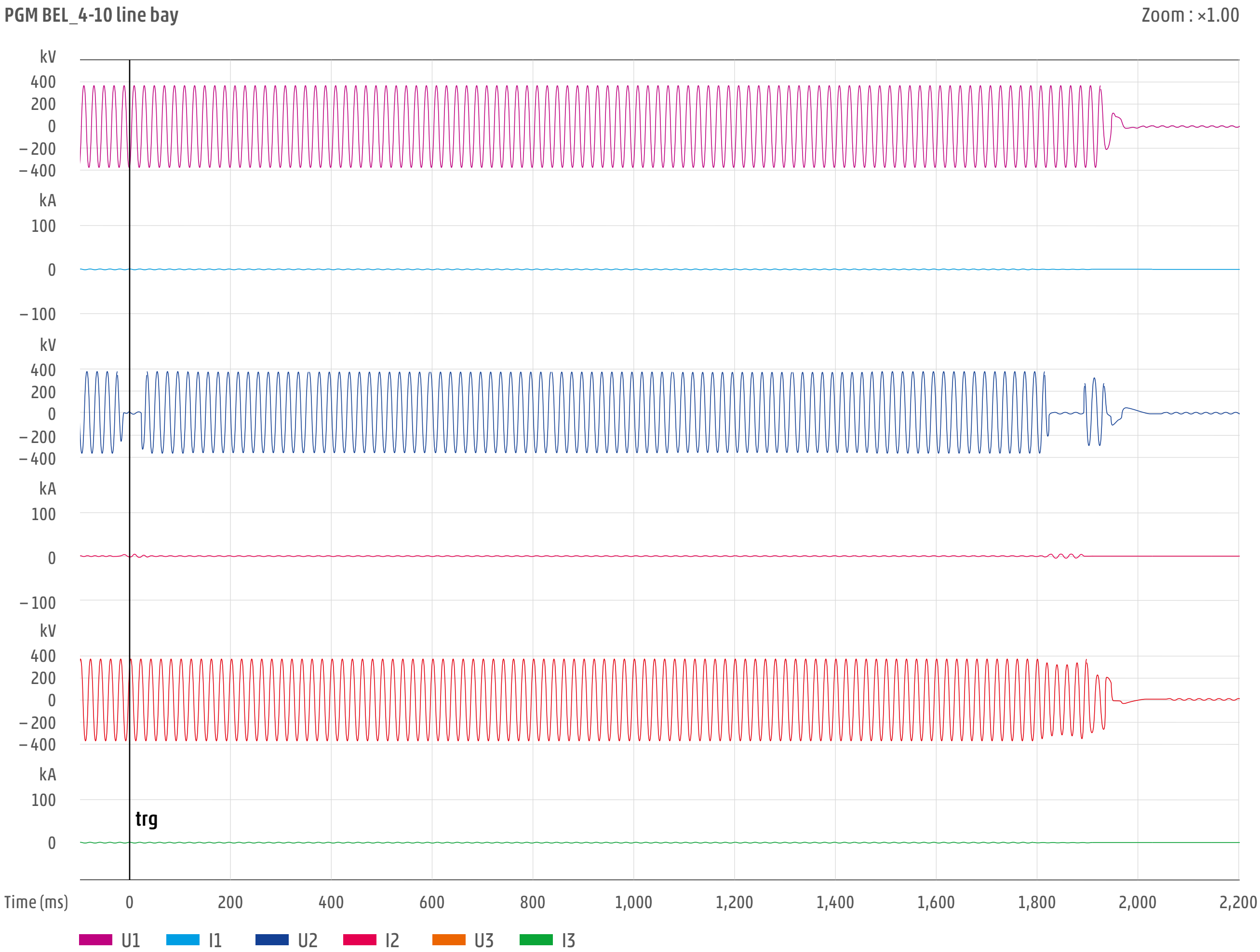



Figure 10: Measurements in the PGM BEL_4-10 line bay at the Rogowiec substation.

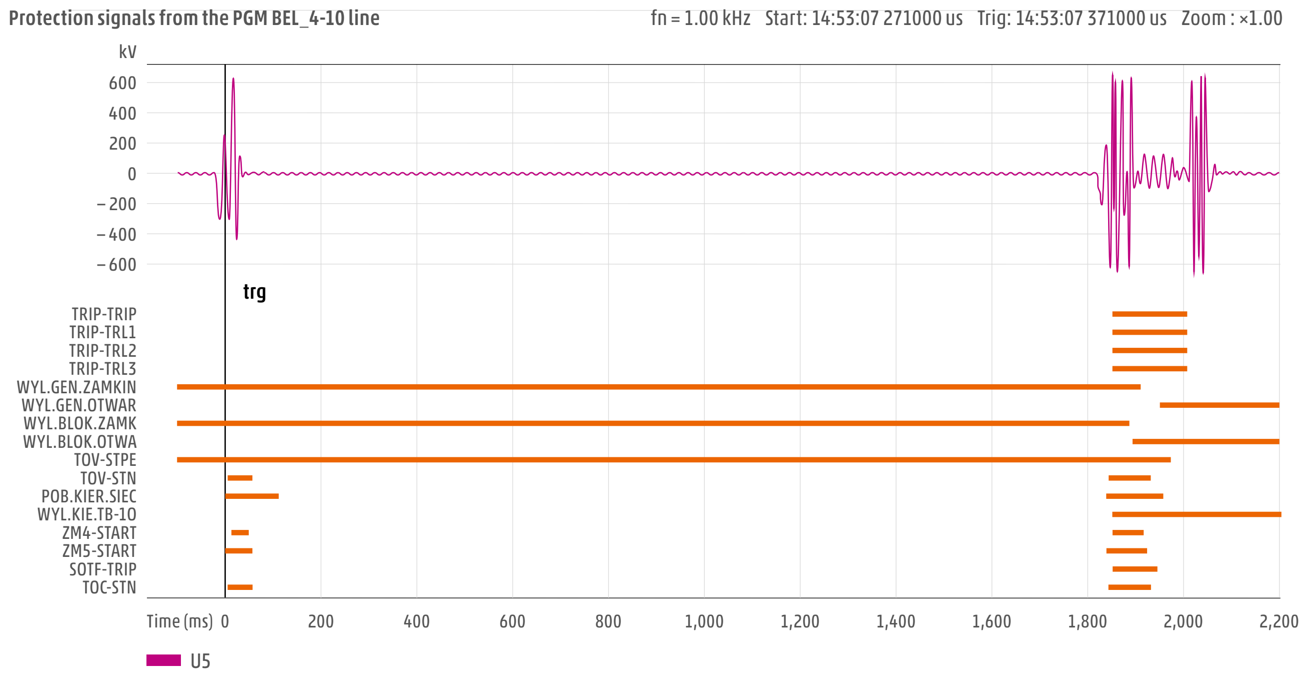



Figure 11: Protection signals from the PGM BEL_4-10 line at the Rogowiec substation.

Protection devices of the TPP Bełchatów PGMs noticed several signals from protection devices. After the first one phase L2 short circuit, cleared by protection devices, PGMs (at figure 11 PGM BEL_4-10 as example) had not received signal SOTF-TRIP.

Approximately 2 seconds later all 10 PGMs in Bełchatów received several signals about disturbance in the system and, among the others, the signal SOTF-TRIP, which caused immediate disconnection from the system.

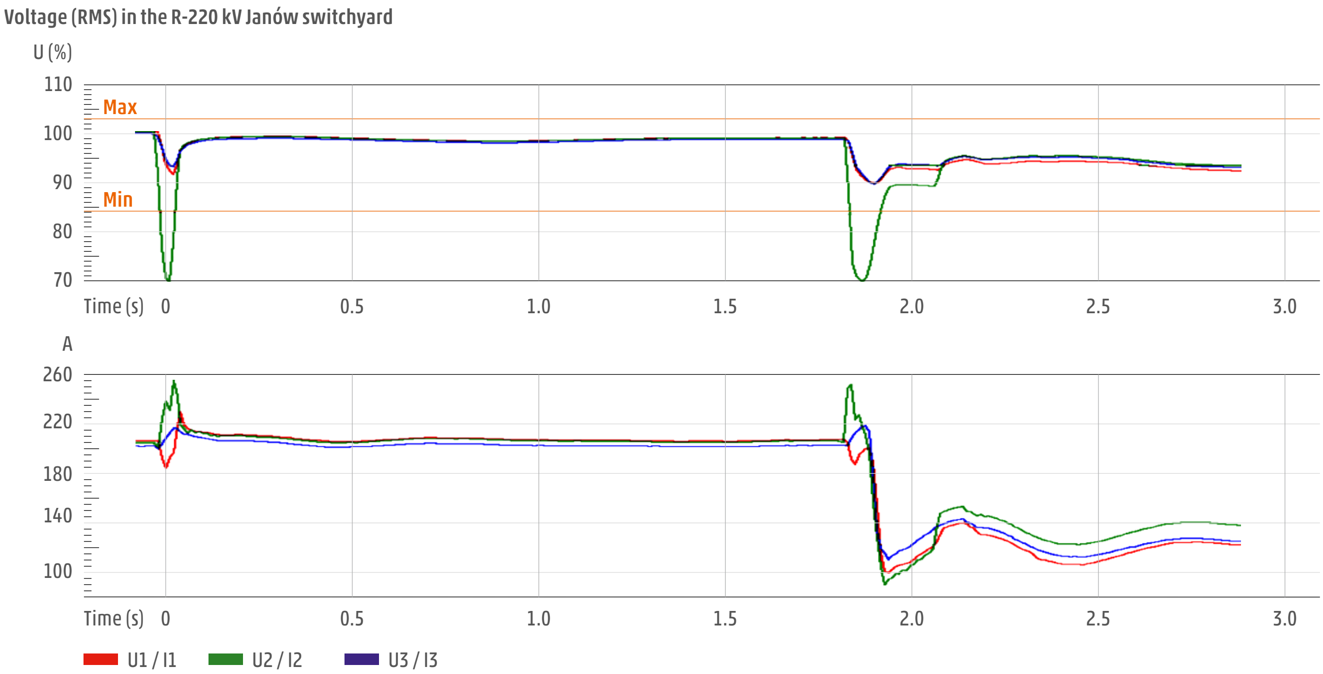



Figure 12: Voltage (RMS) in the R-220 kV Janów switchyard.

Protection devices at the neighbouring substations noticed cleared one phase L2 short circuit current and voltage drop. After ca. 2 seconds, the final tripping of the several circuit breakers in Rogowiec at both substations (R-400 kV and R-220 kV) stabilised the situation in the grid.

Figure 12 presents the voltage and current observed in line protection devices during the incident in the R-220 kV Janów switchyard at the 220 kV line Janów – Rogowiec (JAN2 at the Figure 6). Line disconnected one sided at R-220 kV Rogowiec.

## 2.4.4 Power flow on synchronous profile

Power flow on individual interconnections of PPS synchronous profile

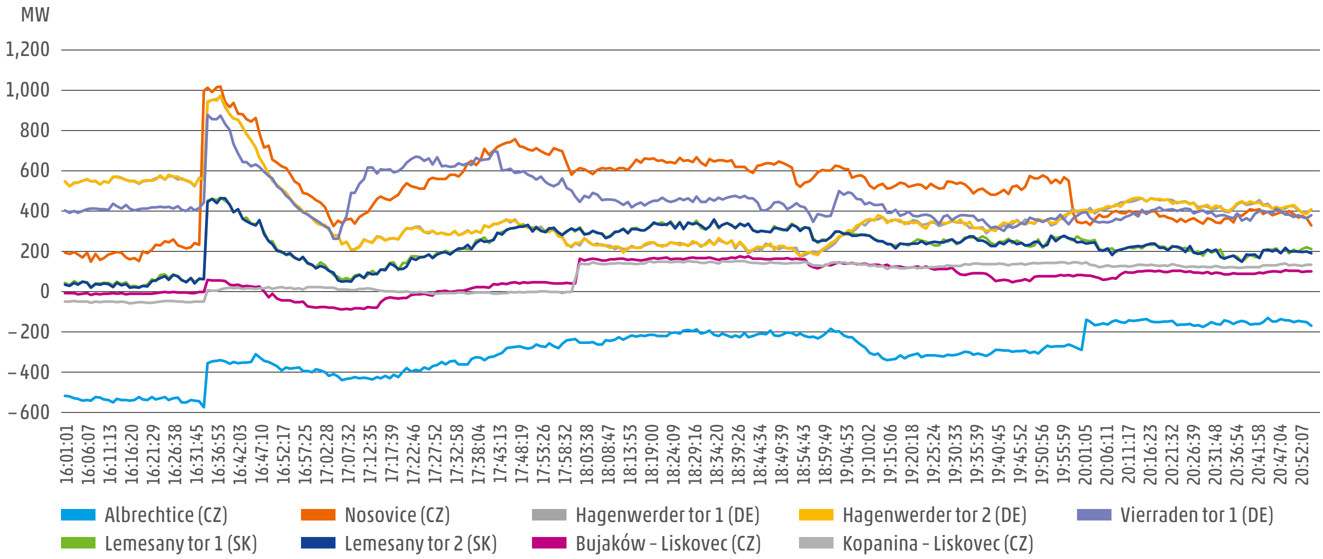



Figure 13: Power flow on individual interconnections of PPS synchronous profile.

Power flow on the whole synchronous profile

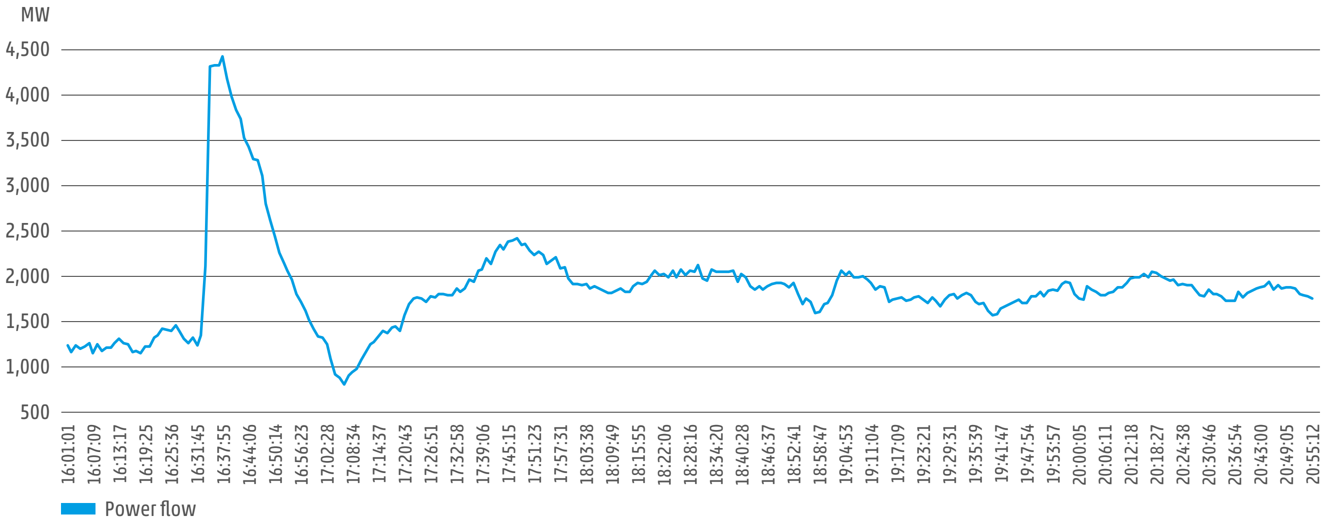



Figure 14: Power flow on the whole synchronous profile.

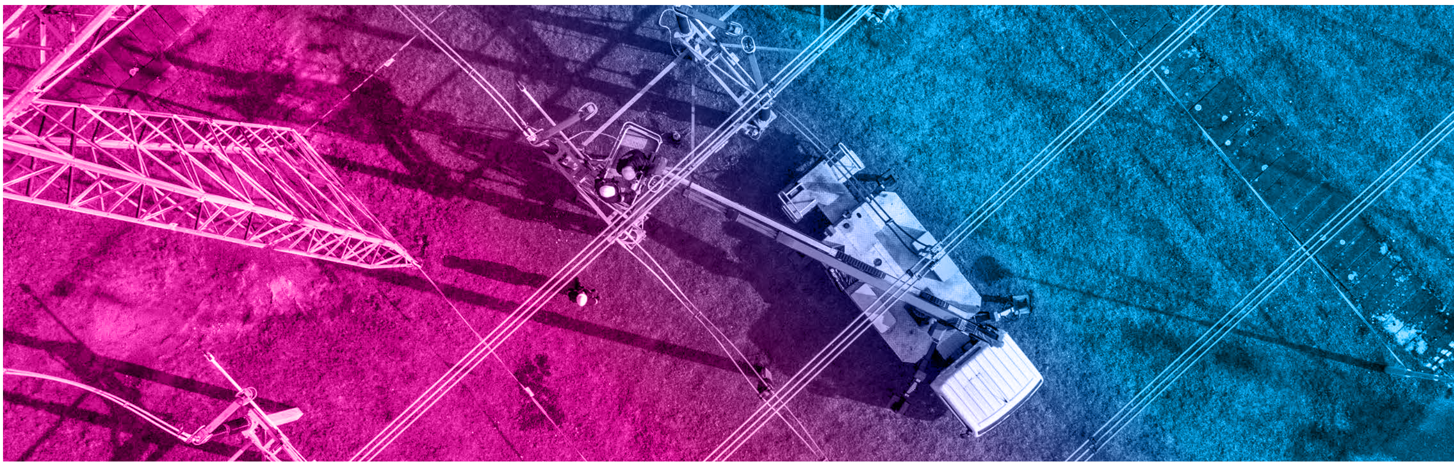


Figure 15 below presents a time close-up diagram of real-time power exchanges on PPS interconnections, split into synchronous profile (i.e. connections with Germany, the Czech Republic and Slovakia) and non-synchronous profile (HVDC with Sweden, radial connection to Ukraine and the Czech Republic). The interconnection to Lithuania (nonsynchronous connection B2B) was under maintenance due to investment works in Alytus (Litgrid) substation. Immediately after the incident, a sudden increase of exchange balance at the synchronous profile can be observed, which is followed by an also sudden decrease of exchange due to implemented countermeasures, as described below.

All non-synchronous interconnections with PPS have no Frequency Containment Reserves (FCR) support capability and remained unaffected.

The power flow on the synchronous profile reached 4.5 GW import direction just after the incident, which was 2.3 GW more than the offered Net Transfer Capacity (NTC) for that hour. PSE, in cooperation with 50Hertz, initiated tap changes and adjustments of Phase Shifting Transformers (PSTs) in Mikułowa and Vierraden simultaneously. At the same time, PSE ordered selected centrally dispatched PGMs to operate at the maximum possible capacity.

Power exchange on cross-border interconnections on 17 May 2021

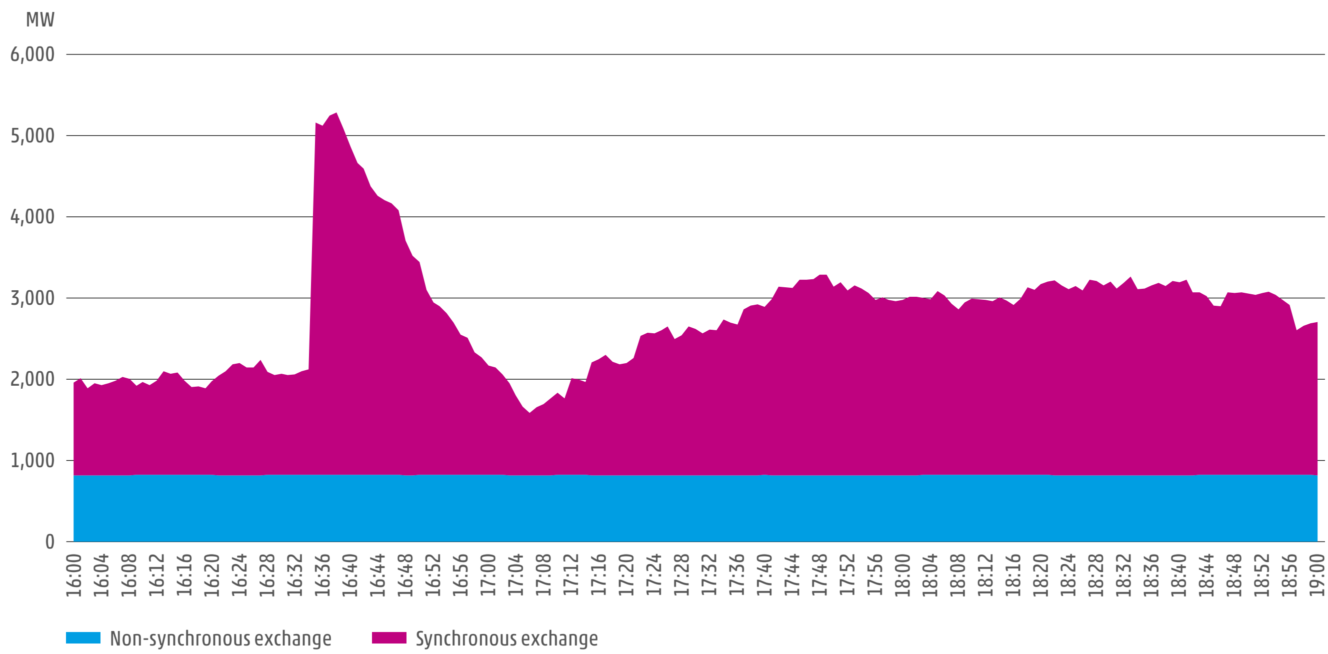
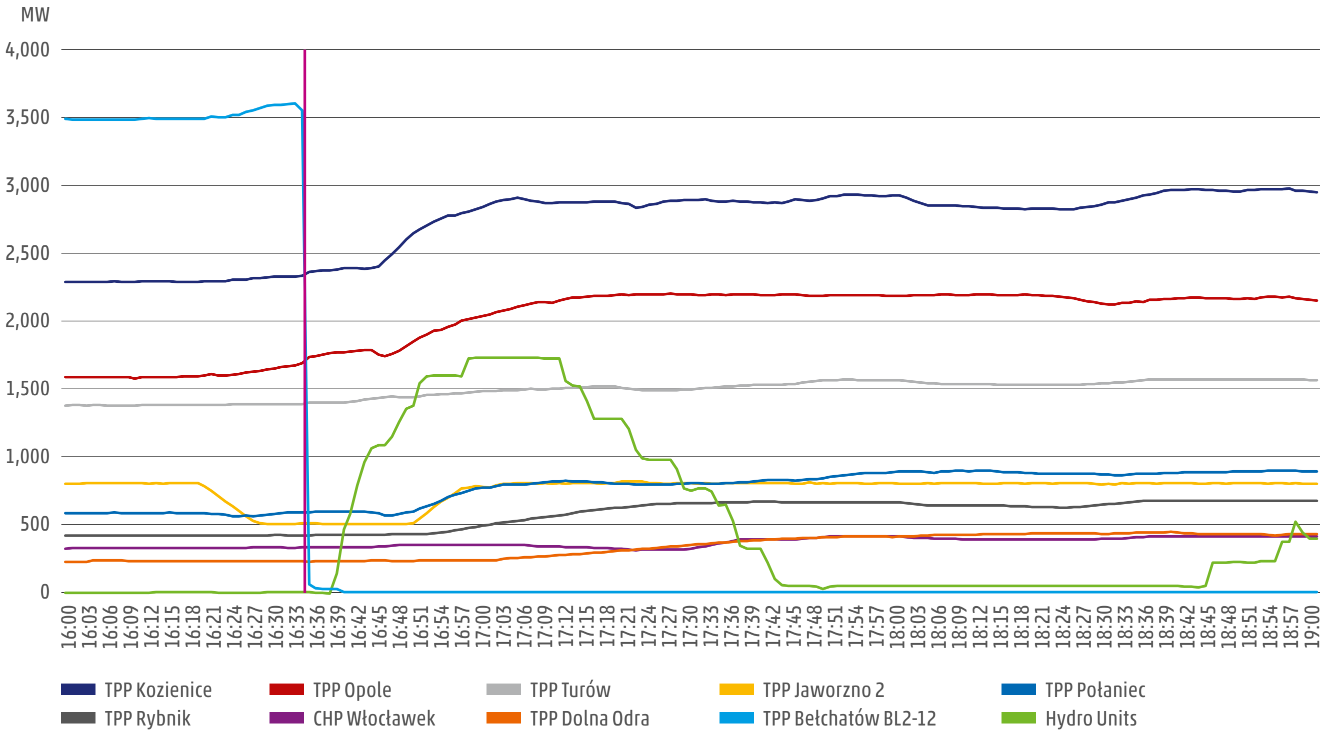



Figure 15: Cross-border exchange on 17 May 2021 (average minutes values).

## 2.4.5 Generation from PGMs

The figures below contain diagrams presenting generation [MW] of selected power generating facilities (PGF), between 16:00 and 19:00, and their response to the tripping of PGMs in the Bełchatów PP. Figures 16 and17 present data on generation from conventional and hydro PGMs.

Figure 16 presents the diagrams of power generated in selected PGFs. The first diagram shows the PGFs with the biggest contribution in covering the power loss after the incident. The second diagram presents the generation of selected remaining PGFs with a lower contribution.



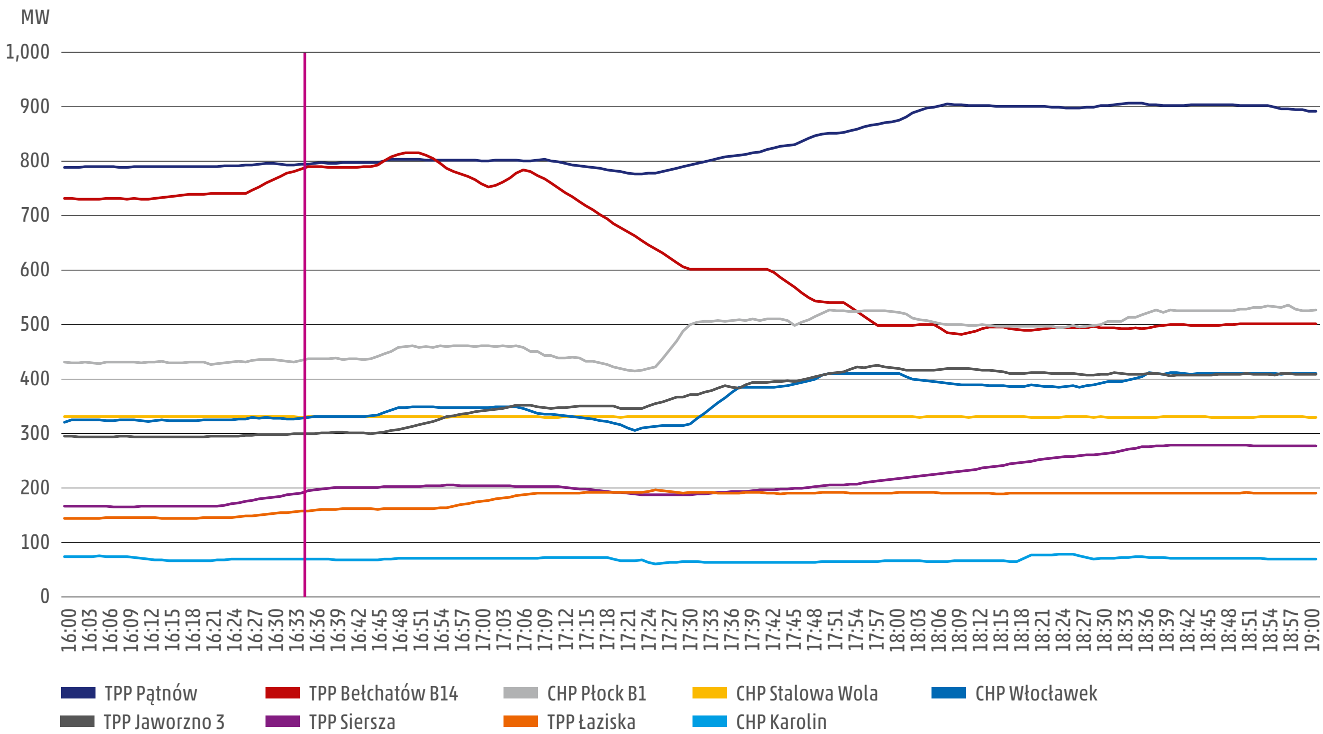




Figure 16: (Gross) generation of selected Centrally Dispatched PGMs.

Figure 17, with the area chart, indicates that at about 17:04, i. e. approx. 30 minutes after the incident, the Centrally Dispatched PGMs generation reached the level prior to the incident.

Area chart with generation (gross) from Centrally Dispatched PGMs

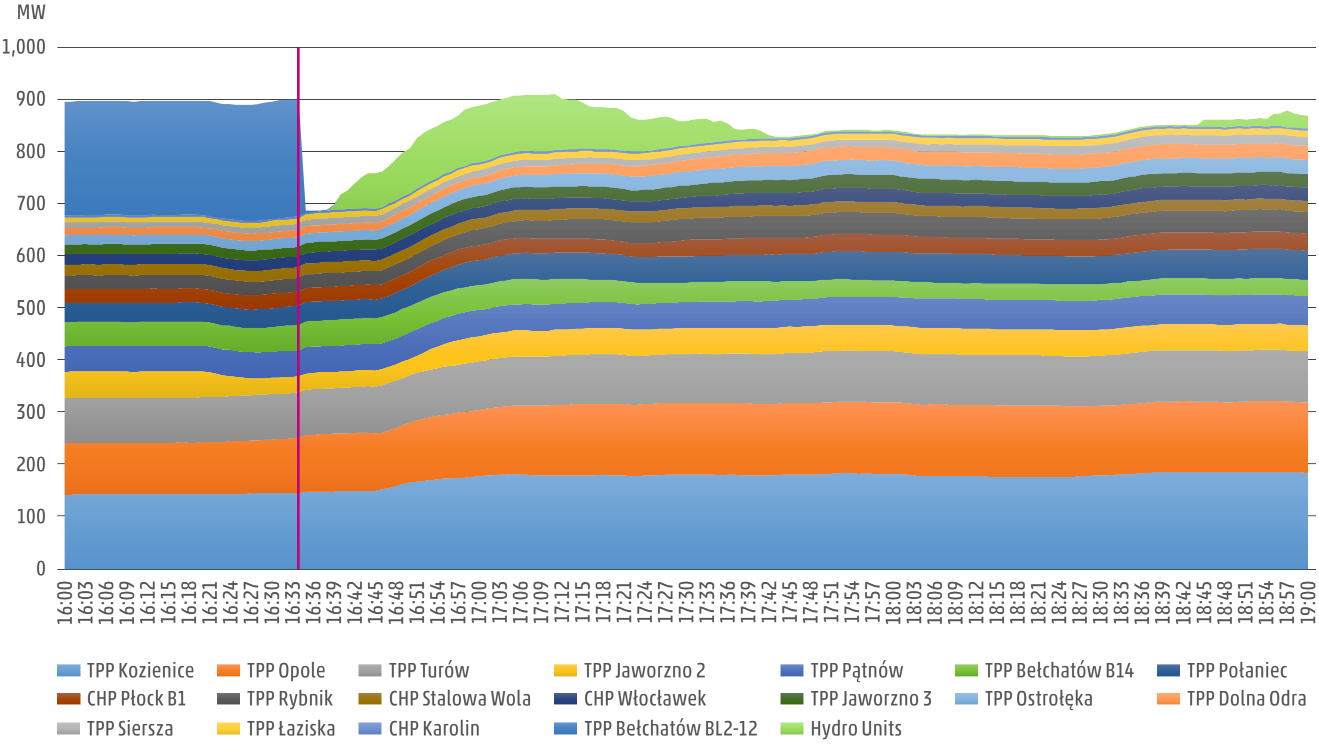



Figure 17: Area chart with generation (gross) from Centrally Dispatched PGMs.

## 2.5 The use of power and frequency control

### 2.5.1 Frequency Containment Reserve

Before the incident, the available FCR amounted to 170 MW, distributed among 8 PGMs, including 4 PGMs of Bełchatów PP. Directly after the incident, due to the tripping of the PGMs of Bełchatów PP, FCR remained on 4 PGMs with a 94 MW value, of which 82 MW was activated.

At 16:39, i. e. 5 minutes after the incidentincident NCC ordered FCR activation on an additional 5 PGMs, which led to a temporary restoration of FCR to the level of 172 MW.

At 16:44, i. e. 11 minutes after the incident, NCC ordered all Centrally Dispatched PGMs to operate at their maximum available capacity, which led to a decrease of available FCR to the level of 60 MW.

The FCR was brought back to the required level at 18:35.

### 2.5.2 Frequency Restoration Reserve

Before the incident, the available aFRR amounted to 563 MW, distributed among 27 PGMs, including 9 PGMs of Bełchatów PP (connected to Rogowiec substation) and PGM BEL_4-14 (connected to Trębaczew substation, which remained in operation after the incident). Directly after the incident, due to the tripping of the 9 PGMs of Bełchatów PP, aFRR remained on 18 PGMs with a 383 MW value.

Before the incident, the LFC operated in automatic mode, with IGCC (International Grid Control Cooperation) correction switched on.

In the control areas which are part of the IGCC cooperation, any imbalances which occur are netted within the possible limits. Therefore, the IGCC process avoids the activation of aFRR due to the netting process and should not affect frequency as well as the balance between load and generation within the synchronous area. Theoretically, in the event of generation outage in one of the TSO's control areas, this could lead to a netting between connected TSOs. Therefore, the imbalance would persist and no aFRR (or additional FRR) would be activated in both areas, even though this would be necessary.

As mentioned above, at 16:44 NCC ordered all Centrally Dispatched PGMs to operate at their maximum available capacity, which led to a decrease range of aFRR to the level of 313 MW.

The LFC performance in Poland during the incident has been satisfactory. LFC operated in automatic mode for the whole incident – it was not switched to Frozen Control Mode, because frequency deviation (maximum drop 158 mHz) was below the limit of activation (requirement from SAFA Annex 5 C-4-1: in case of frequency deviation higher than 200 mHz lasting more than one minute, individual Frequency Restoration Controllers have to be switched to Frozen Control Mode).

The aFRR range reached a level of 430 MW at 18:31, which was entirely activated. ACE (including IGCC correction) was in the range ±200 MW.

From 19:37 onwards, the value of activated aFRR decreased. Around 20:15 the level of activated aFRR decreased to ±100 MW, whereas ACE (including IGCC correction) was in the range below ±100 MW.


## 2.5.3 FCR and aFRR

**Use of PPS reserves at the time of incident**


Figure 18: Use of PPS' reserves at the time of incident.

## 2.5.4 Support from other synchronous areas

Thanks to the frequency support over HVDC links, the CE area received 30 MW of automatic supportive power from the Nordic synchronous area and 22 MW from the Great Britain Synchronous Area (GB). Figure 19 shows the change of power on the Nemolink cable between GB and Belgium. The other HVDC cables (between GB and CE) capable of delivering frequency support were not in service at the time of the event. As the total amount of support provided from GB was relatively small and within the GB dynamic frequency response requirements, there was no noticeable impact on the GB frequency.

The frequency support provided by Nemolink on 17 May 2021 was provided via the Limited Frequency Sensitive Mode-Underfrequency (LFSM-U) of operation and is only available if capacity remains post market closure (there is no reservation of capacity for this support). The support is a technical requirement of the GB Grid Code and is also in place to support compliance with the Regulation (EU) 2016 / 1447 Article 13 (3), Article 39 (4) & (7). The TSO who provides the support, based on applicable bilateral agreements, is responsible for managing any imbalance due to the support given, and the support is not part of the FCR procurement process. It is in place to support events outside normal operation and is used as per bilateral agreements.

LFSM-U varies the output based controller droop and on the CE SA frequency, as the frequency recovers in CE SA towards 49.9 Hz then the support is reduced. Once back at 49.9 Hz, the support is 0 MW.

Similarly to 8 January 2021, there was an automatic Emergency Power Control (EPC) activation from the Nordic SA to support the low frequency in CE SA.

However, as the frequency deviation was smaller in this case, the EPC activation was limited, but fully according to agreed settings. Total EPC Nordic → CE SA was 30 MW on the SE – DK1 HVDC link (Kontiscan) with a trigger of 49.85 Hz. The EPC activation is installed on the different links between the Nordic – CE SA interface with different frequency triggers and volumes. The next trigger level for additional EPC support would be 49.80 Hz.

Active power on the NEMO HVDC link between the UK and Belgium at the time of incident

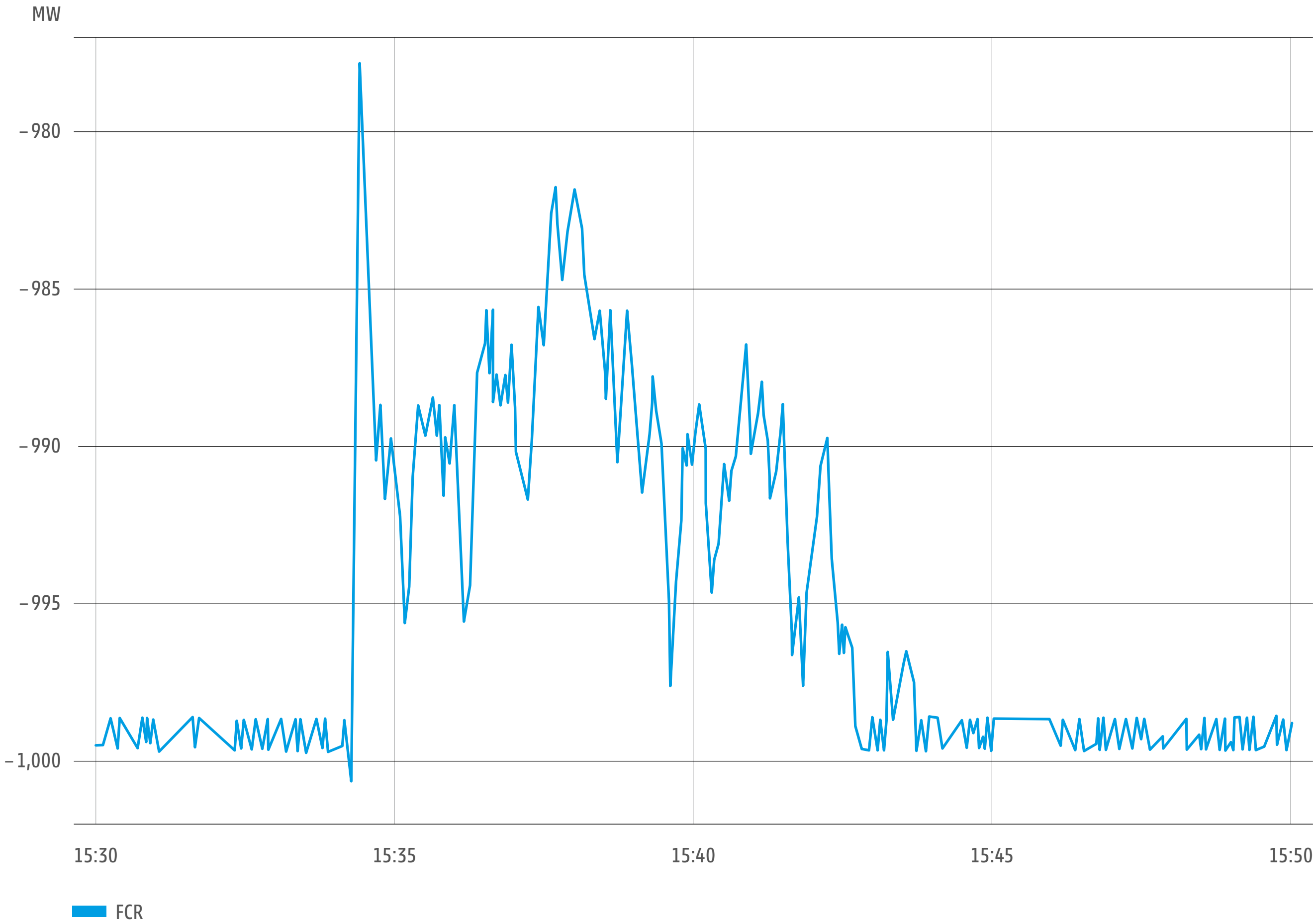



Figure 19: Active power on the NEMO HVDC link between the UK and Belgium at the time of incident.

## 2.6 IGCC during the incident

Before and during the incident, LFC operated with the IGCC correction switched on.

**Transmission capacity limits:**

» in import direction – amounted to 312 MW;

» in export direction – amounted to 500 MW.

Before the incident, the demand for aFRR (Pdemand) amounted to 180 MW and the correction value (Pcorr) amounted to 107 MW.

After the incident, the demand for aFRR (Pdemand) amounted to 3,627 MW and the correction value (Pcorr) amounted to 312 MW (limit towards import).

Therefore, it can be concluded that the IGCC did not affect the security of the network during the incident.

At 17:38:50, the NCC changed the manual value of the IGCC operating limits. As presented in Figure 20, the transmission capacity limit in the import direction was manually increased to 1,000 MW, and in the export direction to 1,500 MW.

Use of IGCC at the time of the incident

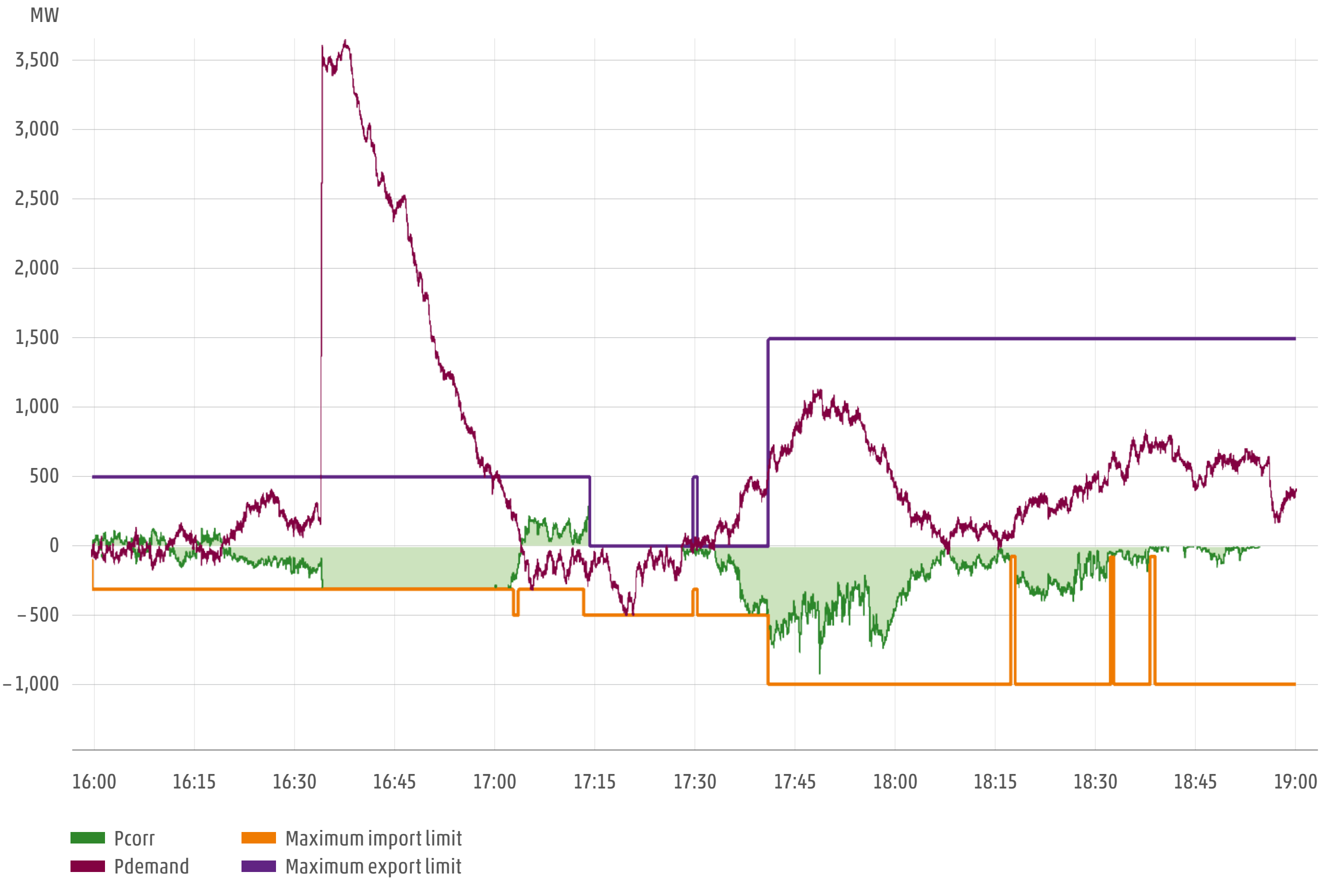



Figure 20. Use of IGCC at the time of the incident.

## 2.7 Grid condition after the incident

### 2.7.1 Rogowiec

Due to the fact that 3 out of 4 of the busbar's sections in 400 kV and both busbars in 220 kV part of substation remained energised, reconnection at Rogowiec substation started in less than 30 minutes.

### 2.7.2 Polish Power System

Loss of 3.3 GW generation in PPS caused unplanned flows on synchronous profile towards Poland. The increased power flow did not cause any overload in N state in PPS. The N-1 situation appeared at the western border or nearby. The most congested elements registered in the Security Analysis function in EMS tool:

» Mikułowa AT2 (128.9 %) after disconnection (N-1 situation) of the 400 kV line Czarna – Mikułowa,
» 220 kV line Polkowice – Leszno (125.4 %) after disconnection (N-1 situation) of the 220 kV line Polkowice – Plewiska,
» Mikułowa PST (115.7 %) after disconnection (N-1 situation) of the 400 kV line Mikułowa – Hagenwerder c.1,
» Line 400 kV Mikułowa – Hagenwerder c.2 (110.6 %) after disconnection (N-1 situation) of the 400 kV line Mikułowa – Hagenwerder c.1,
» Line 220 kV Mikułowa – Leśniów (106.7 %) after disconnection (N-1 situation) of the 400 kV line Krajnik – Vierraden.

The above violations were resolved by PSE in cooperation with 50Hertz (Germany) by simultaneous tap changes of PSTs in Mikułowa and Vierraden. N-1 criteria for connected systems were fulfilled approximately 20 minutes after the incident.

# 3 RECOVERY PROCESS AND ACTIONS TAKEN AFTER THE INCIDENT

## 3.1 Actions taken at the National Control Centre

After the incident, the NCC dispatchers immediately took actions in order to restore operational security limits defined in accordance with Article 25 of SO GL and bring back the safe operation of PPS. The sequence of actions is listed below:

- » **16:36** NCC ordered (by phone) to start-up all hydro PGMs in the PPs Żarnowiec, Solina, Żar and (via RCC Bydgoszcz) Żydowo.
- » **16:37** NCC ordered RCC Poznań to change the tap on PST in Mikułowa substation to position −10, to limit the power flow towards PPS on both circuits of the 400 kV HAG-MIK line below 1,400 MW.
- » **16:38** Polish NCC informed the 50Hertz NCC about the incident and requested for blocking taps on PST in Vierraden substation, simultaneously agreeing on the set point of PST in Mikułowa substation.
- » **16:39** NCC switched on the FCR in the LFC in the PPs: Kozienice (PGM: 1, 5, 6), Opole PGM 6, Turów PGM 3.
- » **16:39** The ENTSO-E Awareness System (EAS) signaled a frequency deviation of more than 100 mHz, changed the state of the system to "alert" (yellow light) – an incident affecting the frequency in CE SA.
- » **16:41 to 16:46** NCC ordered by phone the following PPs – Kozienice, Opole, Ostrołęka, Turów, Dychów, Połaniec, Jaworzno, Nowe Jaworzno – to operate at the maximum possible capacity of all Centrally Dispatched PGMs.
- » **16:46** Polish NCC changed the state of the system to "emergency" (red light) in EAS due to the incident and loss of the whole generation in Rogowiec node.
- » **16:50** NCC ordered by phone the Rybnik PP to operate at the maximum possible capacity.
- » **16:51** NCC ordered Kozienice PP to start up PGM 10.
- » **16:53** Polish NCC informed Amprion (Coordination Centre North) about the incident.
- » **16:56** NCC ordered by phone Dolna Odra PP to operate at the maximum possible capacity.
- » **17:23** Polish NCC changed the state of the system to "alert" (yellow light) in EAS, after balancing the PPS.
- » **17:39** Polish NCC changed the state of the system to "normal" (green light) in EAS, after restoring the required level of reserves in the PPS.
- » **18.56 to 21:52** Polish NCC changed the state of the system again to "alert" (yellow light) in EAS, due to the decrease of PV generation and the evening peak demand, which led to insufficient reserve levels in the PPS.
- » **21:52** Polish NCC changed the state of the system again to "normal" (green light) in EAS, after restoring the required level of reserves in the PPS.

### Comments to action taken

After the adjustments of the PSTs, the power flow at the Poland–Germany interconnections was reduced to approx. 1.8 GW (at 16:50) and PPS was brought back to operation within operational security limits.

As indicated in point 2.6., IGCC had been used during the incident. These actions helped to improve PPS balance and to restore cross-border exchange to the scheduled levels.

The frequency of CE SA was restored to the nominal value at 16:56.

Considering the activation of the whole available reserve in PPS to compensate for power loss in the Rogowiec substation and upcoming evening peak of demand, emergency deliveries from neighbouring TSOs were activated for the timeframe between 17:15 and 23:00 (in the maximum amount of 1.4 GW). Emergency deliveries from neighbouring TSOs:

- » from SEPS: 200 MW at 17:15–21:00, 300 MW at 21:00–22:00;
- » from ČEPS: 300 MW at 17:15–22:00;
- » from 50 Hertz: 500 MW at 18:00–19:30, 900 MW at 19:30–21:00, 800 MW at 21:00–22:00, 300 MW at 22:00–23:00.

Emergency deliveries on 17 May 2021

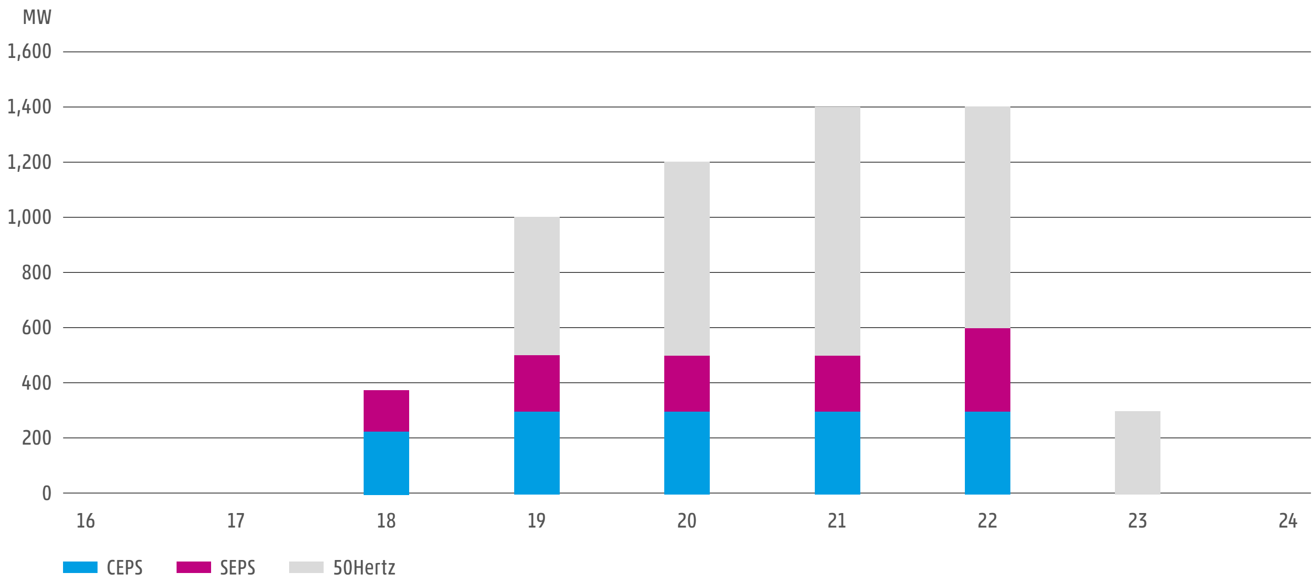



Figure 21: Emergency deliveries on 17 May 2021.

## 3.2 Restoration of normal configuration of Rogowiec substation

The table below contains information of when individual bays in the R-400 kV and R-220 kV switchyards Rogowiec were restored to normal operation.

The 400 kV Rogowiec – Ołtarzew line was switched on 1 June 2021 at 10:45 (after the necessary repairs at bay of this line). The Bełchatów PP PGMs was re-synchronised with the PPS within the schedule in the table below:

| Switchyard | Bay | Readiness for switching operations | Switch on |
|---|---|---|---|
| **R-400 kV ROG** | Busbar coupler B | ready to switch on | 17:01 |
| | Busbar section's coupler of the System 2 | ready to switch on | 17:28 |
| | Joachimów circuit 3 (JOA43) line | ready to switch on | 18:16 |
| | PGM line BEL_4-09 | 17:04 | 18:42 |
| | PGM line BEL_4-10 | 17:04 | 18:50 |
| | PGM line BEL_4-11 | 17:04 | 19:08 |
| | PGM line BEL_4-08 | 18:34 | 19:08 |
| | PGM line BEL_4-07 | 18:34 | 19:09 |
| | PGM line BEL_4-12 with transformer | 18:18 | 19:09 |
| | PGM line BEL_4-06 | 18:34 | 19:10 |
| **R-220 kV ROG** | Pabianice circuit 1 (PAB21) line | ready to switch on | 17:09 |
| | Pabianice circuit 2 (PAB22) line | ready to switch on | 17:10 |
| | Janów (JAN2) line | ready to switch on | 17:11 |
| | Joachimów circuit 1 (JOA21) line | ready to switch on | 17:13 |
| | Transformer TR1 220/MV | 17:13 | 17:35 |
| | Transformer TR2 220/MV | 17:13 | 17:36 |
| | 400/220 kV Autotransformer AT2 | ready to switch on | 17:51 |
| | 400/220 kV Autotransformer AT1 | ready to switch on | 18:01 |
| | PGM line BEL_2-05 | 18:34 | 19:11 |
| | PGM line BEL_2-04 | 18:34 | 19:52 |
| | PGM line BEL_2-03 | 18:34 | 19:53 |
| | PGM line BEL_2-02 | 18:34 | 19:54 |

Table 4: Date/Time of switchyards' restoration to normal operation

| PGM | Date/time of re-synchronization |
|---|---|
| **BEL_4-09** | 17.05.2021, 23:07 |
| **BEL_4-11** | 17.05.2021, 23:12 |
| **BEL_4-10** | 18.05.2021, 00:54 |
| **BEL_2-03** | 18.05.2021, 06:18 |
| **BEL_4-07** | 18.05.2021, 08:11 |
| **BEL_4-08** | 18.05.2021, 11:46 |
| **BEL_2-02** | 18.05.2021, 12:45 |
| **BEL_4-06** | 18.05.2021, 20:11 |

Table 5: Date/Time of Bełchatów PP PGMs' resynchronisation

# 4 EXTERNAL COMMUNICATION DURING THE INCIDENT

## 4.1 Communication with ENTSO-E's TSOs and Coordination Centre – Amprion

Area During the incident, relevant information was exchanged by phone between the NCC and neighbouring TSOs. A detailed sequence of external communication is provided below.

- **16:38** Polish NCC informed 50Hertz about the incident;
- **16:39** Regional alert state (EAS yellow light – an incident affecting the frequency in the RGCE area) – information recipients: ENTSO-E's TSOs, TSCNET;
- **16:46** PSE emergency state (EAS red light);
- **16:53** the national dispatcher informed Amprion (CC North) about the incident;
- **17:19** Polish NCC informed Amprion about receiving emergency assistance from ČEPS, SEPS and 50Hertz to cover the loss of generation;
- **17:23** PSE alert state (EAS yellow light);
- **17:23** PSE normal state (EAS green light);
- **17:53** Polish NCC informed Amprion about the hypothetic cause of the incident, the size of the loss, emergency support and (at that time) not available information about the hour/date of starting up Bełchatów PP PGMs;
- **18:43** Polish NCC informed MAVIR about the incident;
- **18:56** PSE alert state (EAS yellow light), due to the decrease in PV generation and the evening peak demand, which led to insufficient power reserve levels in the PPS;
- **20:06** Polish NCC informed Amprion that additional emergency support from other TSOs was not required;
- **21:11** Polish NCC informed ČEPS on the withdrawal of the consent for the outage of the 220 kV Kopanina – Liskovec scheduled for the next day;
- **21:52** PSE normal state (EAS green light), after restoring the required level of reserves in the PPS;
- **22:11** Publication of the release on the www.pse.pl website;
- **22:26** Polish NCC reconfirmed ČEPS on the withdrawal of the consent for the outage of the Kopanina–Liskovec line scheduled for the next day.

Information about the incident was also communicated directly to ENTSO-E, via business channels, approx. at 18.00, i. e. to the Chair of the System Operations Committee (SOC) and the Secretary-General.

## 4.2 Information for key national stakeholders

Immediately after the incident, the information was provided by phone to the Secretary of State, Government Plenipotentiary for Strategic Energy Infrastructure, the Minister of Climate and Environment and the President of NRA.

## 4.3 Information on PSE website and social media

| Date/time | Description | Comments |
|---|---|---|
| **17.05.2021 22:11** | Publication of the release on the www.pse.pl website | The press release was also published on PSE social media: Twitter and LinkedIn portals. |
| **18.05.2021 13:50** | Publication of updates on the NPS operational safety on the www.pse.pl website | The press release was also published on PSE social media: Twitter and LinkedIn portals. |

Table 6: Communication after incident via Internet

# 5 CLASSIFICATION OF THE INCIDENT BASED ON THE ICS METHODOLOGY

A mandatory classification of the incident has been performed according to the ICS methodology which based or Article 15 in the System Operation Guideline (SO GL). The following analysis was performed based on the presented facts following the whole sequence of events.

## 5.1 Analysis of the incident

The incident began during the switching of the 400 kV Rogowiec (ROG4) – Ołtarzew (OLT4) line into a bypass busbar. As a result of a human error, a switching operation was performed in the incorrect local drive cabinet, which operates the earthing switch instead the disconnector. Consequently, in the Bełchatów Power Plant, 10 working PGMs (2,3,4,5,6,7,8,9,10,11) were disconnected due to the incident on line Rogowiec-Ołtarzew in the Rogowiec 400kV substation. The amount of disconnected generation was 3,322 MW. This implies meeting a G2 criterion according to the ICS methodology classification (Table 5 of ICS methodology). The reason for this classification is that the sum of disconnected and reduced power generating facilities within 15 minutes exceeded 3,000 MW.

Due to the generation loss in Bełchatów Power Plant FCR, aFRR and RR provided from this units were unavailable. This implies meeting a RRC2 criterion according to the ICS methodology classification (Table 10 of ICS methodology). This criterion was reached because the reserve capacity was unavailable more than 30 minutes.

In addition to the scale 2 criteria, the other criteria was of scale 0. There was a T0 because of the tripping of the following network elements: 400 kV busbar section 2A with elements: Rogowiec–Ołtarzew 400 kV Line, Rogowiec – Joachimów 400 kV Line, 3 busbar couplers and transmission lines to generators. The reason for the scale 0 is that there were no violation of the TSO's operational security limits as defined in accordance with Article 25 of SO GL.

## 5.2 Classification of the incidents

The priority of each criterion is shown in table 7 with a number from 1 to 27, where 1 marks the criterion with highest priority and 27 marks the criterion with lowest priority. When an incident meets several criteria, the incident is classified according to the criterion that has the highest priority; however, information regarding all sub criteria is also collected.

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

Table 7: Classification of incidents according to the ICS methodology

The highest criterion from ICS for this incident is a G2, and thus an expert panel for a scale 2 investigation is required (according to Article 15 of SO GL and ICS methodology).

For incidents of scale 2 and 3, a detailed report must be prepared by an expert panel composed of representatives from TSOs affected by the incident, a leader of the expert panel from a TSO not affected by the incident, relevant RSC(s), a representative of SG ICS, the regulatory authorities and ACER upon request. The ICS annual report must contain the explanations of the reasons for incidents of scale 2 and scale 3 based on the investigation of the incidents according to article 15(5) of SO GL. TSOs affected by the scale 2 and scale 3 incidents must inform their national regulatory authorities (NRAs) before the investigation is launched according to article 15(5) of SO GL. In accordance with ICS methodology, ENTSO-E must also inform ACER about the upcoming investigation in due time, before it is launched and not later than one week in advance of the first meeting of the expert panel.

Each TSO must report the incidents on scale 2 and 3 classified in accordance with the criteria of ICS in the reporting tool by the end of the month following the month in which the incident began, at the latest. As the incident occured on 17 May 2021, the affected TSOs had to classify the events during this incident according to the ICS Methodology before 30 June. An expert investigation panel with TSOs, NRAs and ACER was established on 20 October 2021.

# 6 CONCLUSIONS & RECOMMENDATIONS

In accordance with the internal procedures of PSE on 18 May 2021, the Polish Investigation Commission was established. The Commission examined the causes and circumstances related to the incident and investigated remedial actions to address it. The report prepared by the Commission was forwarded to the Polish NRA and competent state administration bodies.

In this chapter the PSE's conclusions regarding the incident are presented in section 6.1. Based on the analysis of the incident improvements have been derived. Furthermore, the chapter presents the recommendations developed by the Expert Panel. Those recommendations have been prepared following an alignment with several specialised ENTSO-E working groups. All groups highlighted the local character of the incident and the correct response of the protection equipment, as well as the root cause of the incident being a human error. After analyses of LFC and LFSM response and fast frequency recovery, the working group concluded that there is no need to increase the amount of FCR in the system. Nevertheless, similar events shall be analysed based on various generation infeed scenarios in CE SA.

## 6.1 PSE's conclusions on the incident

1. The initiating cause of the incident was human error. Incorrect switching of the line earthing switch led to a short circuit in the 400 kV Rogowiec switchyard in the 400 kV Ołtarzew line bay. The short-circuit was eliminated by the tripping of the circuit breaker in this bay, after which the auto-reclosure was activated. Auto-reclosure closed the circuit breaker again, which led to a repeated short circuit which damaged (burnout) the grounding net, cables and internal connections in the line earthing switch drives and fuses in the back-up secondary circuits of the 400 kV Ołtarzew line bay. The construction of the grounding net differed fundamentally from the design, and thus was an immediate cause of an incident.

2. Disconnection of the PGMs in Bełchatów PP occurred as a result of the incorrect activation of some of the protections. The reason for the activation of protections and tripping of the circuit breakers were numerous undesirable impulses (interpreted by the protections as control signals) resulting from the occurring overvoltages, which were a consequence of the short-circuit current not being absorbed by the damaged grounding net.

3. Load and frequency control systems in the PPS and in the connected systems of the CE reacted properly.

4. The actions taken in the NCC to restore the safe operation of the interconnected systems, both in terms of activating the reserves in the PPS and obtaining support from neighbouring TSOs, have been proven correct and adequate.

5. The incident, which resulted in a loss of 3,322 MW (i.e. 3,556 MW gross generation, reduced by the Bełchatów PP auxiliary needs) did not lead to any demand disconnection in the transmission and distribution networks. There were also no negative effects on the operation of the synchronously connected systems of the CE. Operational security limits for the connected systems were restored approximately 20 minutes after the incident.

## 6.2 PSE's countermeasures (implemented recommendations)

As indicated above, the immediate cause of the incident was the construction of the grounding net which was inconsistent with the design; the following measures have been taken:

- » Immediate: division of the R-400 Rogowiec substation into two separate electrical nodes in order to reduce short circuit currents – **DONE**.
- » Short-term: repair and renovation of the grounding net in Rogowiec substation – **IN PROGRESS**.
  - – The maintenance plan of the grounding net assumes its renovation by the end 2022 to the designed functionality, which should allow the substation to work as one electrical node.
- » Long term: **modernisation of the substation Rogowiec**.

In addition to the above, internal works were initiated to calculate the principles for the assessment of resilience of the grounding net on short circuit current. These will subsequently incorporated into the PSE's "Instruction for the organisation and performance of maintenance works on transmission network lines and substations".

To avoid errors in switching operations from the bay level, the following preventive measures were taken:

- » Additional training for personnel concerning the duties and responsibilities during performance of the manual switching operation
- » All bays' drive cabinets of the earthing switches were marked by different colour at all substations;
- » New rules for marking and naming bays and equipment as well as cable and drive cabinets were developed and introduced;
- » Technical and organizational procedures to avoid bypassing the blockades were implemented.

## 6.3 Recommendations of Expert Panel

**1.** In substations where a large scale incident can lead to more than 3,000 MW of generation lost, the TSO shall:

   **a.** Possess a document showing the compliance of the grounding circuits to technical requirements coming from the tests done during the commissioning of the substation, or

   **b.** Possess a document showing the compliance of the grounding circuits to technical requirements coming from the tests done after any substantial modifications of the grounding circuits, or

   **c.** Measure and check the compliance of the grounding circuits to technical requirements in the event that the documents mentioned in paragraphs a. and b. are not available.

**2.** To guarantee a better resilience, in the relevant substations and doubles lines of the network which can cause at least a scale 2 incident according to ICS methodology, there shall be a specific reinforced maintenance on these structures.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **A** | Ampere(s) |
| **AC** | Alternating Current |
| **ACE** | Area Control Error |
| **ACER** | Agency for the Cooperation of Energy Regulators |
| **aFRR** | Automatic Frequency Restoration Reserves |
| **CC** | Coordination Centre |
| **CE** | Continental Europe |
| **CE SA** | Continental Europe Synchronous Area |
| **CET** | Central European Time |
| **DC** | Direct Current |
| **EAS** | ENTSO-E Awareness System |
| **ENTSO-E** | European Network of Transmission System Operators for Electricity |
| **EPC** | Emergency Power Control |
| **FCR** | Frequency Containment Reserves |
| **FRR** | Frequency Restoration Reserve |
| **GB** | Great Britain Synchronous Area |
| **GPS** | Global Positioning System |
| **GW** | Gigawatt |
| **HV** | High Voltage |
| **HVDC** | High Voltage Direct Current |
| **ICS** | Incident Classification Scale |
| **IGCC** | International Grid Control Cooperation |
| **kV** | Kilovolt(s) |
| **LFC** | Load Frequency Controller |
| **LFDD** | Low Frequency Demand Disconnection Schemes |
| **LFSM-U** | Limited Frequency Sensitive Mode – Underfrequency |
| **mHz** | Milihertz |
| **MVA** | Megavolt ampere |
| **MW** | Megawatt |
| **NCC** | National Control Centre |
| **NRA** | National Regulatory Authority |
| **NTC** | Net Transfer Capacity |
| **PGFs** | Power Generating Facilities |
| **PGM** | Power Generation Modules |
| **PP** | Power Plant |
| **PPS** | Polish Power System |
| **PSTs** | Phase-Shifting Transformers |
| **PV** | Photovoltaics |
| **RCC** | Regional Control Centre |
| **RGCE** | Regional Group Central Europe |
| **RMS** | Root Main Square |
| **RR** | Replacement Reserve |
| **SA** | Synchronous Area |
| **SAFA** | Synchronous Area Framework Agreement |
| **SOC** | System Operations Committee |
| **SO GL** | System Operation Guideline |
| **SOTF** | Switch On The Fault |
| **TPPs** | Thermal power plants |
| **TSO** | Transmission System Operator |
| **WAMS** | Wide Area Monitoring System |

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

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