POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2018 ✦ Volume 21 ✦ Issue 3 ✦ 123–136

DOI: 10.24425/124495

Waldemar Dołęga[1]

Operation safety of the national distribution grid

Abstract: The paper looks at the issues of operation safety of the national power grid and the characteristics of the national power grid in the areas of transmission and distribution. The issues of operation safety of the national transmission and distribution grid were discussed as well as threats to operation safety and security of the electricity supply related to these grids. Failures in the transmission and distribution grid in 2017, caused by extreme weather conditions such as: a violent storm at the night of 11/12.08.2017, hurricane Ksawery on 5–8.10.2017, and hurricane Grzegorz on 29–30.10.2017, the effects of which affected tens of thousands of electricity consumers and led to significant interruptions in the supply of electricity were presented. At present, the national power (transmission and distribution) grid does not pose a threat to the operation safety and security of the electricity supply, and is adapted to the current typical conditions of electricity demand and the performance of tasks during a normal state of affairs, but locally may pose threats, especially in extreme weather conditions. A potentially high threat to the operation safety of the national power grid is closely linked to: age, technical condition and the degree of depletion of the transmission and distribution grids, and their high failure rate due to weather anomalies. Therefore, it is necessary to develop and modernize the 400 and 220 kV transmission grids, cross-border interconnections, and the 110 kV distribution grid (especially in the area of large urban agglomerations), and the MV distribution grid (especially in rural areas). The challenges faced by the transmission and distribution grid operators within the scope of investment and operating activities, with a view to avoiding or at least reducing the scale of grid failures in the case of future sudden high-intensity atmospheric phenomena, are presented.

Keywords: power grid, operation safety, security of energy supply

[1] Faculty of Electrical Power Engineering, Department of Electrical Engineering, Wrocław University of Technology, Wrocław; email: waldemar.dolega@pwr.edu.pl

1. The national power grid

The national power grid includes both overhead and cable lines as well as power stations and consists of a transmission and distribution grids. The former is responsible for the transmission of electricity, and is supervised by the transmission grid operator (TSO) – the company Polskie Sieci Elektroenergetyczne SA (PSE 2018). The latter, on the other hand, is responsible for the distribution of electricity, and is supervised by the distribution grid operators. Presently, the most important and largest distribution companies in Poland are: PGE Dystrybucja SA, TAURON Dystrybucja SA, ENEA Operator Sp. z o.o., ENERGA-Operator SA, and innogy Stoen Operator Sp. z o.o. (formerly RWE Stoen Operator Sp. z o.o.) (SPURE 2018). The areas of their operation are shown in Figure 1.

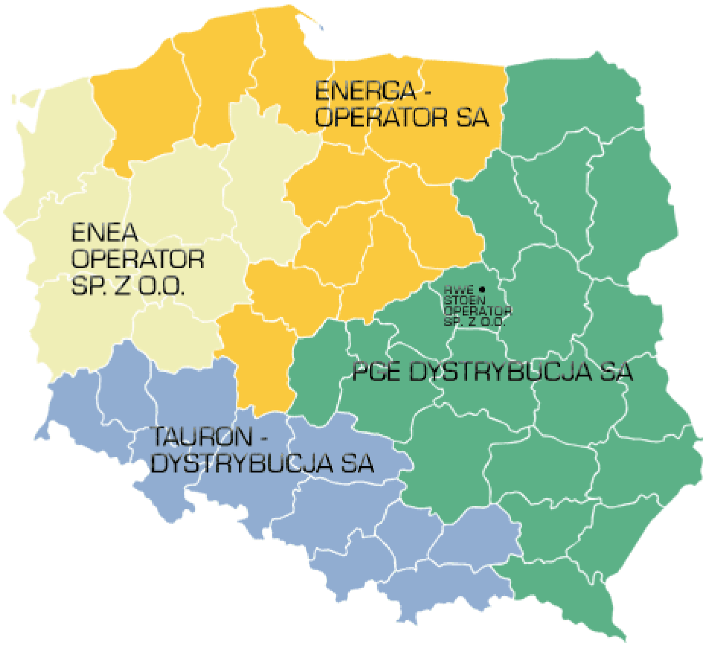

Fig. 1. Areas of operation of Transmission Grid Operators (SPURE 2016)

Rys. 1. Obszary działania Operatorów Systemów Dystrybucyjnych

The transmission grid includes 257 lines with a total length of 14,069 km and 106 high voltage power stations with 220 kV, 400 kV, and 750 kV voltages (PSE 2018). These include: 167,220 kV lines with a total length of 7,971 km, 89 lines with a voltage of 400 kV with a total length of 5,984 km, and 1 line with a voltage of 750 kV with a length of 114 km as well as 69,220 kV stations and 37,400 kV stations, in which used are a total of 211 autotransformers and high voltage transformers (PSE 2018; SMBDEE 2017). The distribution grid includes:

33,757 km of lines and 1,537 110 kV substations, 311,604 km of power lines and 261,169 MV power stations (6, 10, 15, 20, and 30 kV) and 470,142 km of low voltage lines (SMBDEE 2017). In 110 kV stations, there are used 2791 110 kV/MV transformers, while 261,079 MV/LV transformers and 1,179 MV/MV transformers are used in MV stations (SMBDEE 2017).

Due to its location in the National Power Grid (NPG) as a link between generators and consumers of electricity and the function it plays therein (transmission, distribution), the national power grid plays a key role in the NPG and is of strategic importance for its operation. In addition, it determines, to a large extent, the quality and reliability of the electricity supply to end users. In this context, the power grid operation safety defined as uninterrupted operation of the power grid, as well as meeting the requirements for quality parameters of electricity and quality standards for customer service, including permissible interruptions in electricity supply to end users, in predictable operating conditions for this grid are of high importance (IRiESP 2017).

The purpose of the paper is to draw attention to the operational safety of the national power grid in both the area of the transmission and distribution thereof.

2. Operation safety of the national transmission grid

The national transmission grid is adapted to the current typical conditions of electricity demand and the implementation of internal transmission tasks in normal states of affairs, ensuring an adequate level of operation safety and security of electricity supply (Dołęga 2018). However, major threats to the stability of operation of the National Power Grid exist as well as local threats that may cause power supply difficulties in extreme weather conditions, both in summer and in winter.

In 2017, grid failures in the transmission grid occurred. The main reason thereof was the extreme weather conditions in August and October (a storm in August, hurricanes Ksawery and Grzegorz in October). The size and scale of these failures was significant, therefore, their presentation was limited to the first two weather anomalies. Nevertheless, these were not failures resulting in the introduction of restrictions on electricity consumption and the introduction of emergency power levels, which did take place in 2015. Then, within the period August 10–31, 2015 limitations in the supply and consumption of electricity due to insufficient production and transmission capacity of the national power grids relation to the demand for electricity were imposed (SPURE 2016). The transmission grid operator introduced power levels at particular hours of the day. The highest of these degrees, i.e. "the 20th" was effective on August 10, 2015 between 10:00 am – 5: 00 pm (SPURE 2016).

The storm which took place on August 10–12, 2017, which was a hurricane of unprecedented strength and dynamics, along with the occurrence of very intense rainfall, mainly covered the following provinces: Zachodniopomorskie, Kujawsko-Pomorskie, Lubuskie and Wielkopolskie. As a result of strong wind and storms 6 transmission lines were disconnected: 220 kV

Adamów–Pabianice, 220 kV Janów–Zgierz, 220 kV Mory–Podolszyce; 220 kV Janów–Piotrków, 220 kV Ząbkowice–Świebodzice and 220 kV Pątnów–Czerwonak and 3 tracks in double -track transmission lines: 220 kV Rogowiec–Joachimów track 2, 400 kV Dobrzeń–Pasikurowice track 1, and 400 kV Ełk Bis–Alytus track 2 (SPURE 2018). Moreover, 7 power poles were knocked down on the Żydowo-Gdańsk 220kV line, which was turned off for scheduled works. The line was to be activated on August 13, 2017, while its switching on took place only on September 21, 2017 (SPURE 2018).

Hurricane Ksawery covered the entire country. As a result of very strong gusts in the period of October 5–6, 2017, emergency shutdowns of 16 overhead lines occurred in the transmission grid: 220 kV Mikułowa–Leśniów, 220 kV Plewiska–Polkowice, 220 kV Leśniów–Gorzów, 220 kV Polkowice–Żukowice, 220 kV Leśniów–Żukowice, 400 kV Krajnik–Plewiska, 220 kV Wielopole–Blachownia, 220 kV Joachimów–Łośnice, 220 kV Joachimów–Kielce, 220 kV Byczyna–Jamki, 400 kV Joachimów–Trębaczew, 220 kV Radkowice–Połaniec, 220 kV Joachimów–Łagisza/Głowowy, 220 kV Łośnice–Koksochemia, 220 kV Kopanina–Halemba, and 220 kV Siersza–Łośnice and 6 tracks in double-track transmission lines: 220 kV Mikułowa––Polkowice track 1, 220 kV Rogowiec–Bełchatów Mine track 1, 220 kV Pabianice–Rogowiec track 2, 220 kV Rogowiec–Joachimów track 1, 220 kV Kozienice–Puławy track 2, and 220 kV Rogowiec–Joachimów track 2 (SPURE 2018). In addition, one 220/110 kV autotransformer was shut down at the Polkowice station (the AT1 autotransformer).

The above-mentioned failures caused by extreme atmospheric conditions, despite their scale, were possible to be liquidated with the means available to the transmission grid operator. Nevertheless, serious threats to the operational safety of the transmission and the entire power grid exist. These result directly from high grid failure due to weather anomalies and: the low density of the transmission grid and generating units in some parts of the country, limited load capacity of power lines at higher ambient temperatures, increasing the scope of repair and investment works in grids, an excessive increase of voltages in transmission and 110 kV grids, restrictions on the import of electricity from neighboring countries' power grids, and an increase in the load in summer (Dołęga 2014). These threats are compounded by the overlapping of many unfavorable factors, including: extremely high power demand, extreme weather conditions, shutting down of a large number of power grid elements or generating units, or the impact of power flows from neighboring countries (Dołęga 2014). At the same time, the largest threat of extensive grid failure concerns the northern part of the National Power Grid (Dołęga 2018). This may occur under conditions of large active and reactive power transmission from the center of the country to the north. Such a situation is caused by a smaller number of generation sources in comparison with the southern part of the NPG and lower grid density in this area. The occurrence of a failure may result in the loss of voltage stability over a large area. Threats in the power structure also are also an issue for large urban agglomerations: Warsaw, Kraków, Poznań, and Wrocław (Dołęga 2018).

High grid failure rate due to extreme weather conditions (snowstorms, wet snowfall, icing, hurricanes, windstorms, and thunderstorms) and limited capacity of the transmission lines at higher ambient temperatures poses a serious threat to the stable operation of the NPG in conditions of increased demand for electricity (Dołęga 2018). This is closely related to age, technical condition, and the degree of depletion of transmission grids.

The present transmission infrastructure is insufficient, and ensuring the operation safety of the transmission grid and the security of the electricity supply requires investments involving the expansion and thorough modernization of the transmission grid, 110 kV distribution grids in the area of large urban agglomerations, and investments with a view to increasing the export-import capacity of the National Power Grid (Dołęga 2014). The transmission grid operator and distribution grid operators are aware of this fact and are implementing a wide investment program. Challenges and investment intentions in the area of the transmission grid are presented in detail in the paper (Dołęga 2018).

3. Operation safety of the national distribution grid

While the national distribution grid is adapted to the present typical conditions of electricity demand and performs well during a normal state of affairs, locally it poses a great threat to operation safety and security of the electricity supply in extreme weather conditions.

In 2017 grid failures occurred in the distribution grid, which led to significant power outages. The main reason for their occurrence was damage to the power grid infrastructure caused by weather anomalies (snowstorms, wet snowfall, hurricanes, storms, and thunderstorms). Particularly extreme weather conditions were observed in August and October (storm in August, hurricanes Ksawery and Grzegorz in October). Trees fell and broke outside of the standard tree felling strips thus causing permanent damage to overhead power grids (cable curs, pole breakages), and damage to the overhead stations. The scale and extent of these failures and the inclement weather conditions which hindered works carried out with the use of heavy equipment (cranes, lifts) resulted in long delays.

In addition to the above mentioned adverse weather conditions, grid failures were caused by technical reasons, human errors, activities of third parties, animals and birds or incidents occurring in the grids of neighboring operators (SPURE 2018). The former were related to the aging/fatigue of grid infrastructure elements, e.g. breaking/damage of wires, insulators, breaker breakage, transformer explosions, erroneous activities/ security defects. The latter included activities and incidents at the consumers, activities of unauthorized persons, mechanical damage to cables during construction works, foreign elements on devices, or animals and birds.

The scale, severity, and number of failures varied. For instance, in 2017, in the area of operation of Enea Operator Sp. z o.o. distribution grid operator, a total of 47,460 grid failures occurred, causing interruptions in the electricity supply (SPURE 2018). They included 143 events in the 110 kV distribution grid, 12,512 events in the MV grid, and 34,805 events in the low voltage grid (SPURE 2018). In the case of the TAURON Dystrybucja SA operator, 74,342 grid failures in its area of operation occurred: 170 in the 110 kV grid, 30,992 in the MV grid and 43,170 in the low voltage grid (SPURE 2018). The estimated value of electricity not delivered in 2017 as a result of these accidents amounted to approximately 29.9 GWh (Enea Operator) and 7.8 GWh (TAURON Dystrybucja) (SPURE 2018). On the national scale, the amount of power not supplied to consumers in 2017 as a result of grid failures is shown in Table 1.

TABLE 1. Limitations in the electricity supply to consumers in the National Power Grid in 2017 [MWh] (SPURE 2018)

TABELA 1. Ograniczenia w dostawach energii elektrycznej do odbiorców w KSE w 2017 r. [MWh]

Specification	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	2017
Limitations in the electricity supply due to failures in the distribution grid	631	765	531	2765	83	4396	1068	13 192	288	18592	971	5567	48849
– including those caused by adverse weather conditions	452	711	321	2516	59	4324	999	13 061	125	18596	944	5329	47437

The most important consequences in the form of grid failures were attributed to extreme weather conditions such as: violent storm at night from August 11–12, 2017, hurricane Ksawery on October 5–8, 2017, and hurricane Grzegorz on October 29–30, 2017.

A violent thunderstorm on August 11–12, 2018 in the belt from Lower Silesia through Wielkopolska, Kujawy, and Pomorze regions at its culminating point (the night of August 11, 2017) cut off the power within the distribution area of ENEA operating 14 110 kV/MV stations – Main Transformer Stations and 7,268 MV/LV power stations (SPURE 2018). 24 110 kV lines, which were key to the functioning of the local grid, and 313 MV lines were damaged (SPURE 2018). Electricity supply issues affected about 250 thousand consumers. On the other hand, within the TAURON Dystrybucja distribution area of outages of 2 110 kV/MV stations (Main Transformer Station) and 1,412 MV/LV power stations (SPURE 2018) Occurred. 10 lines of 110 kV and 65 MV lines were damaged (SPURE 2018). Electricity supply issues affected about 70 thousand consumers.

The power of the windstorms was great and resulted in the destruction or damage of many power lines (110 kV, MV, LV), and the scale of necessary repairs was enormous and comparable in volume to the construction of a new grid infrastructure.

Hurricane Ksawery cut off 46 110 kV/MV (Main Transformer Station) stations and 15,000 MV/LV power substations (SPURE 2018) in the ENEA Operator distribution area on October 5–8, 2017. 48 110 kV lines were damaged (SPURE 2018). Electricity supply issues affected 600,000 recipients. However, outages of 30 110 kV/MV substations (Main Transformer Station) and 6,063 MV/LV power stations (SPURE 2018) occurred in the TAURON Dystrybucja distribution area. 73 lines of 110 kV and 484 MV lines were damaged (SPURE 2018). Electricity supply issues affected 320 thousand consumers.

The effects in the form of destruction of the grid distribution infrastructure were many times greater than following the incident of August 11, 2017.

Hurricane Grzegorz on October 29–30, 2017 cut off power at 3 kV/MV stations (Main Transformer Station), 3,754 MV/LV power stations in the ENEA Operator distribution area (SPURE 2018). 12 110 kV and 300 MV lines were damaged (SPURE 2018). The electricity supply issues affected more than 160,000 consumers. However, eight 110 kV/MV substations (Main Transformer Station) and 3,499 MV/LV power stations outages occurred in the TAURON Dystrybucja distribution area (SPURE 2018). 37 lines of 110 kV and 244 MV lines were damaged (SPURE 2018). The electricity supply issues affected 194 thousand consumers.

The effects in the form of destruction of the distribution infrastructure grid were significantly greater than following the incident of August 11, 2017.

The operation safety of the national distribution grid depends to a large extent on the condition of the distribution grid. When assessing the state thereof, the following indices are very helpful: the degree of use of the permissible current capacity, lengths of low voltage circuits, lengths of medium voltage wires and cables, cross-sections of installed wires and cables, voltage level at the ends of low voltage circuits and end-user power interruption indicators (SPURE 2018). Distribution grid operators strive to maintain these parameters at the appropriate level by undertaking specific investment and operating activities. They replace overhead lines with cable lines where it is possible and justified, shorten the low voltage circuits and the length of the MV lines, and replace wires and cables of a small diameter for wires and cables of a larger diameter. Increasing the share of cables contributes to reducing the failure of distribution grids (Parol 2014). Such lines are less than overhead lines exposed to weather conditions and mechanical damage.

In the national distribution grid, the predominant number of power lines is used to an extent lesser than 50%, which stands for a large supply capacity of these lines (Dołęga 2013). Power lines with a higher than 90% use of the power carrying capacity constitute about 0.7% of the MV line and about 4% of the low voltage lines at present (SMBDEE 2017). Such lines require urgent modernization.

A very important measure of the distribution grid assessment are indicators of the duration of interruptions in electricity supply for a given year.

The types of interruptions in the electricity supply are stipulated in the Regulations (RMG 2007). The interruptions in the electricity supply are divided into: scheduled and unscheduled, often referred to as emergencies. The characteristics of such interruptions are shown in Table 2. The scheduled interruption, of which the consumer has not been notified at least five days in advance in the form specified in the Regulation (RMG 2007), is treated as an unscheduled interruption (Dołęga 2012).

Depending on the duration, the following interruptions are distinguished: transient (lasting no longer than 1 second), short (lasting longer than 1 second and not longer than 3 minutes), long (lasting longer than 3 minutes and not longer than 12 hours), very long (lasting longer than 12 hours and not longer than 24 hours), and catastrophic (lasting longer than 24 hours) (RMG 2007).

The distribution grid operator provides the following indicators with regard to the duration of interruptions in the electricity supply determined separately for scheduled and unscheduled interruptions (along with catastrophic interruptions):

Table 2. Types of interruptions in electricity supply (RMG 2007)

Tabela 2. Rodzaje przerw w dostarczaniu energii elektrycznej

Types of interruptions	Reason of interruption	Duration of interruption
Scheduled	resulting from the maintenance works schedule for the power grid	from the moment the circuit breaker is opened to the time of resumption of electricity supply
Unscheduled	caused by a failure in the power grid	from the moment an power company dealing in the power transmission or distribution receives information of occurrence thereof until the electricity supply is resumed

- indicator of the average systemic time of a long interruption (SAIDI), constituting a sum of products of the duration time thereof and the number of recipients exposed to the effects of this interruption during the year, divided by the total number of serviced recipients,
- indicator of the average systemic rate for long interruptions (SAIFI), which is the number of all such interruptions during the year, divided by the total number of serviced recipients (Dołęga 2012).

In addition, the distribution grid operator publishes the following:

- average short interruption rate (MAIFI), which is the number of all short interruptions per year, divided by the total number of serviced recipients (Dołęga 2012).

The values of the average systemic power supply interruptions in 2013–2017 are presented in Table 3.

The value of SAIDI indicators for scheduled interruptions is gradually improving, with the exception of ENERGA-Operator SA, for which the SAIDI value for scheduled interruptions was the lowest in 2015 and increased in subsequent years. A similar situation is observed in relation to SAIDI indicators for unscheduled interruptions and SAIDI indicators for unscheduled interruptions including catastrophic interruptions. The exceptions were the years 2015 and 2017, where an increase in values of the indicators was noted. This was related to the occurrence of extreme weather conditions. The value of SAIFI indicators for scheduled interruptions, similarly to SAIDI indicators, is gradually improving. However, no such regularity is observed in relation to SAIFI indicators for unscheduled interruptions and SAIFI for unscheduled interruptions including catastrophic interruptions. The values of these indicators were lower in 2017 in comparison with 2013 for only two operators: ENERGA-Operator SA and innogy Stoen Operator Sp. z o.o. This remains in close relation to the recent intensification of extreme weather phenomena such as: snowstorms, wet snowfall, hurricanes, storms, windstorms, and thunderstorms. The value of the average short interruption rate (MAIFI) ratio in relation to 2013 increased for all distribution grid operators subject to analysis.

Potentially high risks to the operational safety of the distribution grid and the security of electricity supply result directly from: age, technical condition, and the degree of depletion of distribution grids and their high failure rate due to more and more common occurrence of the

TABLE 3. Indicators of average grid interruptions in supplying recipients in the years 2013–2017 (SMBDEE 2015, 2017; SPURE 2018)

TABELA 3. Wskaźniki przeciętnych systemowych przerw w zasilaniu odbiorców w latach 2013–2017

Specification		Unit of measurement	Year	PGE Dystrybucja SA	TAURON Dystrybucja SA	ENEA Operator Sp. z o.o.	ENERGA Operator SA	Innogy Stoen Operator Sp. z o.o.
Indicator of the average systemic duration of a long interruption per one recipient (SAIDI)	SAIDI unscheduled	min./ /recipient	2013	315.93	192.90	353.50	235.69	74.60
			2014	241.60	150.20	219.43	198.30	60.78
			2015	272.16	207.35	372.71	213.80	62.81
			2016	252.05	137.68	184.31	166.10	58.30
			2017	385.89	219.67	403.76	209.40	64.86
	SAIDI unscheduled +catastrophic		2013	343.37	196.16	415.33	283.90	76.89
			2014	279.50	151.10	223.49	203.70	64.03
			2015	283.17	238.67	410.03	239.40	66.03
			2016	281.90	137.94	185.98	177.00	61.40
			2017	461.70	238.41	671.06	298.00	69.81
	SAIDI scheduled		2013	184.13	159.69	127.39	71.14	19.17
			2014	194.60	104.70	106.09	58.40	19.05
			2015	158.89	69.42	110.12	46.40	14.26
			2016	119.41	59.38	103.32	50.80	12.55
			2017	95.05	48.40	55.26	55.40	9.05
Indicator of the average systemic frequency of long and very long interruptions per one recipient (SAIFI)	SAIFI scheduled	item/ /recipient	2013	3.77	2.98	4.18	2.92	1.46
			2014	3.30	2.70	3.21	3.14	1.29
			2015	4.01	3.08	5.35	3.08	1.31
			2016	3.86	2.55	3.53	2.49	0.88
			2017	4.97	3.29	4.15	2.67	0.95
	SAIFI unscheduled +catastrophic		2013	3.80	2.99	4.21	2.95	1.47
			2014	3.30	2.70	3.21	3.15	1.30
			2015	4.02	3.10	5.36	3.09	1.31
			2016	3.88	2.55	3.54	2.50	0.89
			2017	5.00	3.30	4.23	2.69	0.96
	SAIFI scheduled		2013	0.72	0.77	0.51	0.42	0.12
			2014	0.70	0.60	0.47	0.39	0.16
			2015	0.71	0.46	0.50	0.34	0.17
			2016	0.61	0.40	0.59	0.33	0.13
			2017	0.48	0.31	0.35	0.33	0.11
Indicator of the average frequency of short interruptions (MAIFI)		item/ /recipient	2013	3.82	2.62	2.31	5.02	0.54
			2014	3.50	3.20	1.93	7.53	0.44
			2015	5.25	3.12	5.37	9.48	0.41
			2016	8.57	3.49	5.80	8.39	0.55
			2017	9.46	3.97	5.31	9.26	0.61
Number of serviced recipients		item	2013	5 193 721	5 334 408	2 438 037	2 946 008	948 317
			2014	5 225 653	5 334 408	2 460 758	3 036 404	964 802
			2015	5 263 722	5 332 731	2 460 758	2 950 595	978 628
			2016	5 307 050	5 372 951	2 487 023	2 950 595	997 447
			2017	5 350 667	5 532 681	2 552 699	2 992 418	1 015 829

already mentioned high-intensity weather anomalies (Dołęga 2018). This currently remains the key challenge for distribution grid operators.

The assets of distribution grids are outdated and heavily depleted. The 110 kV/MV stations, MV/LV stations, and MV distribution grids in rural areas show the greatest degree of wear (Dołęga 2013). These require urgent modernization in order to ensure the appropriate quality of electricity supplied to end users.

As previously mentioned, the current distribution infrastructure appear to be insufficient. It is therefore necessary to extend and thoroughly modernize it. Distribution grid operators are aware of this fact and are implementing an extensive investment program. In recent years investments in the distribution grids have been carried out at the level of: PLN 5.6 billion (2015), PLN 6 billion (2016), and PLN 5.9 billion (2017), and in the years 2018–2020 distribution grid operators are planning to spend PLN 17.3 billion on this purpose (SPURE 2017, 2018). Most extensively involved in these investments are: PGE Dystrybucja SA, TAURON Dystrybucja SA, and ENERGA-Operator SA.

Improving the operational safety of the distribution grid requires the distribution grid operators to undertake various investment and operational measures which will help to avoid or at least limit the scale of failure in the case of sudden high-intensity atmospheric phenomena in the future.

Limiting the risk of failures and interruptions in the electricity supply to consumers requires the proper, systematic, and scheduled operation of the power grid. Limiting the impact of adverse weather conditions (storms, windstorms, snowstorms, wet snowfall, icing, etc.) may be effected by, among others, a through systematic implementation of such operations as: the inspection of overhead power lines, systematic cutting of trees and shrubs under overhead lines, and inspection of power lines and equipment.

It is necessary to modernize the grid infrastructure with a view to improving the reliability indicators of the distribution grid, especially those regarding the duration of interruptions in the electricity supply. The focus should be paid to the modernization of those MV lines which are most sensitive from the point of view of the electricity supply to consumers (Parol 2014). Such a modernization should take the latest technological solutions in the field of the construction of overhead lines and cables, and should take into account the development of controllable connection points in the depth of the distribution grid into account (SPURE 2018). In addition, it should be geared towards the replacement of overhead lines to cables or the removal thereof from forest areas, where an increased probability of failure in extreme weather conditions exists.

In addition, limiting the severity of failures and power outage duration for consumers requires the implementation of measures aimed at the improving resilience of the distribution grid to adverse weather conditions and improving the process of determining location and removing failures. Such activities include: the replacement of bare wires with cables and non-insulated cables in MV grids and insulated cables in low-voltage grids, automation of MV grids, use of control and supervision (control) grids, implementation of digital communications, increase of MV grid reconfiguration capacity and modernization of MV/LV substations. The said cable replacement significantly limits the number of failures caused by trees and branches. The automation of the

SN grid is connected with the installation of remote control switches in the depth of the MV grid, which allows the the times of determining the failure location and duration of the power outage for some consumers supplied from this distribution grid, which does not include the damaged element, to be shortened. The use of control grids allows the observability of the distribution grid to be increased and the efficiency and speed of switching over such a grid to be improved. The implementation of digital communication allows for a significant increase in the reliability of the control of switches in the MV distribution grid. Boosting the reconfiguration possibilities of the MV grid may be accomplished through the construction of new connections in order to enable the bilateral supply of consumers and the construction of new MV/LV stations and shortening the low voltage circuits. Modernization of the MV/LV substations consists in eliminating unnecessary and replacing worn-out station components and insulating working elements in the case of MV/LV pole stations.

Additionally, in order to minimize interruptions in electricity supply to consumers, distribution grid operators increase the scope of works carried out in with the use of the live work technology in a systematic manner, both by internal and external contractors (SPURE 2017). Works within the scope of the determination of the damage location in the grid, carrying out the necessary switching and repairing in order to restore the power for consumers are undertaken immediately following occurrence of the failure and carried out by employees of distribution companies and cooperating external contractors.

In order to maintain the continuity of electricity supplies to consumers, the power supply of the electricity grid separated from power generators which belong to the distribution grid operators is also used.

Summary

The national power grid including the transmission and distribution energy grids plays a key role in the National Power Grid and is of strategic importance for the operation thereof. As it stands now, it does not pose a threat to the safety of work and security of the electricity supply, because it is adapted to the currently existing typical conditions of electricity demand and tasks in a regular state of affairs, however, it may pose a local threat, especially in extreme weather conditions (snowstorms, heavy and wet snowfall, icing, hurricanes, windstorms, or thunderstorms).

A potentially high threat to the operation safety of the national power grid results directly from: age, technical condition, and the degree of depletion of transmission and distribution grids and high failure rate thereof due to weather anomalies. This necessitates the development and modernization of the 400 and 220 kV transmission grids, cross-border interconnections as well as the 110 kV distribution grid (especially in the area of large urban agglomerations) and the MV distribution grid (especially in rural areas).

In 2017, extreme weather conditions such as: violent storm on the night of August 11–12, 2017, Hurricane Ksawery on October 5–8, 2017 and Hurricane Grzegorz on October 29–30, 2017 resulted in failures in the transmission grid and distribution grid of a considerable scale and size, the effects of which have affected tens of thousands of electricity consumers. These failures revealed the need for the transmission grid operator and distribution grids operators to undertake various investment and operational activities which would help to avoid or at least reduce the scale of grid failures in the case of sudden high-intensity atmospheric phenomena in the future.

References

Dołęga, W. 2012. Standards in the technical parameters of electricity and customer service quality, and the consequences of failure to comply with grid operators (*Standardy w zakresie parametrów technicznych energii elektrycznej i jakości obsługi odbiorców oraz konsekwencje ich nieprzestrzegania dla operatorów systemów*). *Energetyka* Vol. 7, pp. 352–357.

Dołęga, W. 2013. Planning for the development of the power grid infrastructure in terms of the security of energy supply and ecological security (*Planowanie rozwoju sieciowej infrastruktury elektroenergetycznej w aspekcie bezpieczeństwa dostaw energii i bezpieczeństwa ekologicznego*). Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej (*in Polish*).

Dołęga, W. 2014. Development of the transmission grid in terms of security of energy supply (*Rozwój sieci przesyłowej w aspekcie bezpieczeństwa dostaw energii*). *Przegląd Naukowo-Metodyczny "Education for safety"* Vol. 3, pp. 1084–1098 (*in Polish*).

Dołęga, W. 2018. National grid electrical power infrastructure – threats and challenges. *Polityka Energetyczna – Energy Policy Journal* Vol. 21, Iss. 2, pp. 89–103.

IRiESP, 2017 – Transmission Grid Code. Warunki korzystania, prowadzenia ruchu, eksploatacji i planowania rozwoju sieci. PSE SA Warsaw, 1 December 2017 (*in Polish*).

Parol, M. 2014 – Analysis of indicators concerning interruptions in electricity supply at the level of distribution grids (*Analiza wskaźników dotyczących przerw w dostarczaniu energii elektrycznej na poziomie sieci dystrybucyjnych*). *Przegląd Elektrotechniczny* Vol. 90, No. 8, pp. 122–126 (*in Polish*).

PSE 2018 – Polskie Sieci Elektroenergetyczne SA: www.pse.pl.

RMG 2007 – Regulation of the Minister of Economy of 4 May 2007 on detailed conditions for the operation of the power system (*Rozporządzenie Ministra Gospodarki z dnia 4 maja 2007 r. w sprawie szczegółowych warunków funkcjonowania systemu elektroenergetycznego*). The Polish Journal of Laws No. 93, item 623 of 29.05.2007 as further amended (*in Polish*).

SMBDEE 2015 – Report on the results of monitoring of the security of electricity supply for the period from 1 January 2013 to 31 December 2014. The Minister of Energy (*Sprawozdanie z wyników monitorowania bezpieczeństwa dostaw energii elektrycznej za okres od dnia 1 stycznia 2013 do dnia 31 grudnia 2014. Minister Gospodarki*). Warsaw, 2018 (*in Polish*).

SMBDEE 2017 – Report on the results of monitoring of the security of electricity supply for the period from 1 January 2015 to 31 December 2016. The Minister of Energy (*Sprawozdanie z wyników monitorowania bezpieczeństwa dostaw energii elektrycznej za okres od dnia 1 stycznia 2015 do dnia 31 grudnia 2016. Minister Energii*). Warsaw, 2017 (*in Polish*).

SPURE 2016 – Report on the Activity of the President of the Energy Regulatory Office in 2015 – Energy Regulatory Office (*Sprawozdanie z działalności Prezesa Urzędu Regulacji Energetyki w 2015 r. Urząd Regulacji Energetyki*), Warsaw, April 2016 (*in Polish*).

SPURE 2017 – Report on the Activity of the President of the Energy Regulatory Office in 2016 – Energy Regulatory Office (*Sprawozdanie z działalności Prezesa Urzędu Regulacji Energetyki w 2016 r. Urząd Regulacji Energetyki*), Warsaw, April 2017 (*in Polish*).
SPURE 2018 – Report on the Activity of the President of the Energy Regulatory Office in 2016 – Energy Regulatory Office (*Sprawozdanie z działalności Prezesa Urzędu Regulacji Energetyki w 2016 r. Urząd Regulacji Energetyki*), Warsaw, April 2018 (*in Polish*).

Waldemar Dołęga

Bezpieczeństwo pracy krajowej sieci elektroenergetycznej

Streszczenie

W artykule przedstawiono problematykę dotyczącą bezpieczeństwa pracy krajowej sieci elektroenergetycznej i charakterystykę krajowej sieci elektroenergetycznej w obszarze przesyłu i dystrybucji. Omówiono problematykę bezpieczeństwa pracy krajowej sieci przesyłowej i dystrybucyjnej oraz zagrożenia dla bezpieczeństwa pracy i bezpieczeństwa dostaw energii elektrycznej związane z tymi sieciami. Przedstawiono awarie sieciowe w systemie przesyłowym i dystrybucyjnym w 2017 r., spowodowane przez ekstremalne warunki atmosferyczne, takie jak: gwałtowna burza w nocy 11/12.08.2017, orkan Ksawery w dniach 5–8.10.2017 i orkan Grzegorz w dniach 29–30.10.2017, których skutki dotknęły dziesiątki tysięcy odbiorców energii elektrycznej i doprowadziły do znacznych przerw w dostawie energii elektrycznej. Krajowa sieć elektroenergetyczna (przesyłowa i dystrybucyjna) nie stwarza obecnie zagrożenia dla bezpieczeństwa pracy i bezpieczeństwa dostaw energii elektrycznej i jest przystosowana do występujących obecnie typowych warunków zapotrzebowania na energię elektryczną i realizacji zadań w stanach normalnych, ale lokalnie może stanowić takie zagrożenie szczególnie w ekstremalnych warunkach atmosferycznych. Potencjalnie duże zagrożenie bezpieczeństwa pracy krajowej sieci elektroenergetycznej ma ścisły związek z: wiekiem, stanem technicznym i stopniem wyeksploatowania sieci przesyłowych i dystrybucyjnych oraz ich dużą awaryjnością na skutek anomalii pogodowych. Dlatego konieczna jest rozbudowa i modernizacja sieci przesyłowej 400 i 220 kV, transgranicznych połączeń międzysystemowych oraz sieci dystrybucyjnej 110 kV (szczególnie w obszarze dużych aglomeracji miejskich) i sieci dystrybucyjnej SN (szczególnie na obszarach wiejskich). Przedstawiono wyzwania, jakie stoją przed operatorami systemu przesyłowego i systemów dystrybucyjnych w zakresie działań inwestycyjnych i eksploatacyjnych, które pozwolą na uniknięcie lub co najmniej na ograniczenie skali awarii sieciowych w przypadku wystąpienia nagłych zjawisk atmosferycznych o dużym nasileniu w przyszłości.

Słowa kluczowe: sieć elektroenergetyczna, bezpieczeństwo pracy, bezpieczeństwo dostaw energii