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## National grid electrical power infrastructure – threats and challenges

**ABSTRACT:** The aim of the paper is to draw attention to risks and challenges faced by the national grid infrastructure both in the area of transmission and distribution. The study presents the characteristics of the network grid in the area of transmission and distribution. The threats concerning the transmission and distribution infrastructure were also discussed. Both the national transmission and the distribution grids are adapted to presently occurring typical conditions of the demand on electricity and to the execution of internal tasks in normal states, but they may pose a potential threat to the security of the energy supplies. In the context of the forecasted future growth of the electricity demand, the insufficient capacity of the National Power System in domestic sources and sources available through interconnections, the uneven distribution of sources and customers with the lack of adequate grid transmission capacity, the necessity to improve the quality and reliability of energy supply to end users and to intensively develop renewable energy sources, the current grid infrastructure in the area of transmission and distribution will be insufficient. It will be necessary to expand and modernize the 400 and 220 kV transmission grid, the 110 kV distribution grid, in large urban agglomerations in particular, the MV distribution grid in rural areas in particular, and to implement investments aimed at increasing the export and import capacities of the National Power System. The paper presents challenges faced by transmission and distribution system operators. They mainly concern the field of investments and the area related to the preparation and implementation of investments in the grid. These challenges result from national legislation which is inappropriate and imposes many legal and administrative barriers substantially limiting the speed and effectiveness of the investment process.

**KEYWORDS:** power engineering, grid infrastructure, development

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## 1. Grid infrastructure

The power grid infrastructure is the link between generation sources and customers and includes: 400 and 220 kV transmission grid, 110 kV distribution grid (the so-called initial distribution grid), MV distribution grid (6, 10, 15, 20 and 30 kV) and low voltage (0.4 kV) distribution grid. It consists of power substations, overhead and cable lines and power equipment and devices cooperating with each other in order to perform the task which is the transmission or the distribution of electricity.

The transmission grid is used to transmit electricity often over long distances from system power plants to receiving stations located in areas with a high demand for it, where it is transformed into a lower voltage level (e.g. 400/110 kV or 220/110 kV inside the country), transferred to the 110 kV and MV grids for further transformation, distribution and supply to customers. The customers most often receive low voltage energy.

The transmission grid due to its location in the National Power System (NPS) and its function plays a key role in the NPS and is of strategic importance for its operation. Its main task is to balance the demand and generation of electricity, taking the interconnection exchange into account, while ensuring stable operation of NPS and the required quality of electricity supplies (Dołęga 2013). It is therefore responsible for, among others, power evacuation from conventional power plants and its transmission to areas of demand, often over long distances. This function causes the transmission grid to include LV lines and stations with rated voltages equal to or greater than 220 kV. In the past, the transmission grid also included the 110 kV network, which is now considered to the distribution grid.

The transmission grid is always viewed globally on the system scale, and its supervision is exercised by the energy enterprise being the transmission system operator (TSO) (Dołęga 2013). In Poland, Polskie Sieci Elektroenergetyczne SA is such an operator (PSE SA) (PSE 2018).

The national transmission grid consists of 257 lines with a total length of 14,069 km and 106 extra-high voltage substations with voltages of: 220 kV, 400 kV and 750 kV (PSE 2018). The above including: 167 lines of 220 kV with a total length of: 7,971 km, 89 lines of 400 kV with a total length of 5 984 km and 1 line of 750 kV with a length of 114 km, 69 stations of 220 kV and 37 stations of 400 kV with 211 extra-high voltage autotransformers and transformers (PSE 2018; SMBDEE 2017).

As a part of the NPS, the distribution grid with its function plays a central role in supplying customers. It constitutes an important link in the power system and to a large extent determines the quality, reliability and security of electricity supplies to end users (Dołęga 2013). In the NPS it is responsible for the separation and distribution of electricity. This function is the reason why the distribution grid includes HV and MV lines and stations with rated voltages equal to or lower than 110 kV and low-voltage lines. The choice of the distribution grid rated voltage is determined not only by technical factors, but also by factors similar to those in the case of transmission grids.

The distribution grid is treated fragmentarily in the entire system (Dołęga 2013). The distribution grid is supervised by energy enterprises – distribution system operators. These are enterprises with shares owned by both private investors and the State Treasury. In Poland, the most important and largest distribution enterprises currently are: PGE Dystrybucja SA, TAURON Dystrybucja SA, ENEA Operator Sp. z o.o., ENERGA-OPERATOR SA and innogy Stoen Operator Sp. z o.o. (SPURE 2017).

Within the distribution grid, a special role is played by the 110 kV network which, in addition to its distribution function in many regions of the country, is also responsible for transmission (Dołęga 2013). As a result, many of its parts are coordinated by the transmission system operator.

The national distribution grid comprises 33,757 km of 110 kV lines and 1,537 110 kV substations, 311,604 km of MV lines and 261,169 MV substations, as well as 470,142 km of low voltage lines (SMBDEE 2017). The HV stations use 2,791 110 kV/MV transformers, while the MV stations use 261,079 MV/LV transformers and 1,179 MV/MV transformers (SMBDEE 2017).

The basic data characterizing the transmission and distribution grids are presented in Table 1. The 2009 data is presented to highlight the changes that have occurred in the grid infrastructure in recent years.

The aim of the paper is to draw attention to risks and challenges faced by the national grid infrastructure both in the area of transmission and distribution.

## 2. Risks related to the transmission and distribution grid infrastructure

### 2.1. Transmission grid

The national transmission grid is adapted to the current typical conditions of the electricity demand and the performance of internal transmission tasks in normal states, ensuring an appropriate level of security of electricity supply (Dołęga 2014). However, there are high risks to the stable operation of NPS as well as local threats, which may cause difficulties with the power supply in extreme weather conditions, both in summer and winter.

In 2016, the transmission system did not experience any system or grid failures. No significant brownouts or blackouts caused by the lack of generation capacity in the NPS were reported. In 2015, however, in the summer period from August 10 to 31, restrictions on the electricity supply and consumption were imposed, due to insufficient generation and transmission capacity of the NPS with respect to electricity demand (SPURE 2016). At that time, the transmission system operator introduced power rationing levels in specific hours of the day. The highest level, i.e. the “20th” was in force on 10 August 2015 between 10:00 am and 5:00 pm (SPURE 2016).

TABLE 1. Characteristics of the national power transmission and distribution grids  
 (of 31.12.2009 and 31.12.2016) (Dołęga 2012; SMBDEE 2017)

 TABELA 1. Charakterystyka krajowych elektroenergetycznych sieci przesyłowych i dystrybucyjnych  
 (stan na dzień 31.12.2009 i 31.12.2016)

Specification	2009	2016
Length of overhead power lines		
LV + HV	45,914 km	47,432 km
750 kV	114 km	114 km
400 kV	5,261 km	6,139 km
220 kV (including DSOs*)	8,004 km (85 km)	7,950 km (81 km)
110 kV (including DSOs*)	32,535 km (32,471 km)	33,229 km (33,049 km)
MV	234,404 km	230,743 km
40–60 kV	24 km	0 km
30 kV	3,416 km	2,809 km
15–20 kV	229,557 km	226,619 km
Below 15 kV	1,407 km	1,315 km
LV	290,360 km	311,044 km
All voltages	570,678 km	589,219 km
Length of cable power lines		
LV + HV	147 km	528 km
MV	67,565 km	80,861 km
30–60 kV	175 km	269 km
15–20 kV	59,325 km	73,160 km
LV	137,725 km	159,098 km
All voltages	205,437 km	240,487 km
Number of upper voltage substations		
400 and 750 kV	33	44
220 kV	69	64
110 kV	1,391	1,537
MV	244,410	261,169
All voltages	245,903	262,814

\* DSOs – distribution system operators.

Risks to the stable NPS operation result directly from: low density of network and generation units in some parts of the country, limited possibilities of applying load on the power lines at higher ambient temperatures, the growing scope of repair and investment works in the grids, a high failure rate due to weather anomalies, excessive growth of voltage in the transmission and 110 kV grids, limitation of electricity import from the power systems of neighboring countries and load increase in the summer period (Dołęga 2014). These risks are compounded by the combination of a number of adverse factors, including: extremely high demand for power, weather anomalies, a blackout of a large number of electricity grid components or generation units, and the impact of power flows from the neighboring countries (Dołęga 2017).

The limited capacity of transmission lines at higher ambient temperatures poses a serious danger to the stable operation of the NPS in the case of increased demand for electricity (Dołęga 2013). This is closely related to the age, technical condition and degree of use of the transmission grids. With respect to overhead lines, only 20% of 400 kV lines and less than 1% of 220 kV lines are younger than 10 years, 58% of 400 kV lines and 11% of 220 kV lines are younger than 25 years, while 10% of 400 kV lines and as much as 74% of 220 kV lines are older than 35 years (Dołęga 2017). Moreover, these lines were designed for significantly lower flows than those currently observed (Dołęga 2017).

The age and technical condition of the transmission grids results in large number of failures of these grids, particularly in the conditions of recently more frequent weather anomalies (Dołęga 2017).

The limited capacity of cross-border interconnections results in the reduction of electricity import from the power systems of the neighboring countries. This is compounded by the circular power flows generated by wind power plants located in northern Germany. This constitutes a barrier to the exchange of electricity with foreign countries and limits the use of cross-border interconnections to the import of energy in situations in which meeting the demand from domestic sources is not possible (Dołęga 2017).

The increase of load in summer period limits the possibility of performing repairs in this time and reduces reserve levels in other periods of the year. In the last few years, there has been a much higher than average increase in the demand for active power in the summer time and its concentration in some large urban agglomerations (Warsaw, Kraków, Wrocław, Poznań) (Dołęga 2014). This is accompanied by a much higher increase in reactive power demand, the increase of which poses a threat to the security of the power supply to the consumers in a specific area.

In summer periods problems with the supply of electricity to such areas of the country where there is a large preponderance of consumption over the local generation may occur. This results from the unfavorable geographical distribution of generation sources, under-compensation of reactive power in energy consumers and distribution grids, and the lack of transmission capacity and equipment for reactive power compensation (Dołęga 2017).

The greatest risk of extensive network failure, in the event of accumulation of extremely unfavorable operating conditions of the transmission grid, refers to the northern part of the NPS (Dołęga 2014). This may occur in the conditions of large active and reactive power transfers from the center of the country to the north. This situation is caused by a lower number of generation sources and lower grid density in this area comparing to the southern part of the NPS. In the event of a failure, the voltage stability of a large area of the country may be lost. Risks in the power supply structure relate to large urban agglomerations.

Risks to the security of electricity supply resulting from insufficient NPS power in domestic sources and sources available through interconnections, as well as from the uneven distribution of sources and consumers without adequate transmission capacity of the grid, will already appear in the nearest future in view of the forecasted increase in electricity demand (Dołęga 2014). The current forecast of the electricity demand indicates that the demand will rise at an annual

average rate of 1.7% until the year 2035 (SMBDEE 2017). The demand will vary considerably for the winter and summer peaks (around 1.6% and 2.2% respectively). In addition, the growth will become stronger if the domestic economy experiences a fast pace of development. In such a case, the current transmission grid infrastructure will prove insufficient, and ensuring the security of the electricity supply will require the implementation of investments consisting in the expansion and modernization of the transmission grid, the 110 kV distribution grid in the area of large urban agglomerations as well as investments aimed at increasing export and import capacities of the NPS (Dołęga 2014). The necessity to expand and modernize the grid infrastructure is also connected with the intensive development of renewable energy sources (RES), the planned development of nuclear power and the need to build modern, environmentally friendly, conventional generation sources.

## 2.2. Distribution network

Although the national distribution network is adapted to the current typical conditions of electricity demand and the performance of tasks in normal states, it poses a potentially high threat to the security of the electricity supply (Dołęga 2014). In addition, there are strong local threats which may cause difficulties in supplying power to consumers in extreme weather conditions, especially in winter.

Potentially major threats to the security of electricity supply result directly from: age, the technical condition and the degree of exploitation of the distribution grids, and their high failure rate as a result of weather anomalies. Moreover, the threats are linked to the limited capacity of the 110 kV grid.

The assets of the distribution grids are outdated and heavily used. The highest wear level can be observed for 110 kV/MV stations, the MV/LV stations and the MV distribution grids in rural areas (Dołęga 2013). They urgently need to be modernized in such a scope as to ensure the appropriate quality of the electricity supply to end users.

The limited capacity of the 110 kV grid is closely linked to its age, technical condition and degree of use, and the lack of investment required to prevent the progressive depreciation of the grid assets. Due to insufficient thermal load capacity of 110 kV lines, there are, among other things, limited possibilities of supplying energy to large urban agglomerations (Warsaw, Poznań) (Dołęga 2013). Moreover, overloads occurring in the area of a 110 kV grid have an adverse impact on the operation of the transmission grid. A disadvantageous phenomenon, in terms of electricity supply security, consists in a very low level of investments carried out by distribution system operators concerning the construction of new 110 kV lines, which results in a low dynamics of increase in the length of these lines.

In view of the forecasted future growth of electricity demand, the need to improve the quality and reliability of the energy supply to end users and the intensive development of RES, the current distribution infrastructure will be insufficient. It therefore requires expansion and

thorough modernization, with regard to the 110 kV and the MV grids in particular. Moreover, the transmission functions imposed on the 110 kV distribution grid should be partially and gradually withdrawn.

### 3. Challenges concerning the transmission and distribution grid infrastructure

The challenges are directly related to the necessity of expansion and modernization of the grid infrastructure. Their scale is the largest for the transmission grid and cross-border interconnections and concerns the area of investments. That is why special attention has been paid to this area.

The necessity to expand and modernize the transmission grid, as mentioned above, results primarily from forecasts relating to the increase in demand for power and electricity from consumers, customers' requirements regarding the reliability and stability of the power supply as well as investments needed to connect and evacuate power from new generation units (Dołęga 2017). Such an extension and modernization should be aimed at: creating conditions for safe NPS operation, increasing the security of supply in large urban agglomerations, strengthening the role of the transmission system in the NPS, increasing operation capacity in the NPS, increasing the capacity of voltage regulation, power evacuation from connected sources and extension of cross-border interconnections (Dołęga 2013). This requires, among others, a significant extension of the structural transmission grid, structural changes in the power supply systems in critical areas of the country, enabling the sources with diversified generation technology and various parameters of operation to cooperate with one another, and the removal of transmission functions from the 110 kV distribution grid, which still takes place in many regions of the country (Dołęga 2014).

The necessity to develop cross-border interconnections aims at providing the security of electricity supply and removing barriers to free trade in energy on the domestic and international market.

Currently, the NPS is equipped with synchronous and non-synchronous interconnections. The former include cross-border connections with: Germany (220 kV Krajnik–Vierraden dual-track line and 400 kV Mikułowa–Hagenverder dual-track line), the Czech Republic (220 kV Kopanina–Liskovec and Bujaków–Liskovec single-track lines and 400 kV Wielopole–Nosovice and Dobrzeń–Albrechtice single-track lines) and with Slovakia (400 kV Krosno Iskrzynia–Lemesany dual-track line). The latter include cross-border connections with: Ukraine (750 kV Rzeszów Widełka–Chmielnicka single-track line, 220 kV Zamość–Dobrotvor single-track line), Belarus (220 kV Białystok–Roś single-track line), Sweden (450 kV Słupsk–Starno direct current cable line) and, more recently, Lithuania (400 kV Ełk Bis – Alytus dual-track line with DC link). However, two of these routes: Rzeszów Widełka–Chmielnicka and Białystok–Roś are closed.

In addition to the above mentioned routes, there are also operating connections with the Czech Republic and Germany (synchronous) and Belarus (asynchronous) within the 110 kV transmission grid. The number of all cross-border connections and their capacity is insufficient.

Investments in the area of the transmission grid constitute the most important and by far the greatest challenge for the transmission system operator.

The plan for the modernization and development of the grid infrastructure adopted by the TSO for the years 2010–2025 (PSE 2009) takes: the connection of new conventional sources to the transmission grid, planned withdrawals and decommissioning of selected generation units, connection of renewable energy sources with capacities resulting from the objectives of the Climate and Energy Package to the grid and the expected locations of nuclear power plants in the country into account. The plan is based on the concept of developing 400 kV networks on the routes of already existing 220 kV lines and the extension of 400 kV and 220 kV grids in areas of increased wind generation (North-Western Poland).

In the NPS development plan for 2010–2025, the transmission system operator has declared to allocate PLN 18,301.5 million for investments, of which PLN 8,546 million (Phase I) by 2015, PLN 7,530.5 million (Phase II) by 2020 and PLN 2,225 million (Phase III) by 2025 (PSE 2009). These investments are mainly focused on: connecting the NPS with the Lithuanian system by means of a synchronous LIT-POL Link connection, facilitating the connection of wind power sources in the north-western part of the country and limiting the adverse impact of wind power generation in Germany on the domestic transmission grid (installation of phase shifters). These investments will increase the NPS export and import capacities.

The planned electricity investments in the transmission grid have been clearly specified in the publication (PSE 2009) and grouped in the following areas: connections (system power plants and RES), power evacuations (from system power plants and RES), the NPS operational safety and cross-border connections (asynchronous, synchronous). At the same time, the NPS operational safety is combined with the adjustment of the grid infrastructure to the increase in power and energy demand, proper adjustment of voltage and reactive power as well as the elimination of grid constraints resulting from the implementation of the grid voltage changing strategy, the increase in the reliability of supply and coupling of the 400 and 220 kV grids.

The implementation of the planned investment projects will result in significant qualitative and quantitative changes in the transmission grids structure.

For example, as a result of the Phase I activities, the length of 400 kV line will be increased by nearly 1,800 km while at the same time the 220 kV line will be reduced by 800 km (PSE 2009). The transmission capacity of almost 190 km of 220 kV lines will be increased. The transformation capacity of the transmission grid will also be significantly increased. However, in the case of 400/110 kV transformation, the increase will be by 11 060 MVA, in the case of 400/220 kV transformation by 5160 MVA, and in the case of 220/110 kV transformation by 3305 MVA (PSE 2009). The adjustment capacity of the transmission grid reactive power will grow as well. The adjustment capacity will be increased in the range of +800 to –400 MVar (PSE 2009). The installation of phase shifters on the western border of Poland will allow the circular flows, also called the “loop flows” to be restricted.

The planned changes in the transmission grid are adequate and will allow for: covering the forecasted demand for power and electricity, connection of renewable energy sources with a capacity of approx. 5000 MW to the power grid, connection of conventional sources with the planned capacity of 3,500 MW to the transmission grid, creation of grid conditions for the evacuation of power from new sources planned to be connected, implementation of cross-border power flows between the Polish and Lithuanian systems, improvement of the voltage adjustment possibilities in the transmission grid, reduction of the loop flows and effective exchange of power with the German system as well as improvement of reliability of urban agglomerations power supply through structural changes in the power supply systems in critical areas of the grid (Dołęga 2017).

Among the investments included in the development plan aimed at meeting the present and future demand for electricity for the years 2010–2025 (PSE 2009) a group of investments being of strategic importance for the operation of the NPS is included, which are also considered a priority task by the European Union in terms of the energy supply security and the development of competition (the so-called projects of common interest). This group includes 23 strategic investments in the grids, such as the construction of 400 kV lines: Elk Bis–Polish Border, Elk Bis–Łomża, Ostrołęka–Stanisławów, Ostrołęka–Olsztyn Mątki, Płock–Olsztyn Mątki, Kozienice–Siedlce Ujrzanów, Kozienice–Ołtarzew, Krajnik–Baczyna, Baczyna–Plewiska, Plewiska–Eisenhüttenstadt (Germany), Mikułowa–Świebodzice, Mikułowa–Czarna–Pasikowice, Podborze – tie into the existing Wielopole–Nosovice line (Czech Republic) together with the construction of the 400/220 kV Podborze substation, Czarna–Polkowice, Dobrzeń – tie into the existing Pasikowice–Wrocław line, Dunowo–Żydowo Kierzkowo–Piła Krzewina–Plewiska, Pątnów–Jasiniec–Grudziądz, Grudziądz–Pelplin–Gdańsk Przyjaźń lines, Piła Krzewina–Bydgoszcz, Żydowo Kierzkowo–Słupsk, Gdańsk Przyjaźń–Żydowo Kierzkowo and construction of a multi-voltage 400 and 220 kV Buczyna – Podborze line as well as the modernization of 220 kV Blachownia–Łagisza line (UPRSI 2015).

One of the most important investment projects in transmission grids area was the construction of the so-called LIT-POL Link energy bridge between Poland and Lithuania carried out in recent years. The project was completed in 2015 and covered not only the construction of the connection of Elk Bis station with the Alytus station in Lithuania, but also the construction and modernization of LV power lines and stations in the north-eastern part of the country. Under this project, 11 large network investments have been performed in the transmission, comprising: the construction of 4 overhead power lines of 400 kV with the total length of 400 km, the construction of 5 LV substations and modernization of the 2 existing ones (PSE 2018). The total value of expenditures incurred for the implementation of investment tasks amounted to approx. PLN 1,800 million (PSE 2018). They enabled not only the transmission of electricity between Poland and Lithuania, thus contributing to the elimination of barriers in the functioning of the European energy market and the European Transmission System by closing the so-called “Baltic Ring”, but have also increased the reliability and stability of power supplies in central and north-eastern Poland.

As part of the construction of the LIT-POL connection, the following investments have been performed:

- ◆ construction of a 400 kV Ełk Bis dual-track line – the Polish border (Alytus direction) with a length of 112 km, being a direct link between the Polish and Lithuanian power systems,
- ◆ construction of a 400 kV Ostrołęka–Łomża–Narew line with a total length of 117 km, consisting of a dual-track section (Ostrołęka–Łomża) and a single-track section (Łomża–Narew),
- ◆ construction of a 400 kV Ełk Bis dual-track line–Łomża, 83 km long,
- ◆ construction of the 400 kV Miłosna–Siedlce Ujrzanów single-track line, 90 km long,
- ◆ construction of 400/220/110 kV Ołtarzew substation, consisting of 400 kV, 220 kV indoor switchgears and a 110 kV switchgear with SF<sub>6</sub> insulation,
- ◆ construction of the 400/110 kV Ełk Bis substation consisting of the 400 kV and 110 kV overhead switchgear, being the connection point between the Polish and Lithuanian power systems,
- ◆ construction of a 400 kV Łomża substation consisting of a 400 kV overhead switchgear connecting transmission lines from the direction of the substations: Ostrołęka, Ełk Bis and Narew,
- ◆ construction of a 400 kV Stanisławów substation consisting of a 400 kV overhead switchgear, connecting transmission lines from the direction of the substations: Ostrołęka, Narew, Siedlce Ujrzanów and Miłosna,
- ◆ construction of a 400/110 kV Siedlce Ujrzanów substation, consisting of a 400 kV and 110 kV overhead switchgear,
- ◆ extension of the 220/110 kV Ostrołęka substation by a 400 kV switchgear; construction of new 400 kV and 110 kV indoor switchgears with SF<sub>6</sub> insulation and modernization of the existing 220 kV overhead switchgear substation,
- ◆ extension of the 400 kV switchgear at the 400/110 kV Narew substation; in the scope enabling the line introduction from the direction of Łomża substation.

The scale of investments in the transmission infrastructure is very large. In 2015, in addition to the above projects related to the implementation of the LIT-POL connection, the transmission system operator managed to complete the implementation of the following grid investments related to power evacuation from generation sources: modernization of the 220/110 kV Kopanina substation, extension of the 400/110 kV Słupsk substation, extension of the 220 kV switchgear at the 220/110 kV Włocławek Azoty substation, extension of the 220/110 kV Stalowa Wola substation with the 220 kV switchgear, extension of the 400/110 kV Żarnowiec substation for the connection of new wind farms (SPURE 2016). In 2016, the following investment tasks were completed to remove transmission congestion in the NPS operation: installation of phase shifters on the 400 kV Mikułowa–Hagenwerder line, extension of the 220/110 kV Radkowiec substation, extension of the 400 kV switchgear at the 400/110 kV Narew substation together with installation of reactive power compensation equipment, modernization of the 220 kV Morzyczyn–Police substation – stage I, modernization of the 220 kV Stalowa Wola–Chmielów substation (SPURE 2017). In the scope of power evacuation from generation sources, the following investments have been completed: construction of the 400 kV Dobrzeń line–tie into the Pasikurowice–Wrocław line, construction of the 220 kV Stalowa Wola line – tie point into Chmielów–Abramowice line, extension of the 400 kV Stanisławów substation for the connection of the wind farm, exten-

sion of the 110 kV switchgear at the 220/110 kV Adamów substation in order to connect the technical gas production plant, extension of the 220/110 kV Gorzów substation in order to connect the EC Gorzów gas and steam unit and extension of the 110 kV switchgear in the 220/110 kV Piła Krzewina substation in order to connect new wind farms (SPURE 2017). At present, 60 investment projects in the area of transmission infrastructure are at various stages of implementation (PSE 2018). They include: construction of the 400 kV Bydgoszcz Zachód–Piła Krzewina line, construction of the 400 kV Gdańsk Przyjaźń–Żydowo Kierzkowo line, construction of the 400 kV Żydowo Kierzkowo–Słupsk line, construction of the 400/110 kV Żydowo Kierzkowo substation, construction of a dual-track 400 kV Grudziądz Węgrowo–Pelplin–Gdańsk Przyjaźń line, construction of a 400 kV Jasiniec–Grudziądz Węgrowo line, construction of the 400 kV Pątnów–Jasiniec line, construction of the 400/110 kV Pelplin substation, extension of the 400/220/110 kV Grudziądz Węgrowo substation, extension of the 400 kV and 110 kV switchgears at the 400/220/110 kV Dunowo electrical substation, extension of the 220/110 kV Bydgoszcz Zachód substation, construction of a 400 kV switchgear at the 220/110 kV Jasiniec substation, construction of the 400/110 kV Gdańsk Przyjaźń substation, extension of the 220/110 kV Skawina substation by a 400 kV and 110 kV switchgear, construction of the 400 kV Skawina line–tie into the Tarnów–Tucznawa and Rzeszów–Tucznawa lines, extension and modernization of the 400/220/110 kV Buczyna substation and many other projects (PSE 2018).

Extension and modernization of the grid infrastructure is combined with many investment and modernization activities to be carried out within a strictly defined time horizon. This is a very complex process performed by the transmission system operator and distribution system operators, which depends on many different determined and undetermined factors of a technical, economical, legal, political and social nature (Dołęga 2013). At the same time, the process of grid investments implementation strongly depends on the national legal conditions in this scope, that significantly lengthen the investment cycle for these facilities or may completely block their implementation (Dołęga 2016).

The execution of grid investments requires the preparation of complex documentation for the decision-making process, covering technical, economical as well as formal and legal issues. In the formal and legal aspect, the process requires various agreements, permissions, opinions and decisions, which at present make this stage the most important and the longest one in the preparation of the investment project.

The legal regulations related to the preparation and execution of investments in grid infrastructure are dispersed in many statutes and their subordinate legislation, they are targeted at cubic objects and do not take the specific nature of line facilities into account. They are imprecise, inconsistent and often change as a result of multiple amendments, and the resulting difficulties create legal and administrative barriers that effectively limit the speed and effectiveness of the investment process (Dołęga 2013). Moreover, they impose a significant financial burden on the system operators and put the utilization of European funds for financing grid investments at risk.

As a result of ambiguities and contradictions contained in the provisions of law and their different interpretation by local administration bodies, complexity, large number of parties involved at all stages of the proceedings and the need of reconciliation of their conflicting inte-

rests, as well as the necessity to acquire land for construction from many owners and users, and the completion of formal and legal procedures needed to obtain a building permit may last up to several years if the owners and users of the land employ appeal procedures (Dołęga 2016). Such a state of affairs is to a large extent the responsibility of the complex, long-term, multi-stage procedure in such a case, applied by the local administration body competent for the investment location (the commune head, the mayor, the president): including the investment in the study on the conditions and directions of spatial development in the commune, adopting the commune's local spatial development plan and issuing the decision on environmental conditions of the power grid investment.

When implementing the grid investments, special legislation, which describes the entire process of various infrastructural investments of public interest in a single legal act, is of great help. At present, only the Act on Preparation and Implementation of Strategic Investments in Transmission Networks (UPRSI 2015) is in force in the area of network infrastructure, which facilitates and accelerates the construction of transmission grids of strategic importance for the operation of the national power system and determines the sources of financing for the investment process. Unfortunately, it refers only to the above mentioned 23 strategic grid investments, which are included in the development plan for meeting current and future electricity demands for the period of 2010–2025 (PSE 2009). The procedures introduced in this Act for the preparation and implementation of strategic investments of the public objective in the area of grid investments in the transmission area will enable the efficient implementation of this process, prevent its blocking and counteract prolongation of administrative procedures during the construction of transmission grids. This will allow for their implementation and disbursement of the EU funds allocated for this purpose. The solutions contained in the Act do not apply to the construction or modernization of other 400 and 220 kV lines, 110 kV grids and other investments accompanying the aforementioned grid investments.

In the past, a Special Act on the preparation of the final tournament of the UEFA EURO 2012 European Football Championship was very helpful in the implementation of grid investments (UPFT 2007). The solutions and facilitations included in this Act enabled the construction and modernization of many kilometers of 400 kV transmission and 110 kV and MV distribution lines, especially in such agglomerations as: Warsaw, Wrocław, Poznań and Gdańsk.

In light of the existing legal regulations concerning the preparation and execution of investments, the extension and modernization of grid infrastructure poses a huge challenge to system operators, as favorable legal solutions relate only to a narrow, precisely defined group of strategic grid investments. The Operator cannot count on facilitations, simplifications and streamlining of formal, legal and administrative procedures when implementing other grid investments. Therefore, shortening the investment cycle in terms of limiting the investment preparation phase requires significant improvement of the grid investment management process on the level of system operators relevant services. This is the only way of improvement as the simplification and acceleration of the process of preparing and implementing grid investments in the current legal environment is not possible. Moreover, it allows for a significant increase in the use of EU funds allocated for financing projects in the area of grid infrastructure.

## Conclusions

The Polish transmission grid plays a key role in the National Power System and is of strategic importance for its operation. Currently, it does not pose a threat to the security of electricity supply, as it is adapted to the typical conditions of electricity demand and the performance of internal tasks in normal states. However, it presents a great threat to the stable operation of the National Power System and may cause difficulties with the transmission of electricity locally, especially in extreme weather conditions.

In the future, in view of the projected increase in electricity demand, the current grid infrastructure in the transmission area will be insufficient. The threats to the security of electricity supply will occur, resulting from insufficient power in the National Power System in domestic sources and sources available through the interconnections, as well as from the uneven distribution of sources and consumers in the absence of adequate transmission capacity of the grid. Therefore, ensuring the security of electricity supply will require the implementation of investments consisting in the expansion and modernization of the 400 and 220 kV transmission grids, as well as investments aimed at increasing the export and import capacities of the National Power System.

The national distribution network is adapted to the current typical conditions of electricity demand and to the performance of tasks in normal states. However, it presents a potential high threat to the security of electricity supplies, which results directly from the age, technical condition and degree of use of distribution grids, their high failure rate due to weather anomalies and limited capacity of the 110 kV network. In addition, there are strong local risks which may cause difficulties in supplying power to consumers in extreme weather conditions.

In the future, in view of the projected increase in electricity demand in the future, the necessity to improve the quality and reliability of the energy supply to end users as well as the intensive development of renewable energy sources, the current grid infrastructure in distribution area will be insufficient. Its expansion and thorough modernization will be essential, especially with regard to the 110 kV distribution network (especially in large urban agglomerations) and the MV grid. Moreover, it is necessary to partially and gradually withdraw the transmission functions from the 110 kV distribution grid.

The expansion and modernization of the grid infrastructure in the area of transmission and distribution constitutes the largest and most important challenge for system operators. This is due to the fact that the legal regulations concerning the preparation and implementation of grid investments impose many congestions and barriers effectively limiting the speed and effectiveness of the investment process, significantly increase the costs of these investments and present a threat to the use of EU funds in their financing.

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Waldemar DOŁĘGA

## Krajowa sieciowa infrastruktura elektroenergetyczna – zagrożenia i wyzwania

### Streszczenie

Celem artykułu jest zwrócenie uwagi na zagrożenia i wyzwania stojące przed krajową infrastrukturą sieciową zarówno w obszarze przesyłu, jak i dystrybucji. W opracowaniu przedstawiono charakterystykę infrastruktury sieciowej w obszarze przesyłu i dystrybucji. Omówiono zagrożenia dotyczące infrastruktury przesyłowej i dystrybucyjnej. Zarówno krajowa sieć przesyłowa, jak i dystrybucyjna jest przystosowana do występujących obecnie typowych warunków zapotrzebowania na energię elektryczną i realizacji wewnętrznych zadań w stanach normalnych, ale może stwarzać potencjalne zagrożenie dla bezpieczeństwa dostaw energii elektrycznej. W kontekście prognozowanego wzrostu zapotrzebowania na energię elektryczną w przyszłości, niedostatecznej mocy w Krajowym Systemie Elektroenergetycznym w źródłach krajowych i dostępnej poprzez połączenia międzysystemowe, nierównomiernego rozłożenia źródeł i odbiorów przy braku odpowiednich zdolności przesyłowych sieci, konieczności poprawy jakości i niezawodności dostawy energii do odbiorców końcowych oraz intensywnego rozwoju odnawialnych źródeł energii obecna infrastruktura sieciowa w obszarze przesyłu i dystrybucji będzie niewystarczająca. Konieczna stanie się rozbudowa i modernizacja sieci przesyłowej 400 i 220 kV, sieci dystrybucyjnej 110 kV szczególnie w obszarze dużych aglomeracji miejskich, sieci dystrybucyjnych SN szczególnie na obszarach wiejskich oraz realizacja inwestycji mających na celu zwiększenie możliwości eksportowo-importowych Krajowego Systemu Elektroenergetycznego. Przedstawiono wyzwania, jakie stoją przed operatorami systemu przesyłowego i systemów dystrybucyjnych. Dotyczą one głównie sfery inwestycyjnej i obszaru związanego z przygotowaniem i realizacją inwestycji sieciowych. Wyzwania te wynikają z krajowych uregulowań prawnych, które są niewłaściwe i wprowadzają wiele barier prawnych i administracyjnych skutecznie ograniczających szybkość i efektywność procesu inwestycyjnego.

SŁOWA KLUCZOWE: elektroenergetyka, infrastruktura sieciowa, rozwój

