E3S Web of Conferences **84**, 02002 (2019) https://doi.org/10.1051/e3sconf/20198402002
PE 2018

Development of electric power network infrastructure in aspect of electric energy supply security – case study Poland

Waldemar Dolega[1,*]

[1]Wroclaw University of Science and Technology, Faculty of Electrical Engineering, Department of Electrical Power Engineering, 50-370 Wroclaw, Wybrzeze Wyspianskiego 27, Poland

Abstract. In this paper, an analysis of issues related to development of national electric power network infrastructure in aspect of electric energy security is performed. Profile of network infrastructure in area of transmission and distribution is performed. Threats for electric energy supply security connected with transmission and distribution infrastructure are discussed. Both transmission and distribution electric power network are adapted for presently occurred typical conditions of electric energy demand and realization of internal tasks in normal conditions, but can create potential threat for electric energy supply security. In the context of forecasted increase of electric energy demand, inadequate power in National Electric Power System (NEPS) in domestic sources and available through intersystem connections, uneven location of sources and consumers at shortage of proper network transmission capacities, necessity of improvement of quality and electric energy supply reliability to final consumers and intensive development of renewable energy sources, present network infrastructure in area of transmission and distribution will be insufficient. Development of 400 and 220 kV transmission network, 110 kV distribution network especially in area of cities, MV distribution network especially in rural areas and realization of investments for improvement of export-import possibilities of NEPS will be necessary. Challenges for transmission and distribution system operators in area of network development are performed. They concern mainly investment sphere and area connected with preparation and construction of network investments.

1 Introduction

The electric power network infrastructure is the link between generation sources and customers (consumers of electricity) and includes: 400 and 220 kV transmission grid, 110 kV distribution grid, MV distribution grid (6, 10, 15, 20 and 30 kV) and low voltage (0.4 kV) distribution grid. It includes both overhead and cable lines as well as power substations. The former is responsible for the transmission of electricity, and is supervised by the transmission system operator (TSO) – the company Polskie Sieci

* Corresponding author: waldemar.dolega@pwr.edu.pl

Elektroenergetyczne SA. The latter, on the other hand, is responsible for the distribution of electricity, and is supervised by the distribution system operators (DSOs). 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. [1].

The transmission grid includes 257 lines with a total length of 14,069 km and 106 high voltage power substations with 220 kV, 400 kV, and 750 kV voltages [2]. These include: 167 lines with a voltage of 220 kV 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 substations and 37,400 kV substations, in which used are a total of 211 autotransformers and high voltage transformers [2,3].

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 [3]. In 110 kV substations, 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 [3].

Due to its location in the National Electric Power System (NEPS) and the function it plays therein (transmission, distribution), the national electric power network plays a key role in the NEPS 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.

Electric energy supply security is often defined as the security of supplies of electric energy at any time, in a sufficient quantity, at possibly the lowest (optimum) price and in compliance with the environment protection regulations [4]. The assurance of electricity supply security at the national level is the primary goal of the energy policy of the state.

The aim of the paper is to draw attention to risks and challenges faced by the national transmission and distribution network in aspect of electric energy supply security.

2 Transmission network infrastructure – threats for electricity supply security

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 security of electricity supply [5]. However, major threats to the stability of operation of the NEPS exist as well as local threats that may cause power supply difficulties in extreme weather conditions, both in summer and in 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 NEPS were reported [6]. In 2017, grid failures in the transmission grid occurred [1]. 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, 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 [7]. TSO 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 [7].

Risks to the stable NEPS operation and security of electricity supply result directly from: low density of network and generation units in some parts of the country, limited capacity of the transmission lines at higher ambient temperatures, the growing scope of repair and investment works in the grids, a high failure rate due to weather anomalies (snowstorms, wet snowfall, icing, hurricanes, windstorms, and thunderstorms), 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 [5]. 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 [5].

The limited capacity of transmission lines at higher ambient temperatures poses a serious danger to the stable operation of the NEPS in the case of increased demand for electricity [8]. 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 [9]. Moreover, these lines were designed for significantly lower flows than those currently observed [9].

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 (snowstorms, wet snowfall, icing, hurricanes, windstorms, and thunderstorms) [5].

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 [9].

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) [5]. 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 [9].

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 NEPS [5]. 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 NEPS. 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 NEPS 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 [5].

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 [3]. 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 NEPS [5].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 [5].

3 Distribution network infrastructure – threats for electricity supply security

The national distribution network is adapted to the current typical conditions of electricity demand and the performance of tasks in normal states, but it poses a potentially high threat to the security of the electricity supply [5]. In addition, there are strong local threats which may cause difficulties in supplying power to consumers in extreme weather conditions.

In 2017, 2016 and 2015 grid failures occurred in the distribution grid, which led to significant power outages [1,6,7]. The main reason for their occurrence was damage to the power grid infrastructure caused by weather anomalies (snowstorms, wet snowfall, hurricanes, storms, and thunderstorms). For instance, in 2017, particularly extreme weather conditions were observed in August and October (storm in August, hurricanes Ksawery and Grzegorz in October) [1]. 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 [1].

The scale, severity, and number of failures varied. For instance, in 2017, in the area of operation of one of DSO - Enea Operator Sp. z o.o., a total of 47,460 grid failures occurred, causing interruptions in the electricity supply [1]. 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 [1]. In the case of next DSO - 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 [1]. 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) [1].

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 [5]. 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 [8]. 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, Poznan) [8]. 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 [5]. 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.

4 Transmission network infrastructure – challenges for TSO

The challenges for TSO are directly related to the necessity of expansion and modernization of the transmission grid infrastructure and cross-border interconnections and concerns the area of investments.

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 [9]. Such an extension and modernization should be aimed at: creating conditions for safe NEPS operation, increasing the security of supply in large urban agglomerations, strengthening the role of the transmission system in the NEPS, increasing operation capacity in the NEPS, increasing the capacity of voltage regulation, power evacuation from connected sources and extension of cross-border interconnections [8]. 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 [5].

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 NEPS is equipped with synchronous and non-synchronous interconnections. The former include cross-border connections with: Germany (220 kV dual-track line and 400 kV dual-track line), the Czech Republic (two 220 kV single-track lines and two 400 kV single-track lines) and with Slovakia (400 kV dual-track line). The latter include cross-border connections with: Ukraine (750 kV single-track line and 220 kV single-track line), Belarus (220 kV single-track line), Sweden (450 kV direct current cable line) and, more recently, Lithuania (400 kV dual-track line with DC link). However, one of connection with Ukraine (750 kV single-track line) and connection with Belarus are closed. The number of all cross-border connections and their capacity is insufficient [5].

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 adapted by the TSO for the years 2010–2025assumes: 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 [10]. 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 NEPS 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 [10].

These investments are mainly focused on: connecting the NEPS 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) [5]. These investments will increase the NEPS export and import capacities.

The planned electricity investments in the transmission grid have been clearly specified in the publication [10] and grouped in the following areas: connections (system power plants and RES), power evacuations (from system power plants and RES), the NEPS operational safety and cross-border connections (asynchronous, synchronous). At the same time, the NEPS 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 [5].

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

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 [9].

Among the investments included in the development plan aimed at meeting the present and future demand for electricity for the years 2010–2025 a group of investments being of strategic importance for the operation of the NEPS 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: Ełk Bis–Polish Border, Ełk 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–Pasikurowice, 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 Pasikurowice–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 Byczyna – Podborze line as well as the modernization of 220 kV Blachownia–Łagisza line [5].

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 Ełk Bis station with the Alytus station in Lithuania, but also the construction and modernization of UHV 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 UHV substations and modernization of the 2 existing ones [2]. The total value of expenditures incurred for the implementation of investment tasks amounted to approx. PLN 1,800 million [2]. 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.

The scale of investments in the transmission infrastructure is very large. At present, 60 investment projects in the area of transmission infrastructure are at various stages of implementation [2]. 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–Jasieniec 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 Jasieniec 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 Byczyna substation and many other projects [5].

Extension and modernization of the transmission 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 TSO, which depends on many different determined and undetermined factors of a technical, economical, legal, political and social nature [8]. 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 [11].

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 [11].

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 the result of multiple amendments, and the resulting difficulties create legal and administrative barriers that effectively limit the speed and effectiveness of the investment process [8]. Moreover, they impose a significant financial burden on the TSO and put the utilization of European funds for financing grid investments at risk.

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 TSO.

Transmission system operator cannot count on facilitations, simplifications and streamlining of formal, legal and administrative procedures when implementing other grid investments [5].

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 [5]. Moreover, it allows for a significant increase in the use of EU funds allocated for financing projects in the area of grid infrastructure.

5 Distribution network infrastructure – challenges for DSOs

The challenges for DSOs are directly related to the necessity of expansion and modernization of the distribution grid infrastructure.

Distribution system 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 [1,6]. Most extensively involved in these investments are following DSOs: PGE Dystrybucja SA, TAURON Dystrybucja SA, and ENERGA-Operator SA.

Improving the electricity supply security requires the distribution system operators to undertake various investment and operational measures which will help to avoid or at least limit the scale of failure, especially, 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 electric 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 (SAIDI,SAIFI,MAIFI) 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 [12]. 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 [1]. 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 MV grid is connected with the installation of remote control switches in the depth of the MV grid, which allows 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 [6].

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.

The extension and modernization of distribution grid infrastructure poses a huge challenge to DSOs [5]. Distribution system operators have the same problems in light of the existing legal regulations concerning the preparation and execution of investments, as TSO.

6 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 Electric 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 Electric 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 Electric 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

https://doi.org/10.1051/e3sconf/20198402002

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.

References

1. *Report on the Activity of the President of the Energy Regulatory Office in 2017* (Energy Regulatory Office, Warsaw, April 2018) (in Polish).
2. Polskie Sieci Elektroenergetyczne SA [Online] www.pse.pl [Accessed: 2018-09-01] (in Polish).
3. *Report on the results of the monitoring of the security of electricity supply for the period from 1 January 2015 to 31 December 2016* (Minister of Energy, Warsaw, 2017) (in Polish).
4. W. Dołęga, Przegląd Elektrotechniczny, V **87**, E 2, pp. 57-60 (2011).
5. W. Dołęga, Polityka Energetyczna – Energy Policy Journal, V **21,** E 2, pp. 89-103 (2018).
6. *Report on the Activity of the President of the Energy Regulatory Office in 2016* (Energy Regulatory Office, Warsaw, April 2017) (in Polish).
7. *Report on the Activity of the President of the Energy Regulatory Office in 2015* (Energy Regulatory Office, Warsaw, April 2016) (in Polish).
8. W. Dołęga, *The planning of electric power network infrastructure development with regard to energy supply security and environmental safety* (Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 2013) (in Polish).
9. W. Dołęga, Przegląd Naukowo-Metodyczny "Edukacja dla bezpieczeństwa", V **10**, E 1, pp. 1201–1213 (in Polish).
10. *Development Plan for meeting current and future electricity demand for the years 2010–2025* (Polskie Sieci Elektroenergetyczne Operator SA, Warsaw, 2009) (in Polish).
11. W. Dołęga, Polityka Energetyczna – Energy Policy Journal, V **19,** E 3, pp. 121-131 (2016) (in Polish).
12. M. Parol, Przegląd Elektrotechniczny, V **90**, E 8, pp. 122-126 (2014) (in Polish).