DEVELOPMENTAL TRENDS OF THE ELECTRICAL ENERGY DISTRIBUTION SECTOR IN POLAND

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Abstract: The report presents the main problems focused in the frame of development of network system in Poland.Author used owner metholodogy which give the opportunity to analize the solution of working electricity system in future. The presented methodology iscribe in practical logistic solutions in energy sector.

Keywords: development trends, energy system

Introduction

The projections and models of the functioning of the power industry in Poland against the background of other European countries presented in this chapter specify the technological and management-related conditions which have to be met if Poland is to reduce the distance to the EU 15 countries by the year 2030, achieving significant progress in creating GDP at the level approaching the developed countries.

The projections of the development trends for the power industry in Poland vs. the corresponding trends in EU 15 and other newly acceding countries shed light on the crucial global indicators, such as electrical energy production, GDP, and total energy consumption. For these indicators to reach, or exceed the target values the appropriate power infrastructure has to exist. Such infrastructure, constituting the electrical power system consists of the following elements:

- power plants,
- system networks – 220, 400, 750 kV for the transmission of electrical energy,
- 110 kV, medium-voltage, and low-voltage networks for the distribution of electrical energy.

The analysis conducted refers to two sectors of the system, namely the transmission networks and distribution networks. The parameter on which the output is dependent is the unitary production of electrical energy, since this particular parameter appeared in the investigations performed so far. Since the transmission and distribution networks carry the gross amount of used energy, first the relation between unitary energy production and gross energy consumption had to be analysed. If the correlation coefficient between these parameters is high enough, it is possible to base the projection of the network development on the energy produced in power plants., the calculated correlation coefficient is

$$r_{pee-zee} = 0,994$$

It is mean that the trends pee and *eec*, that is, the production and consumption of electrical energy are practically equivalent.
The functions presented above were approximated by means of straight lines, matching the real values to a sufficient extent, as the correlation coefficients are over R^2=0,85 for all the functions. The correlation equations were also formulated, so that the line length can be obtained from the following formula

$$L_{NN} = 3,851 \times pee - 2315,6 \tag{1}$$

$$L_{110} = (0,8054 \times pee + 16,279) \cdot 10 \tag{2}$$

$$L_{SN+nN} = (1,3748 \times pee + 1278,6) \cdot 10^2 \tag{3}$$

Similar analysis was performed for stations feeding the power networks.
As in the case of lines, some irregularities can be seen in the number of stations in the nineties. However, significant correlations were obtained, as the coefficient R exceeds the value 0,80 for all the functions. The functions determining the number of stations feeding the particular types of networks are as follows:

$$F_{NN} = 0,0358\ pee - 47 \tag{4}$$

$$F_{110/SN} = (0,0452 \times pee - 51,896) \cdot 10 \tag{5}$$

$$F_{SN/nN} = (0,061 \times pee - 33,667) \cdot 10^3 \tag{6}$$

Above-examples used to the qualification of the length of the line and the number of stations feeding of network for the year 2015. This permitted the removal of comparative research for two states - the year 2007 and 2015.

Efficiency evaluation of the distribution logistics system

The efficiency evaluation of the logistic subsystems provides an additional valuable criterion for assessing the logistic system as a whole. For the evaluation of subsystems, four categories of indicators are used: structural, productivity, cost-effect, and quality. The structural indicators are associated with the supply departments, production departments, and distribution departments [1]. The efficiency indicators of the logistic distribution system can be divided into two groups: quantitative indicators and qualitative indicators. For the evaluation of the efficiency of the logistic system in the electrical energy distribution the quantitative indicator was used, which was defined in the form of the average length of distribution lines for every level of the network.
The analysis were performed for two states: the year 2007 and the year 2015, for the trend TS [2].
In the Table 1, the densities of the particular types of lines and transformer stations are given in relation to the area of Poland. Besides, three parameters characteristic of the logistic system of electrical energy distribution are introduced, namely average lengths of 110 kV lines, medium-voltage lines and low-voltage lines, defined as

$$l_{110} = \frac{L_{110}}{F_{NN} \times n_{NN}} \tag{7}$$

$$l_{SN} = \frac{L_{SN}}{F_{110/SN} \times n_{110}} \quad (8)$$

$$l_{nN} = \frac{L_{nN}}{F_{SN/nN} \times n_{SN}} \quad (9)$$

where

l_{110} is the average length of a single 110 kV line,

l_{SN} is the average length of a single medium-voltage line,

l_{nN} is the average length of a single low-voltage line,

n_{NN}, n_{110}, n_{SN} are the average numbers of linear outputs from the transformer stations feeding 110 kV, medium-voltage, and low-voltage networks, for the calculations it was assumed [3]: $n_{NN} = 4$, $n_{110} = 10$, $n_{SN} = 3$,

F_{NN}, $F_{110/SN}$, $F_{SN/nN}$ are the numbers of stations feeding the particular network levels.

Table 1 Set of data for determining the efficiency of the logistic system of electrical energy distribution *Source: Prepared by the author*

Parameter	**Year**	
	2007	**2015**
$\sigma_{L_{NN}}$, km/km^2	0,04122	0,0633
$\sigma_{L_{110}}$, km/km^2	0,1033	0,1485
$\sigma_{L_{SN}}$, km/km^2	0,8902	1,2228
$\sigma_{L_{nN}}$, km/km^2	1,2469	1,7128
$\sigma_{F_{NN}}$, item/km^2	3,006 x 10^{-4}	5,008 x 10^{-4}
$\sigma_{F_{110/SN}}$, item/km^2	4,183 x 10^{-3}	6,646 x 10^{-3}
$\sigma_{F_{SN/nNN}}$, item /km^2	0,7018	1,0135
l_{110}, km	85,86	73,03
l_{SN}, km	21,28	18,40
l_{nN}, km	0,5922	0,4021

The efficiency was evaluated on the basis of the distribution network schema presented in Fig.1. The diagram includes all the voltage levels at which electrical energy is distributed by a company, i.e. 110 kV, medium-, and low voltage.

The analysis of the data from Table 1 leads to the conclusion that the development of the distribution network proceeds in the right direction. This conclusion is supported by the fact that the average line lengths will be shortened between 2007 and 2015, for all the voltage levels. The shortenings, marked "δ", are indexed for the voltage level they refer to.

Evaluating the two states, the efficiency indicators were determined for the logistic electrical energy distribution system. The distribution network supplies energy to consumers at the level of 110 kV – type Z_A consumers, medium voltage – type Z_B consumers, and low voltage - type Z_C consumers.

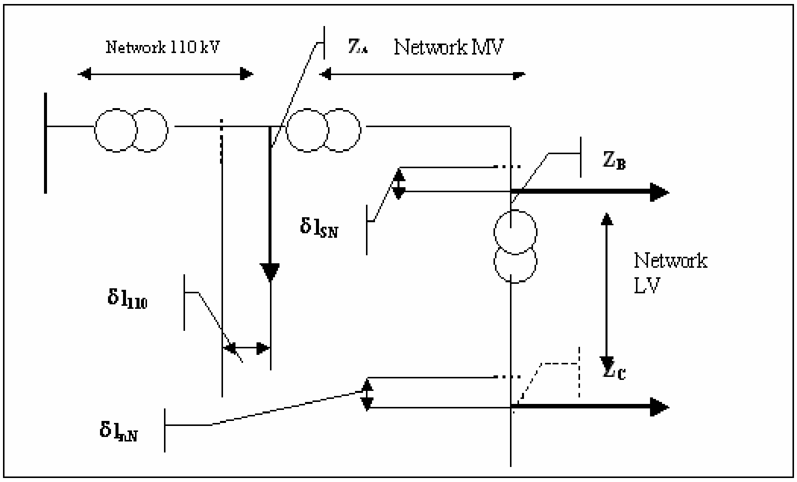

Figure 1 Diagram of the model distribution network
Source: Prepared by the author

As evident from Table 1, the shortening of distribution lines will affect all the networks. The data from the table were used for creating the following quantitative structural indicators for the improvement in the logistic distribution system of electrical energy:

- absolute indicator of improvement in the logistic distribution system

$$W_{esldee} = \delta_{110} + \delta_{SN} + \delta_{nN} \tag{10}$$

where

δ_{110} is the difference in the length of 110 kV lines between the year 2015 and 2007,

δ_{SN} is the difference in the length of medium-voltage lines between the year 2015 and 2000,

δ_{nN} is the difference in the length of low-voltage lines between the year 2015 and 2000.

- relative indicator of improvement in the logistic distribution system

$$w_{esldee} = \frac{W_{esldee}}{l_{110_{sw}} + l_{SN_{sw}} + l_{nN_{sw}}} \tag{11}$$

where

$l_{110_{sw}}$ is the average length of the 110 kV lines for the initial state (the year 2007),

$l_{SN_{sw}}$ is the average length of the medium-voltage lines for the initial state,

$l_{nN_{sw}}$ is the average length of the low-voltage lines for the initial state.

- partial relative indicator of improvement in the logistic distribution system for the 110 kV network

$$w_{esldee_{110}} = \frac{\delta_{110}}{l_{110_{sw}}} \tag{12}$$

- partial relative indicator of improvement in the logistic distribution system for the medium-voltage network

$$w_{esldee_{SN}} = \frac{\delta_{SN}}{l_{SN_{sw}}} \tag{13}$$

- partial relative indicator of improvement in the logistic distribution system for the low-voltage network,

$$w_{esldee_{nN}} = \frac{\delta_{nN}}{l_{nN_{sw}}} \tag{14}$$

At the initial stage of the analysis (the year 2007), the consumers fed from the 110 kV network are arranged along the line path. On average, the distance from the 110 kV network feed point, i.e. the length of line feeding a 110 kV consumer is $l_{dlzee_{110}}$ = 85,86 km. The medium- and low-voltage networks are fed from the 110 kV network in the cascade-radial manner, so the maximal length of energy flows for these network are

- medium-voltage network

$$l_{dlzee_{SN}} = l_{110} + l_{SN} \tag{15}$$

where

$l_{dlzee_{SN}}$ is the length of line supplying energy to a medium-voltage consumer.

- low-voltage network

$$l_{dlzee_{nN}} = l_{110} + l_{SN} + l_{nN} \tag{16}$$

where

$l_{dlzee_{nN}}$ is the length of line supplying energy to a low-voltage consumer.

Below, the values of so determined characteristics are given for the two states of the analysis:

2007	**2015**
$l_{dlzee_{110}}$ = 85,86 km	$l_{dlzee_{110}}$ = 73,03 km
$l_{dlzee_{SN}}$ = 107,72 km	$l_{dlzee_{SN}}$ = 91,43km
$l_{dlzee_{nN}}$ = 108,3112 km	$l_{dlzee_{nN}}$ = 91,8321 km

The values of indicators defined in formulas 10 ÷ 14 are as follows:

W_{esldee} = 16,4791 km

$w_{esldee_{110}}$ = 0,149 w_{esldee} = 0,152 $w_{esldee_{SN}}$ = 0,158 $w_{esldee_{nN}}$ = 0,312

Conclusion

The projected changes in the structure of the distribution network, which were evaluated from the logistic viewpoint by means of the efficiency indicators for electrical energy distribution, are going to affect the low-voltage networks, i.e. the network serving the most consumers, to the greatest extent. The changes will lead to the improvement in the conditions of electrical energy supply.

The above-mentioned indicators could be supplemented with additional comparative analysis, which would be significant from the consumer's viewpoint. The most reliable evaluation of the customer services, reflecting the customer's satisfaction from the company's operation is provided by qualitative indicators.

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