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ANALYSIS OF THE ELECTRIC POWER DISTRIBUTION SYSTEMS ON THE RURAL AREAS OF CENTRAL POLAND

Małgorzata Trojanowska*

Department of the Power Industry and Automation of Agricultural Processes
University of Agriculture in Kraków
*Contact details: ul. Balicka 116B, 30-149 Kraków, e-mail: malgorzata.trojanowska@ur.krakow.pl

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ABSTRACT

Dynamics of the quantity and quality changes of the rural electric power distribution systems compared to the urban systems was analysed. It was found out that in 2006-2011 at the 18% growth of electric energy consumption by rural households approx. 0.5% development of the distribution systems, through which these households are supplied with electric power, was reported. Nonetheless, values of indicators which characterize the quality of supply of recipients have not deteriorated. The degree of use of the line capacity is still low. The issue, from the point of view of the electric power system capacity, are small fragments of overloaded distribution networks, improvement of which is first of all justified by the intensification of existing networks capacity, not by development.

Introduction

In the document by the Ministry of Economics *Energy policy of Poland to 2030* (2009) attention is paid to the necessity of development of the electric power systems in order to improve reliability of their operation, thus certainty of supplying recipients with electric energy. Reliable supplies of electric energy to recipients require a correctly operating electric power system with sufficient capacity and a satisfactory technical condition.

Along with a systematic increase of demand for electric energy and development of dispersed sources, particularly the wind power industry, there is a need to increase the capacity of supplying lines. The necessity of improving the technical condition of the electric power systems follows also from their age, which results not only in the unsatisfactory quality of supply but also excessive network losses. Thus, ensuring an efficient electric power system requires modernization of the existing network systems and construction of new network elements. In order to plan these undertakings, systematic analyses of sizes, which characterize network qualities, particularly their changes in time, are necessary. In the subject literature, there are many works on this scope (Kulczycki et al., 2009; Maciejewski, 2011; Marzecki, 2005; Niewiedział and Niewiedział, 2012; Strożek, 2009; Trojanowska, 2008, 2009). Mainly they concern the whole country or a region. Today, however, the local power industry determines planning trends. Territorial self-governments and distribution enterprises are responsible for supply in electric energy on the local level (Journal of Laws No. 54, 1997).

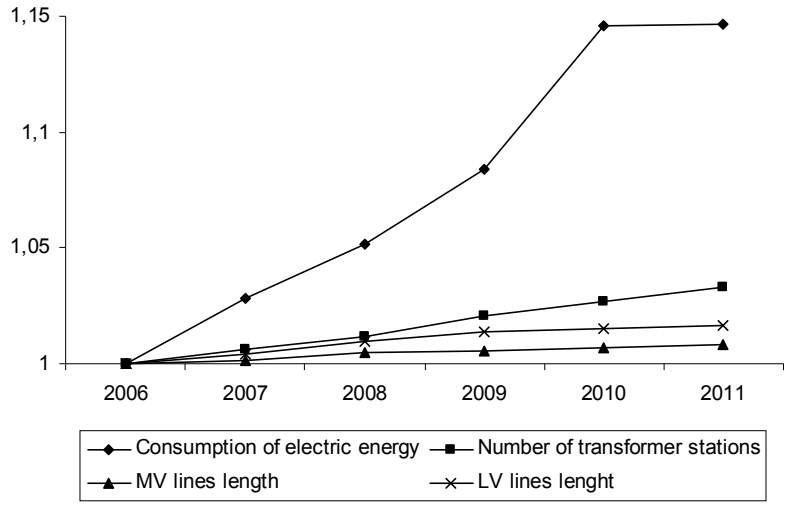
The objective, scope and object of the paper

The objective of the paper was the analysis of development of distribution networks through which rural households are supplied with electric energy, in particular the quantity and quality analysis of these networks. To execute the objective of the paper, dynamics of the electric power infrastructure and indicators, the most frequently used in power industry for assessment of networks' condition, were researched and the description of networks on rural areas was compared to the description of urban networks. The objective of the paper was executed on the example of the rural networks from central Poland located in the region of electric power operation of one distribution enterprise. These networks consist in more than 3,600 km of MV lines, 5,200 km of LV lines and 2,600 of MV/LV power transformer stations.

Research results

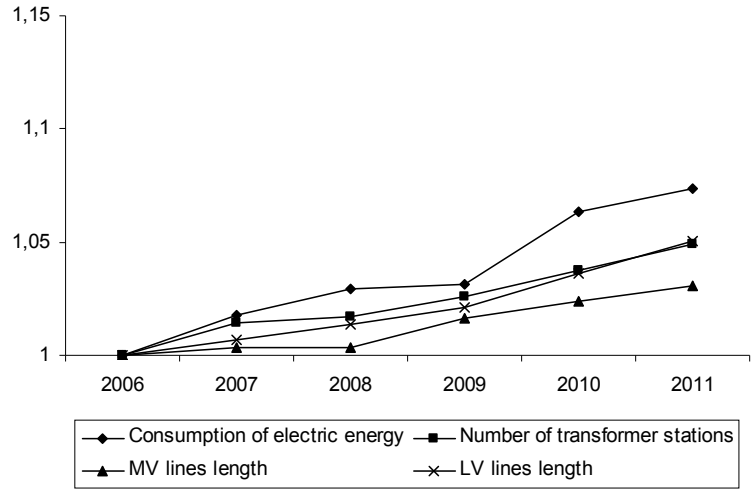
The quantity analysis of the system

Development of electric power networks should be connected with inter alia changes of recipients' demands for electric energy. Figure 1 presents dynamics of changes of electric energy consumption by households on the investigated rural area within 5 years compared to the dynamics of quantity changes of MV and LV lines and the power transformers stations of MV/LV through which these households are supplied with energy. Analogous courses, but referred to the cities were presented in figure 2.



Source: author's own calculations based on data of a distribution company

Figure 1. Dynamics of electric energy consumption by households and development of electric power infrastructure on rural areas



Source: author's own calculations based on data of a distribution company

Figure 2. Dynamics of electric energy consumption by households and development of electric power infrastructure in cities

One may notice that in the analysed period of time dynamics of changes in consumption of electric energy by rural households was considerably higher than in urban households. Annual average increase of this consumption shaped on the level of 3.6% and 1.1% respectively in the country and in the city. Such great increase in the demand for electric energy of rural households results mainly from moving citizens of big agglomerations' to the country. Moreover, rural households consume per one recipient at the average 2.4 MWh of electric energy, i.e. approx. 10% more than the households in cities. Accompanying development of infrastructure was considerably lower in the country than in the city. Therefore, in the investigated period average annual increase of the number of power transformers stations and the MV and LV lines lengths were for rural areas respectively 0.65%, 0.17% and 0.33% whereas for cities – 0.99%, 0.62% and 1.01%.

This tendency does not concern only the recent years. As a result, participation of rural system in the entire system decreases systematically, but in a small degree, which presently for the MV line is 72%, for the LV line – 67% and for the power transformer stations of MV/LV – 73%. At a more dynamic increase of energy consumption than in case of rural electric power infrastructure, profitability of investing in local distribution networks rises. We can only wonder what impact such situation has on their quality.

Analysis of the system quality

Indicators, which directly or indirectly describe the quality of the supplied energy, in particular the supply voltage, are the best for assessment of the quality of networks.

Value of voltages at the ends of power lines depends on their length, cross section and indirectly from the use of admissible load. It is considered that in order to ensure the re-

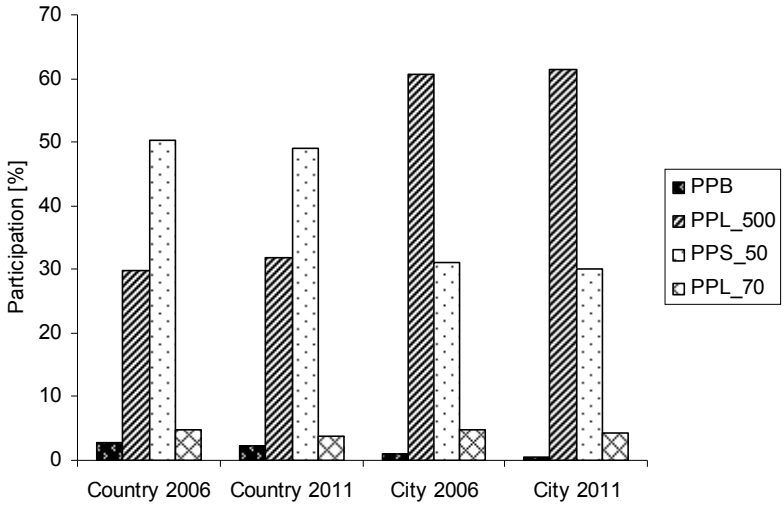
quired level of voltage at the end of the MV power lines, the total length of supply lines from one field of main switching station should not exceed 50 km.

On the investigated rural areas, participation of the MV power lines with the length exceeding 50 km on the rural areas is 10.6% and in the cities 0.4% and it has not changed for years. Many circuits of medium voltage have small cross sections of conduits i.e. bigger than 35 mm^2. In the country they amount to 63% and in the cities to 43% of all MV circuits.

On account of the lines capacity in the country and in the city, situation is similar and participation of circuits with the capacity higher than 50% (but lower than 80%) shapes at the level of 0.07.

For assessment of the quality of low voltage networks, distribution companies use the following indexes:

– percentage participation of the LV circuits with the phase voltage above the rated voltage (Uzn), within the norm, within the scope from Uzn – 10% to Uzn – 20%, below Uzn – 20%,
– percentage participation of circuits with the length below 500 m, from 500 to 1000 m, above 1000 m.
– percentage participation of circuits of the cross section of conduits below 25 mm^2, 35 mm^2, 50 mm^2, 70 mm^2, above 70 mm^2,
– percentage participation of circuits with the use of the line capacity above 90%, from 70 to 89%, from 50 to 69%, to 49%.



Source: author's own calculations based on data of a distribution company

Figure 3. Indexes describing quality of low voltage network in the country and in the city, where: PPB – participation of LV circuits of inadmissible voltage, PPL_500 – participation of LV circuits of the length below 500 m, PPS_50 – participation of LV circuits of the cross-section of conduits below 50 mm^2, PPL_70 – participation of LV circuits of the admissible capacity use degree above 70%

Although, these are recognized values, not all are equally important, and thus useful for assessment of the network quality. According to the research carried out by Trojanowska and Nęcka (2010) to such sizes one should include: participation of LV circuits of inadmissible voltage (PPB) i.e. exceeding ±10% rated voltage Uzn, of the length below 500 m (PPL_500) and the cross-section of conduits below 50 mm^2 (PPS_50) and the circuits of the admissible capacity use degree above 70% (PPL_70). The research was limited only to the analysis of these indexes. Calculations results were presented in figure 3.

As it can be seen in the analysed period, indicators characterizing the quality of the low voltage network have not changed a lot and the quality of rural networks was and is slightly worse than the urban ones. On the rural areas participation of the LV circuits, where voltages inadmissible by provisions occur, reaches 2, 3% locally decreasing below the rated value even by more than 20%. In the cities this phenomenon is marginal. Such state of affairs is influenced by, inter alia, the length of circuits and their cross-sections. In the country approx. 70% of circuits is longer than 500 m and 50% of circuits has cross-sections not bigger than 35 mm^2. The capacity of rural and urban networks is similar. Majority of lines is overloaded to a small extent. However, there are fragments, where overloads occur, which result in limitation of transmitting capacities of networks.

Conclusion

There is a constant need to increase the network capacity on account of development of the dispersed power industry especially the wind power industry. In present realities, however, it seems that instead of expensive and risky development of the electric power systems, first of all, the use of transmission capacities of the existing networks should be intensified. The easiest possibility to increase the overhead line capacity is to increase border working temperature of conduits, which should be accompanied by regulation of the power line sag. Furthermore, the analysis should be carried out to find out whether assumed exploitation times of basic elements of a network, after which they should be replaced, are not too short.

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ANALIZA ROZWOJU ELEKTROENERGETYCZNYCH SIECI ROZDZIELCZYCH NA TERENACH WIEJSKICH POLSKI CENTRALNEJ

Streszczenie. Przeanalizowano dynamikę zmian ilościowych i jakościowych wiejskich sieci elektroenergetycznych na tle sieci miejskich. Stwierdzono, że w latach 2006-2011 przy 18% wzroście zużycia energii elektrycznej przez gospodarstwa wiejskie nastąpił ok. 0,5% rozwój sieci, za pośrednictwem których gospodarstwa te zasilane są w energię elektryczną. Pomimo tego wartości wskaźników charakteryzujących jakość zasilania odbiorców nie uległy pogorszeniu. Stopień wykorzystania przepustowości linii jest w dalszym ciągu nieduży. Problemem z punktu widzenia przepustowości systemu elektroenergetycznego są niewielkie odcinki przeciążonych sieci rozdzielczych, których poprawę stanu upatruje się w pierwszej kolejności nie w rozwoju, a w intensyfikacji przepustowości sieci istniejących.

Słowa kluczowe: elektroenergetyczne sieci rozdzielcze, jakość energii elektrycznej