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DISTRIBUTION OF POWER LOSSES IN ELECTRICAL TRANSMISSION NETWORKS BETWEEN ELECTRICITY GENERATING AND DISTRIBUTION COMPANIES

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Abstract

This article examines the issue of power loss distribution in the process of electric power transmission between electric power producers and distribution organizations based on the currents flowing from the elements of the electric grid.

Keywords

electric power, investments, protection mechanisms, power losses, stations.

Аннотация

В данной статье рассматривается вопрос распределения потерь мощности в процессе передачи электроэнергии между производителями электроэнергии и распределительными организациями на основе токов, текущих от элементов электрической сети.

Ключевые слова

электроэнергия, инвестиции, механизмы защиты, потери мощности, станции.

In recent years, large-scale reforms have been implemented to accelerate the development of all sectors of the economy, enhance investment attractiveness, create favorable conditions for increasing business activity among the population, expand production and service sectors, and improve the social sphere and the standard of living of citizens.

To create favorable conditions for the development of a healthy competitive environment in the energy sector, increase the inflow of foreign and private investments, and establish wholesale and retail electricity markets based on free and transparent pricing mechanisms, activities are being carried out to establish a liberalized electricity market for the period 2023–2030.

The above-mentioned reforms provide for the following:

a) A gradual transition to wholesale and retail electricity market mechanisms for 2023–2030 based on the following approaches:

- Gradual formation of competitive wholesale and retail electricity markets;
- Increasing the investment attractiveness of the electric power industry and creating conditions for broader participation of the private sector in the industry;
- Ensuring the continuity and reliability of electricity supply and improving the quality of services provided to consumers;
- Introducing social protection mechanisms in the determination of electricity tariffs for the population and ensuring that electricity is sold to households throughout all regions of the Republic under a unified pricing policy by 2035;
- Granting households and business entities the right to freely choose their electricity suppliers.
- Ensuring that electricity prices in the wholesale market are freely determined based on supply and demand, introducing day-ahead trading, and conducting all purchase and sale transactions through an online trading platform;
- Expanding the scale of "green energy" production through the extensive utilization of renewable energy sources;

b) In accordance with the Roadmap for the implementation of the Concept for the gradual transition to wholesale and retail electricity market mechanisms for 2023–2030 during 2023–2024:

- The transition from one stage to the next in the formation of competitive wholesale and retail electricity market mechanisms shall be carried out only after the conditions specified in the Concept for the gradual transition to wholesale and retail electricity market mechanisms for 2023–2030 have been fully satisfied;
- Beginning in 2024, the Cabinet of Ministers shall develop, by December 1 of each year, a program of practical measures for implementing the Concept for the gradual transition to wholesale and retail electricity market mechanisms for 2023–2030 for the following year.

The above-mentioned reforms require the scientific and technical resolution of a number of issues. This article addresses the problems of allocating power losses in electrical networks during electricity transmission between generating and distribution companies, as well as the allocation of associated costs in the organization of wholesale and retail electricity markets.

To determine tariffs for transit services, the transit operator must conduct a technical analysis to assess the degree of impact that electricity transit has on its power system. First, possible routes for electricity flow throughout the network are analyzed. Furthermore, experience shows that it is necessary to study the network elements involved in providing transit services and the characteristics of the required services.

The transmission capacity available for providing transit services varies among different power systems and may also differ at various points within the same system. Unused transmission capacity in a system may be suitable for a particular transmission transaction but not for another, even when the transmitted power is the same. This is related to the physical configuration of the system, including power generation locations and dominant power flow patterns within the transmission network.

In one particular case, a transit customer may conclude a contract for transit services during a period when the available transmission capacity is at its minimum. Such a situation may require additional investments for the modernization of the transmission system. Consequently, tariff determination in this case is associated with an increase in long-term costs.

In another case, a transit customer may sign a contract for transit services during a period when sufficient transmission capacity is available. Under such circumstances, only minor modifications may be required in the future. Therefore, tariff determination may be based on incremental costs or short-term marginal costs. If there are insufficient prospects for alternative use of the transmission capacity during the service period, the transit operator may, in certain cases, provide services at a price lower than the short-term adjusted cost.

Typically, a transit operator is positioned between these two situations. Some parts of its system may have adequate transmission capacity, while other parts may require new investments, sometimes within a few years. In such cases, the basis for determining transit tariffs consists of the agreed contractual conditions, including the contract duration, the guaranteed level of service, and procedures for future tariff revisions.

Under conditions of transition to market relations in the electric power industry, one of the most important tasks is determining payments made by electricity producers to transit enterprises for the delivery of electricity from generating companies to distribution companies. The payment amount should reflect the total costs incurred by the transmission company, including the maintenance of electrical networks, dispatch control services, compensation for capacity and energy losses, and other related expenses.

The solution to these problems may be based on the share of power flows in the electrical network attributable to each individual generating company (GC) and distribution company (DC). Various methods may be proposed to determine the degree of participation of market participants, including generating companies, distribution companies, and large consumers. Agreements concluded among market participants should also be taken into account.

It is well known that the active power losses in the *i–j* transmission line are determined by the following expression:

For the transmission line *i–j*, the active power loss DP$_{ij}$ is given by the following equation:

- $\Delta P_{ij} = I_{ij}^2 R_{ij}$

Alternatively, using bus voltages and power-flow parameters, active power losses may be expressed in a more detailed form depending on the adopted power-flow model.

If you provide the next part of the text (especially the formula following this sentence), I can continue the translation while preserving the academic and journal style throughout the paper.

For a steady-state operating condition, in order to allocate power losses among distribution companies (DCs), the nodal powers of generating sources are represented as shunt injections, while the powers of nodal loads are represented in the form of current injections. The total power losses in a network element, determined using steady-state power flow analysis methods, can be expressed as follows:

Here, I$_{ijn}$- (n=1,...,nl) i-j denotes the current in branch *i–j* corresponding solely to the current injected at node *n* of the network.

By transforming Equation (2), the following expression is obtained:

$$\Delta P_{ij} = I_{ij1} R_{ij} (I_{ij1} + I_{ij2} + I_{ij3} \ldots + I_{ijn}) + I_{ij2} R_{ij} (I_{ij1} + I_{ij2} + I_{ij3} + \ldots + I_{ijn})$$
$$+ \ldots + I_{ijn} R_{ij} (I_{ij1} + I_{ij2} + I_{ij3} \ldots + I_{ijn}) = \Delta P_{ij1} + \Delta P_{ij2} + \ldots + \Delta P_{ijn},$$

where DPijn –(n=1,...,nl) n-i-jrepresents the share of the **n-th consumer** in the active power losses of the *i–j* network element.

From Equation (3), the contribution of the **k-th consumer** to the total power losses can be determined as follows:

$$\Delta P_{ijn} = I_{ijn} R_{ij} \sum_{n=1}^{k} I_{ijn}$$

The distribution of power losses between main power stations is determined in a similar manner; however, in this case, the nodal powers of generating sources are treated as current injections, while the powers of nodal loads are represented as shunt admittances.

The proposed methodology can be applied in determining tariffs for electricity transit services, as well as in the formation of tariffs for electricity supply to individual consumers.

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