Application of energy efficiency indicators in electric power distribution tariff-setting

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Abstract. To increase the energy efficiency of the Russian economics it is necessary to incentivize the reduction of consumption of energy resources by different organizations including Distribution Network Operators. The existing system of regulation of electricity distribution tariffs in the Russian Federation contains incentives for Distribution Network Operators to reduce only their electricity losses. The paper develops a method of calculating energy efficiency indicators for Distribution Network Operators and an approach to accounting these indicators in electric power distribution tariffs in case of setting tariffs using benchmarks or using the method of long-term indexation of the total required revenue. The advantage of the method suggested in the article compared to energy efficiency incentives used in different European countries and the US consists in the fact that it does not complicate tariff-setting procedures and does not require significant investments, increasing transaction costs or extensive amendments to existing legislation.

1. Introduction
Today the importance of energy saving and increasing energy efficiency is of no doubt. As it is shown in [1], reduction of electric energy losses in distribution and transmission lines in 142 countries of the world can reduce the carbon emissions for 544 million metric tons of carbon dioxide equivalents per year. Besides, Distribution Network Operators can enhance their energy efficiency by decreasing the consumption of such energy resources as thermal energy, gas, fuel and so on.

According to the Russian legislation Distribution Network Operators form energy saving programs, set targets for increasing energy efficiency and represent information about the actual amounts of energy consumption to the Ministry of Energy of the Russian Federation.

The existing system of regulation of electricity distribution tariffs in the Russian Federation provides compensation of costs on regulatory losses of electric energy. The costs on excess losses are not covered by the payments for distribution of electric energy and they are to be covered by other income of Distribution Network Operators. Thus, Distribution Network Operators are interested in reduction of their actual electricity losses to the level of regulatory losses. There are many research papers devoted to problems of calculating and reducing losses of electric energy [2-4].

But nowadays economic incentives to reducing the consumption of other energy resources (thermal energy, gas, fuel etc.) are not used in Russia. Though electric power distribution tariffs are set for a long-term period for which Distribution Network Operators may use their savings, Distribution Network Operators are not interested in reducing the consumption of energy resources because the expenses of Distribution Network Operators on energy resources seldom exceed 4% of their total
required revenue. So even if the Distribution Network Operators reduce the consumption of energy resources for 10%, the reduction of the total costs of the Distribution Network Operators is less than 0.4%. Taking into account the fact that energy saving activities usually require some investments, the total savings of the Distribution Network Operators got due to implementation of energy saving activities are in fact too little and create no incentives for the Distribution Network Operators to increase their energy efficiency.

Nevertheless, there are more than 1600 Distribution Network Operators in the Russian Federation, and even a small reduction of consumption of energy resources by each one of the Distribution Network Operators can save a great amount of energy resources across the entire country. Therefore, it is necessary to implement incentives for Distribution Network Operators for reduction of consumption of energy resources.

The paper develops a method of calculating energy efficiency indices for Distribution Network Operators and an approach to accounting these indices in setting electric power distribution tariffs which creates incentives for Distribution Network Operators for reduction of consumption of energy resources.

2. Incentives for increasing energy efficiency of Distribution Network Operators used in different countries

In most countries of the world the electric power distribution tariffs are set by regulatory organizations on basis of the amount of all the costs of Distribution Network Operators that should be covered by electricity distribution charges and adjustments that create incentives for different operation models (reduction of operational costs, attraction of investments, increasing the reliability and quality of electric energy supply etc.).

Approaches to creating energy efficiency incentives used in different European countries and the US are analysed in [5]. Among them are the following ones:

1) the duty of a Distribution Network Operator to invest a set part of its revenue in activities that increase its energy efficiency (in Brazil this part of revenue equals 1%);
2) separate accounting of expenses of Distribution Network Operators on increasing their energy efficiency (for example, California, US):
   - initially power distribution tariffs are set on a rate that covers the costs of distributing electric energy plus 1% of these costs for forming a fund for implementing energy saving activities;
   - the energy saving activities are planned and analysed with special computer tools and information systems developed by request of regulatory organizations;
   - the execution of energy saving projects is controlled by regulatory organizations;
3) the system of “White Certificates” (for example, in Italy) which are given for reduction of consumption of energy resources and can be sold or purchased in a special market [6].

The analysis of these approaches has shown that the implementation of them in Russia requires either the growth of transaction costs (because it is necessary to approve and control the execution of energy saving projects) or significant investments in creating computer tools, information systems or a whole system that allows to trade white certificates.

Today individual tariffs for Distribution Network Operators in Russia are set with the methods of regulatory asset base or long-term indexation of the total required revenue. In the latter case regulatory authorities of the regions set the sum of the total required revenue for the year \(i\) (\(TRR_i\)), which is calculated by each Distribution Network Operator on basis of the formula:

\[
TRR_i = TC + TRR_{i-2} \cdot K_{R\&Q},
\]

where \(TC\) is the sum of the total costs of the Distribution Network Operator (and Distribution Network Operators have to prove to regulatory authorities that these costs are really necessary); \(TRR_{i-2}\) is the Total Required Revenue of the Distribution Network Operator set by the regulatory authorities for the past regulatory period (year \(i-2\)); \(K_{R\&Q}\) is the coefficient which increases or decreases the rate of the Total Required Revenue according to the actual reliability and quality of the electricity supply.

Energy Service Agreements (Contracts) are used to incentivise the execution of energy efficiency
activities [7-8]. Energy Service Providers develop energy saving programs and help Distribution Network Operators to execute them. The payments to the Energy Service Providers depends on the achieved results. But in Russian practice the cost of these services is very often included in the sum of total costs of Distribution Network Operators, and the achieved results of the energy saving programs are not assessed.

It follows from the foregoing that it is necessary to develop an incentive for Distribution Network Operators to reduce the consumption of energy resources. Moreover, the implementation of this incentive should not require significant investments or extensive amendments to existing legislation.

**3. Method of calculating the energy efficiency indicators for Distribution Network Operators**

The Order of the Ministry of Energy of the Russian Federation No 401, dated June 30, 2014, sets the order of presenting information about energy efficiency of Distribution Network Operators. This information includes the data about the amounts of consumed energy resources (thermal energy, gas, fuel etc.) and their price for several years previous to the regulatory period. The information that can be used for calculating energy efficiency indicators is shown in table 1.

**Table 1**: Information presented by Distribution Network Operators to the Ministry of Energy of the Russian Federation that can be used for calculating energy efficiency indicators.

| Information about the consumed energy resources | The years previous to the regulatory period |
|------------------------------------------------|------------------------------------------|
| The output $Q$                                  | $Q_{i-5}, Q_{i-4}, Q_{i-3}, Q_{i-2}$    |
| The amount of the consumed energy resource $V_j$ ($j$ is the number of the resource in the list) | $V_{j,i-5}, V_{j,i-4}, V_{j,i-3}, V_{j,i-2}$ |
| The cost of the consumed energy resource $C_j$ ($j$ is the number of the resource in the list) | $C_{j,i-5}, C_{j,i-4}, C_{j,i-3}, C_{j,i-2}$ |
| The total cost of all the consumed energy resources $\sum_{j=1}^{n} C_j$ | $\sum_{j=1}^{n} C_{j,i-2}$ |

The energy efficiency indicator of a Distribution Network Operator $E$ depends on the efficiency of the executed energy saving activities except the reduction of electricity losses. This indicator is defined by the formula:

$$E = \sum_{j=1}^{n} (k_j R_j),$$

where $j$ is the number of the consumed energy resource; $n$ is the number of all the consumed energy resources; $k_j$ is the weight of the consumed energy resource number $j$; $R_j$ is the rate of change in the consumption of the energy resource $j$.

The weight of the consumed energy resource $j$ ($k_j$) is defined as the ratio of the cost of the consumed energy resource $j$ for the year $i-2$ ($C_{j,i-2}$) to the total cost of all the consumed energy resources:

$$k_j = \frac{C_{j,i-2}}{\sum_{j=1}^{n} C_{j,i-2}}. \quad (3)$$

The rate of change in the consumption of the energy resource $j$ ($R_j$) equals 1 if the actual amount of consumption ($V_{j,i-2}$) of the energy resource $j$ for the past year $i-2$ normalized to the output $Q_{i-2}$ has decreased significantly (for more than 20%) compared to the average consumption of the resource $j$ for the previous years ($i-3, i-4, i-5$) normalized to the average amount of the output for the
relevant years. That is:

\[
R_j = 1 \text{ if } 1 - \frac{V_{ij-2} \cdot (Q_{i-3} + Q_{i-4} + Q_{i-5})}{Q_{i-2} \cdot (V_{ij-3} + V_{ij-4} + V_{ij-5})} > 0.02 .
\] (4)

The rate of change in the consumption of the energy resource \( j \) (\( R_j \)) equals 0 if the actual amount of consumption \( (V_{ij}) \) of the energy resource \( j \) for the past year \( i-2 \) normalized to the output \( Q_{i-2} \) has not decreased significantly (for less than 20%) compared to the average consumption of the resource \( j \) for the previous years \((i-3, i-4, i-5)\) normalized to the average amount of the output for the relevant years. That is:

\[
R_j = 0 \text{ if } 0 \leq 1 - \frac{V_{ij-2} \cdot (Q_{i-3} + Q_{i-4} + Q_{i-5})}{Q_{i-2} \cdot (V_{ij-3} + V_{ij-4} + V_{ij-5})} \leq 0.02 .
\] (5)

The rate of change in the consumption of the energy resource \( j \) (\( R_j \)) equals \((-1)\) if the actual amount of consumption \( (V_{ij}) \) of the energy resource \( j \) for the past year \( i-2 \) normalized to the output \( Q_{i-2} \) has increased compared to the average consumption of the resource \( j \) for the previous years \((i-3, i-4, i-5)\) normalized to the average amount of the output for the relevant years. That is:

\[
R_j = -1 \text{ if } 1 - \frac{V_{ij-2} \cdot (Q_{i-3} + Q_{i-4} + Q_{i-5})}{Q_{i-2} \cdot (V_{ij-3} + V_{ij-4} + V_{ij-5})} < 0 .
\] (6)

4. Method of accounting energy efficiency indicators in electric power distribution tariffs

Individual tariffs for Distribution Network Operators in Russia are set by regulatory authorities based on the total required revenue, the connected load and the output of electric energy.

To incentivize energy saving by Distribution Network Operators when tariffs are set with the method of long-term indexation of the total required revenue, it is suggested to supplement the formula (1) with a term that adjusts the total required revenue depending on the actual consumption of the energy resources \( K_E \):

\[
TRR_i = TC + TRR_{i-2} \cdot K_{RQ} + TRR_{i-2} \cdot K_E.
\] (7)

The coefficient \( K_E \) adjusts the total required revenue of a Distribution Network Operator depending on the results of the energy saving activities except the reduction of the electric energy losses. It is suggested to calculate this coefficient as follows:

\[
K_E = k_{\text{max}} \cdot E,
\] (8)

where \( k_{\text{max}} \) is the maximum rate of adjustment; \( E \) is the energy efficiency indicator, calculated by the formula (2).

The analysis of expenses of the Distribution Network Operators in the central region of Russia has shown that their expenses on energy resources vary from 0.4% to 5% of the total required revenues.

The individual tariffs for Distribution Network Operators depend on the total required revenues. Thus the change of the total required revenues results in the change of electric power distribution tariffs. Though Distribution Network Operators are commonly qualified as natural monopolies the analysis of the elasticity of demand on electric energy [9-10] shows that growth of tariffs on electric energy for 1% results in reduction of energy consumption for 1-1.5%, wherein 0.5% is the reduction of the energy consumption by the population and 1.2% is reduction of the energy consumption by the industry (of which 0.4-0.55% is the reduction of the electrical intensity of the industry and 0.3-0.7% is the reduction of the economic activity). Therefore, the maximum rate of adjustment of the total required revenue should be set taking into account the desirable consumer behaviour model depending on the aims of the public policy.

Application of the energy efficiency accounting methods suggested in the paper is also possible when electric power distribution tariffs are set with benchmarking [11]. In this case the total required revenue is calculated as the sum of expenses that are defined on basis of benchmarking and the adjustments depending on the reliability and quality of electricity supply and the efficiency of energy
saving activities.

5. Implementation of accounting energy efficiency indicators in electric power distribution tariffs

The method of calculating the energy efficiency indicators for Distribution Network Operators developed in the paper is based on the data that Distribution Network Operators present to the Ministry of Energy of the Russian Federation. Thus, it is not necessary to collect any additional information and to create new databases. However, the forms set by the Order of the Ministry of Energy of the Russian Federation No 401, dated June 30, 2014, are filled manually and may contain some mistakes.

Meanwhile the transfer to the digital economy is being carried out and many processes are being automated. Smart meters allow to collect, analyze and transmit data (including information about the consumed thermal energy and gas) automatically. According to the Federal Law No. 223-FZ, dated 18.07.2011, state information systems contain information about all the purchases of Distribution Network Operators (including the purchase of fuel and lubricants). This information can be transmitted to other systems through the system of interagency collaboration.

In view of the above, the process of accounting energy efficiency indicators in electric power distribution tariffs can be automated on basis of accurate and reliable data. Figure 1 shows the structure of information flows of an automated process of calculating the energy efficiency adjustments.

Figure 1. The structure of information flows for an automated rapid accounting of the adjustments of the total required revenue.

6. Conclusion

The methods of calculating and accounting energy efficiency indicators for Distribution Network Operators suggested in the paper incentivizes the reduction of consumption of energy resources (such as thermal energy, gas, fuel and lubricants). The implementation of these methods does not complicate tariff-setting procedures and does not require significant investments, increasing transaction costs or extensive amendments to existing legislation.

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