Quality management of electric energy and compensation of reactive power in the electric power system by means of stimulating tariffs

Vladislav Chikin[1,*], *Anatoly* Kuznetsov [1], and *Diana* Rebrovskaya[1]

[1]Ulyanovsk State Technical University, 32, Severny Venetz str., 432027 Ulyanovsk, Russia

Abstract. The article noted that feed-in tariffs are effective enough to attract consumers to participate in the process of improving power quality and reactive power compensation. It is shown that the application of premiums and discounts must not modify the revenues of the budget of ESO. Otherwise there is a contradiction to the principles of state regulation of tariffs for services of natural monopolies. In this case, legal barriers do not allow to use the model in practice. The proposed criteria that must be considered in the development and approval of the scale of discounts and allowances to ensure the legal purity of the incentive rate, to avoid its cancellation, as it was in 2000. Then, the proposed mechanism of discounts and allowances with the support of the Antimonopoly service and the Ministry of justice of the Russian Federation was cancelled as violating the principles of state regulation of tariffs in the conditions of the natural monopoly position of the network organization.

1 Introduction

Stimulating tariffs are widely used in world practice to attract electricity consumers to participate in the process of improving the quality of electricity and compensating for reactive power. The incentive rate C_{stim} for the consumer is the sum of the main C_{bas} and incentive part. The main part is the same for all consumers of the electric grid organization, receiving power at the same voltage level, and includes the average costs associated with the production and transmission of electricity [1].

The stimulating part is not the same for all consumers, it represents a fee for the distortion of power quality indicators (PKE) or for violation of the mode of reactive power consumption and is formed by surcharges and discounts to the main part of the tariff [2,3].

2 Relevance, scientific significance

For certain values of the incentive part of the tariff ΔC_{ND}, the installation and operation of technical means improving the quality of electric power and improving the mode of consumption of reactive power in a customer's network can be beneficial and stimulated to actions aimed at their use [4]. Unfortunately, the application of incentive tariffs is currently facing legal barriers. Attempts to introduce incentive tariffs in the form of discounts and surcharges fail. The lack of scientific knowledge and approaches for making organizational decisions currently does not allow the use of incentive tariffs.

3 Formulation of the problem

Despite the saturation of the market, stimulating tariffs are not acquired by technical means and are not used by electricity consumers. The quality of electrical energy (QE) remains low. The damage from low QE in Russia is estimated at a minimum of about $ 25 billion per year [5]. Reactive power flows are increasing. Nevertheless, the need to develop and implement a scale of discounts and allowances in the Russian Federation are actively discussed in the technical literature [6]. The development of a scale of discounts and allowances is associated with the need to formulate requirements, conditions and restrictions that should remove the legal barriers to their use in practice. Without this, it is not possible to interest consumers in the use of technical means of improving the quality of electricity and compensation of reactive power.

4 Theoretical part

The mathematical expression for the incentive tariff in the case of the use of allowances ΔC_{ND} in one form of the record has the form

Equations should be centred and should be numbered with the number on the right-hand side.

$$C_{stim} = C_{bas} + \Delta C_{ND} \quad (1)$$

Or in another form

* Corresponding author: chikin_vladislav@mail.ru

$$C_{stim} = C_{bas}\left(1+\frac{\Delta C_{ND}}{C_{bas}}\right) \quad (2)$$

At the same time ($1+ \Delta C_{ND}/C_{bas}$) a can be called a raising factor to the tariff.

If a discount ΔC_{CK} is applied to a consumer, then the expressions for the incentive tariff take the form:

$$C_{stim} = C_{bas} - \Delta C_{CK} \quad (3)$$

or:

$$C_{stim} = C_{bas}\left(1-\frac{\Delta C_{CK}}{C_{bas}}\right) \quad (4)$$

where ($1- \Delta C_{ND}/C_{bas}$) can be called a reduction factor.

The effectiveness of the incentive tariff should be considered on the model. To this end, it is proposed to consider the incentive tariff model, which consists of three interrelated elements. One of them is the energy supplying organization (ESO). The second is a consumer with a load that distorts the power quality indicator or a consumer that violates the mode of consumption of reactive power. We call this consumer culprit violation of electricity consumption (CVC). The third element is a consumer who is forced to perceive the consequences of a violation of the mode of electricity consumption by a consumer CVC. Consequences may be associated with low power quality, limited ability to increase power consumption due to network load reactive power, which limits the bandwidth of the supply network and so on. Using legal terminology we will call this consumer "victim" (PVS). The consumer of the VC seems to be a kind of equivalent generalized consumer, which unites all the consumers of the network organization except the consumer CVC.

It is obvious that there are a lot of parameters of the mode of electricity consumption, which may not meet the established requirements. Among them are PKE, indicators of consumption of reactive power and energy. In the model, the consumer CVC is considered as a violator of one of the parameters of the mode of electricity consumption. If the violation of the mode of power consumption occurs by several parameters, it is necessary to consider the model for each of these parameters separately. Suppose this parameter is non-sinusoidal [7, 8].

In this case, CVC violates the requirements for the PKE not only in its network, but also in the network of the energy supplying organization, which, due to circumstances beyond its control, has to supply poor quality electricity to the consumer VS. This consumer is harmed. The incentive tariff model assumes a formalized way of compensating for damage to a consumer PVS as the culprit for the distortion of the PKE - the consumer CVC, but not directly, indirectly through the ECO. Damages occur in two stages.

At the first stage, the damage to the consumer CVC will compensate the ECO in the form of a discount to the tariff. At the same time, the income of the ECO will be reduced, which it could have received if it were not a consumer CVC, distorting the PKE in the network of the energy supplying organization. From a legal point of view, the right of the ECO to supply high-quality electricity to the consumer of the CVC is violated. As a result, the energy supplying organization does not receive a portion of the income that it could receive under normal conditions of civilian traffic. Lost are referred to as lost profits incomes in accordance with Art. 15, p. 2 of the Civil Code of the Russian Federation. The loss of profit for the ECO is measured by the amount of compensation for damage ΔC_{CK} to the consumer PVS.

At the second stage, the consumer CVC compensates to the ECO the lost profit in the amount of the damage paid to the consumer VS. Consumer CVC provides a premium to the tariff ΔC_{ND}. The energy supplying organization at the same time compensates for its expenses for indemnification of damage to the PVS. The premium ΔCND is presented as a formalized way to compensate for the loss of benefits to the ECO on the one hand, and as compensation for damage to the consumer VS on the other hand. The role of the energy supplying organization in this model is to pay damages ΔC_{CK} to the consumer of the PVS and recover damages ΔC_{ND} from the consumer CVC in the form of the loss of profit resulting from this.

The model assumes the participation of the energy supplying organization in the process of collecting and paying for damage, although this activity is not the main activity for it. Nevertheless, the supply of poor-quality electricity to the consumer PVS for the energy supplying organization affects its interests. She is forced to supply poor quality electricity and is responsible for this.

It is obvious that the model provides for the responsibility of the offender in the form of a surcharge to the tariff and implies the inevitability of its application. The premium is a stimulating factor. It has quite a strong influence on the consumer in terms of the installation of compensating and filter-compensating devices (FCD). Without it, it is hardly possible to influence the consumer's decision to install and operate such devices.

5 Research results, practical significance

Successful operation of the model is possible only under certain conditions and requirements. The requirements relate to the correctness of the application of discounts and surcharges by the state regulatory authority in case of formalized compensation to the consumer PVS at the expense of the consumer CVC. The discount is a refund. Surcharge is for lost profits. Discounts and allowances, one way or another, change the income part of the ECO budget. When using discounts, the revenue side decreases. When applying allowances, the revenue side increases. In this case, it is necessary to provide guarantees to the energy supplying organization not to have difficulties associated with the main activity and to keep the budget revenues unchanged, due to the basic component of the incentive tariff C_{bas}. Prevent its

unjustified reduction, on the one hand, and increase, on the other.

This requirement is dictated by the principle of state regulation of tariffs for the services of natural monopolies. Revenues of the network organization as a natural monopoly should be economically justified. The tariff for the transmission of electricity, included in the main, basic part C_{bas} of the incentive tariff, is subject to state regulation and approved by government bodies. This is the Federal and Regional Tariff Service (FST and RST). When using the incentive part, the change in income of the ECO is unacceptable. Otherwise, a legal inconsistency arises.

The latter is quite possible in the conditions of market relations, when officials who make decisions about the size of discounts and premiums do not have clear and definite criteria for assessing decisions made. They must ensure the accuracy and transparency of information about the absence of additional income from the network organization. Incomes in excess of revenues due to the approved tariff for transmission of electricity. In this case, consumers will not have distrust and doubts about the fairness of the use of allowances. They will be ready to accept and maintain the mechanism for applying discounts and surcharges.

This criterion decisions can be the criterion of economic feasibility of the revenue of the ECO, which was first proposed in [9].

For the model, it represents

$$k_{ECO} = 1 + \frac{D^*_{ECO} + \Delta C_{ND} - \Delta C_{CK} - D^*_{ECO}}{D^*_{ECO}} \quad \to 1 \qquad (5)$$

where D^*_{ECO} - the value of the income of the ECO related to the supply of electricity to consumers CVC and VS, which is formed by charging fees associated with the supply of electricity without discounts and premiums; ΔC_{ND} and ΔC_{CK} - the value of the allowance to the consumer CVC and the amount of the discount to the consumer PVS.

In general case ΔC_{CK} in this model represents

$$\Delta C_{CK} = \frac{\sum_{i=1}^{n-1} \left(\Delta C_{CK,i} \cdot W_{\text{PVS},\,i} \right)}{W_{\text{PVS}}} \qquad (6)$$

where $\Delta C_{CK,j}$ - the discount for everyone i-consumer in the ECO except the culprit; $W_{PVS,i}$ - electricity consumed by each consumer in an ECO, except for the culprit; n - the number of consumers in an ECO; W_{PVS} - electricity consumed by the equivalent consumer PVS.

$$W_{\text{PVS}} = \sum_{i=1}^{n-1} W_{\text{PVS},\,i} \qquad (7)$$

When k_{ECO}=1, the income of the energy supplying organization does not depend on the application of discounts and surcharges. The principle of economic feasibility of income is not violated.

The criterion for evaluating the decision made (5) implies the interdependence of the amount of the allowance and the discount. For example, if a surcharge is defined, the discount cannot be selected without considering its value. The communication between their values is as follows.

$$\Delta C_{ND} W_{\text{CVC}} = \Delta C_{CK} W_{\text{PVS}} \qquad (8)$$

where W_{CVC} - electricity is consumed by the CVC.

$$\frac{\Delta C_{ND}}{\Delta C_{CK}} = \frac{W_{\text{PVS}}}{W_{\text{CVC}}} \qquad (9)$$

If take

$$W_{\text{ECO}} = W_{\text{CVC}} + W_{\text{PVS}} \qquad (10)$$

$$W^*_{\text{CVC}} = \frac{W_{\text{CVC}}}{W_{\text{ECO}}} \qquad (11)$$

$$W^*_{\text{PVS}} = \frac{W_{\text{ECO}} - W_{\text{CVC}}}{W_{\text{ECO}}} = 1 - \frac{W_{\text{CVC}}}{W_{\text{ECO}}} = 1 - W^*_{\text{CVC}} \qquad (12)$$

Condition (8) translates to

$$\frac{\Delta C_{ND}}{\Delta C_{CK}} = \frac{1 - W^*_{\text{CVC}}}{W^*_{\text{CVC}}} \qquad (13)$$

or

$$\Delta C_{ND} = \Delta C_{CK} \left(\frac{1 - W^*_{\text{CVC}}}{W^*_{\text{CVC}}} \right) = \Delta C_{CK} \left(\frac{1}{W^*_{\text{CVC}}} - 1 \right) \qquad (14)$$

In expressions (8) - (14): W_{ECO} - electricity consumed by all consumers ECO; W^*_{CVC} - represents the proportion of electricity consumption by the consumer of security products; W^*_{PSV} - represents the share of electricity consumption by the consumer PVS.

6 Conclusion

Condition (14) must be considered when developing and approving a scale of discounts and premiums. If this is not done, legal barriers arise that will not allow the mechanism to be used to control the quality of electricity and the process of compensation and reactive power.

An attempt to introduce a stimulating tariff model at the state level took place [2, 3]. However, she failed. The implemented mechanism for applying discounts and surcharges caused great resistance from consumers, and with the support of the Anti-monopoly Service and the Ministry of Justice of the Russian Federation was canceled as violating the principles of state regulation of tariffs in the context of the natural monopoly position of the grid organization [10].

Acknowledgements

The study was carried out with the financial support of the Russian Foundation for Basic Research and the Ulyanovsk Region in the framework of the research project № 18-48-730025.

References

[1] A.V. Kuznetsov, The use of incentive tariffs to improve the quality of electricity and reduce reactive power flows in the electric power system, Elektrika **12**, 12–17 (2012)

[2] Rules for applying discounts and surcharges to tariffs for the quality of electricity, Industrial energy 8, 49–52 (1991)

[3] Rules for applying discounts and surcharges to tariffs for electric energy for the consump-tion and generation of reactive energy, Entered into force on 1 December 1997), Industrial energy **10**, 43–52 (1998)

[4] A.V. Kuznetsov, The organizational and legal aspects of the management of power con-sumption modes, Power Stations **12**, 52–56 (2003)

[5] L.A. Dobrusin, Investments in the power industry of Russia and the program of increasing their efficiency, Report, VI All-Russian Energy Forum Fuel and Energy Complex of Russia in the XXI Century, Moscow, the State Kremlin Palace (1-4 April 2008)

[6] V.E. Vorotnitsky, Energy Efficiency and Reactive Power Compensation in Electrical Net-works. Problems and solutions [Electronic resoruce], Energy Council **1**, 47 (2017). Available at: http://www.energosovet.ru/ (accessed: 21.04.19)

[7] GOST 32144-2013, Standards of quality of electric energy in general-purpose power supply systems [Electronic resource], Electronic fund of legal and regulatory and technical documentation. Available at: http://docs.cntd.ru/document/1200104301 (accessed: 25.04.19)

[8] G.Ya. Vagin, A.A. Sevostyanov, *Indicators of the quality of electricity in power supply systems: studies, Po-dobe* (Nizheoro. state Tech. Unto them. R.E. Alek-seeva, N.Novgorod, 188, 2017)

[9] A.V. Kuznetsov, L.T. Nagazinnik, *Improving the management efficiency of electrical energy consumption modes* (M.: Energoatomizdat, 105, 2006)

[10] Regarding the application of the provisions of the Instructions on the procedure for pay-ments for electric and thermal energy [Electronic resource], Electronic Fund of legal and regulatory and technical documentation. Available at: http://docs.cntd.ru/document/gost-r-7-0-5-2008 (accessed: 21.04.19)