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Evaluation Of The Economic Efficiency Of Energy Saving Measures In Rural Electrical Networks.

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ABSTRACT

This article outlines the methodological provisions for calculating the economic efficiency of energy-saving measures in a market economy. The drawbacks of the method of technical and economic calculations previously applied in the Russian Federation on reduced costs are noted. An example of modernizing the distribution network of a rural settlement is considered by replacing uninsulated wires of an overhead power line with a voltage of 0.38 kV with self-supporting insulated wires that will be used in engineering education at the university. The calculation was carried out using the system of indicators net present value, internal rate of return and dynamic payback period.
Keywords: energy saving; economic efficiency; electrical distribution networks; net present value; internal rate of return; dynamic payback period.

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INTRODUCTION

Energy saving is a state priority, determining the country's energy security. Currently, Russia is implementing the Federal Law No. 261-ФЗ dated November 3, 2009 "On Energy Saving and Improving Energy Efficiency". It defines the basic principles of energy saving policy, establishes the economic and financial mechanisms for its implementation.

Unfortunately, this law does not directly apply to the production of agricultural products. On the other hand, the interests of raising the efficiency of production require that work on energy saving be carried out systematically, constantly and in all areas of economic activity of enterprises of the agro-industrial complex.

Rural electric grids are notable for their considerable length, radial construction principle, high dispersion on the ground, low load density, which predetermines a significant level of electric power losses at such facilities. According to the data available in technical literature, electrical energy losses in power lines with a voltage of 0.38–10 kV are up to 33%, and taking into account losses in transformers of consumer transformer substations, they reach 50% of the total network losses [1].

The level of electric power losses in rural electrical networks reflects their technical condition and level of operation of power grid equipment, the state of the metering system and metrological support of metering devices, and the efficiency of energy-saving measures.

The implementation of energy saving measures requires investment. If there are several alternative options for such activities, it is necessary to conduct their comparative technical and economic assessment.

It should be noted that with the transition of Russia to market relations, the methodology for assessing the economic efficiency of investments used in the USSR is outdated. The disadvantage of the previous method is mainly in the criterion of choosing the best option, which was used as the reduced costs, in the existing realities such is profit. In addition, the previously used approach is incorrect to use for projects, as a result of the introduction of which the quality of manufactured products changes for the better, as a result of increased production and sales costs through the use of innovative materials, the use of highly skilled labor and other factors. In the case of applying the previous approach for this case, the result will be undoubtedly negative.

Indicators that do not take into account the dynamics of costs and the time factor, such as at least the present value and the payback period of additional investments, are applicable only in solving static problems. In this case, it is assumed that capital investments are made only once (as a rule, one time before the start of operation), such indicators as cost, current running costs do not change over time. These indicators are applicable when the production volumes are the same for the compared options [1].

The system of economic indicators of investment projects, such as payback period, net present value, internal rate of return and profitability index used in world practice, is recommended to be used at this stage.

The use of dynamic indicators to determine investment efficiency, taking into account the distribution in time of the net outflow and capital inflows during the entire lifecycle of the object is the most acceptable, because investors are interested in making profit at earlier stages of the project. This should take into account the specific use of borrowed funds.

The problem of energy saving is equally a technical and economic problem. And the main lever of energy saving is currently the economy.

The theory of innovation activity of enterprises is the theoretical and methodological basis of the technical and economic assessment of the effectiveness of energy-saving measures.

In accordance with the main provisions of this theory, energy-saving measures should be considered as an innovation of the organizational-technical type, the main purpose of which is to reduce costs (consumption of fuel and energy resources) in the implementation of a particular type of economic activity.

Electrical networks themselves do not produce products that could be sold for profit, but provide services for the transport of electricity, management of modes, operational maintenance of networks, etc. Therefore, the effectiveness of electrical grid facilities should be evaluated by their impact on the cost of the supplied electricity consumers. Since the investments necessary for the modernization of electrical networks aimed at reducing electricity losses ultimately affect all consumers through electricity tariffs, the effectiveness of measures should be considered from the standpoint of a socio-economic effect reflecting their interests.

No matter how it may seem to us that the assessment of the economic efficiency of the project is a rather trivial thing, because it uses a completely objective indicator - money. However, the profit is obtained, as a rule, not immediately after the completion of the project, but during the entire period of its operation.

Another important factor to be taken into account is the cost of money, which changes over time and the cause of these changes is not just inflation. Always investing money this or that project competes with several options for their use, for example, with investing in securities.

The investor is always interested in the same question when it starts to make a profit. At the same time, long-term projects, especially in our unstable legal field, are fraught with great risks, which are sometimes impossible to predict.

It is customary to classify energy-saving projects, depending on their scale, into capital-intensive and low-cost ones.

When considering energy-saving projects, preference is given to those proposals that have low costs and low payback periods. Usually, low-cost organizational and technical measures that lead to a simple order in the use of energy resources make it possible to obtain even the smallest amount of savings of up to 15–25% reduction in energy consumption. Then follow measures with low financial costs and short payback periods. The implementation of projects with high costs and payback periods is usually postponed to a later date and is taken into account when planning major works on the modernization of electrical installations [2, 3].

In the conditions of market relations in matters of energy saving, priority is usually given to low-cost measures, the payback period of which does not exceed 3-4 years.

MATERIALS AND METHODS

Evaluation of measures to reduce electricity losses requiring additional capital investments should be carried out in accordance with the "Methodological recommendations for evaluating the effectiveness of investment projects ..." [4].

In accordance with paragraph 12.3 of these recommendations, the main indicator characterizing the absolute and comparative efficiency of investment projects is the value of the expected net present value. If there are several alternative projects, the most effective of them, from the point of view of the project participants, is the one that provides them with the maximum NPV value, and this value is not negative.

Net present value (NPV) - the excess of income over cost by cumulative total for the billing period T, taking into account discounting, is determined by the following formula [1, 5].

$$\mathrm{NPV} = \sum_{t}^{T} \frac{\left(R_t - Z_t\right)}{\left(1+E\right)^t}, \quad (1)$$

where R_t – results achieved at the t-th calculation step;
Z_t – costs associated with the implementation of energy saving measures at the t-th calculation step;
E – discount rate at t-th step;
T – calculation horizon.

If the costs of implementing the measure are made within one year, and the operating costs are relatively stable over the years of the billing period, the payback period is a fairly obvious indicator of the comparative efficiency of the energy-saving project. During the payback period of T_{pay}, equipment costs will be offset by the cost of the saved electricity, and then the economic effect will be a certain amount annually.

In practice, based on the calculated data, the dynamic payback period is determined graphically. On the abscissa axis, equal periods of time are laid over the years of the calculation period. The ordinate is the NPV value for a given year. The intersection of the curve with the abscissa gives a point that determines the dynamic payback period.

The graphic interpretation of the dynamic payback period for the considered example will be as follows (Figure 1):

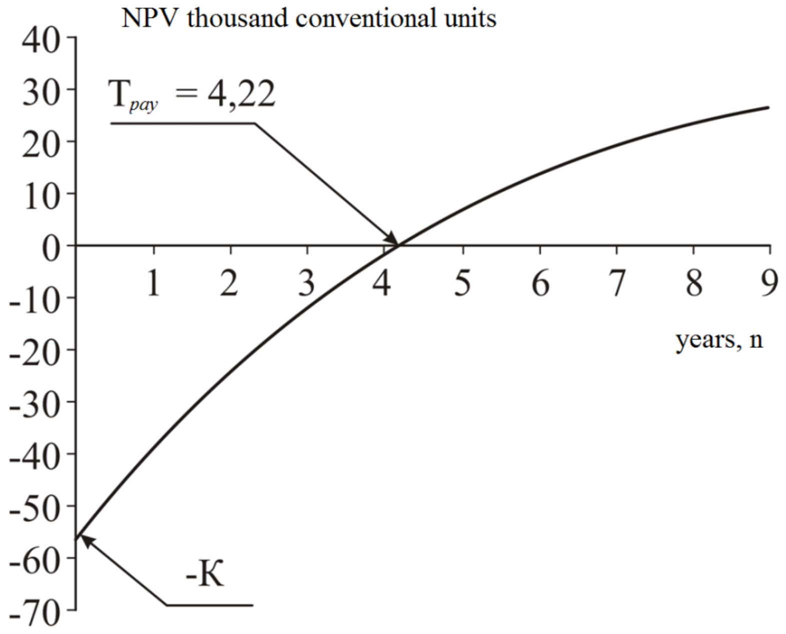

Figure 1: Graphic determination of dynamic payback period

When determining the dynamic payback period, it is usually green juice insideт Method of extrapolation using the formula

$$T_{pay} = \mathrm{N} - 1 + \frac{K - \sum_{N-1} F}{F(N)}, \qquad (2)$$

where N – step of the calculation period in which the total discounted cash flows (F) exceeded capital investments;

K – capital investment;

$\sum_{N-1} F$ – sum of discounted cash receipts in N - 1 steps;

$F(N)$ – discounted cash flow at the N-th step, which overlapped the amount of capital investments.

In order to establish the possibility of attracting borrowed bank funds, it is also appropriate to determine the internal rate of return (IRR) of the network modernization project, which is calculated using the equation:

$$\mathrm{IRR} = E_1 + \frac{\mathrm{NPV}(E_1)}{\mathrm{NPV}(E_1) - \mathrm{NPV}(E_2)}(E_2 - E_1), \qquad (3)$$

where E_1 – interest rate in a discount multiplier minimizing a positive value of NPV;
E_2 – interest rate value in a discount factor maximizing a negative NPV value.

RESULTS AND DISCUSSION

A methodical approach to assessing the economic efficiency of energy saving measures will be considered on the example of the reconstruction of aerial PL of a rural settlement.

In a rural settlement, it is planned to reconstruct a 0.38 kV overhead transmission line by replacing wires. Replacement is caused by unsatisfactory voltage at remote consumers and the achievement of the standard lifetime of the active part of PL. In this case, two variants of modernization are being considered: Option 1 - the use of new uninsulated wires of the same cross section as the existing ones, Option 2 - the use of SIW brand wires. During the reconstruction, the replacement of supports is not provided.

SIW wires have an inductive resistance of three times less than uninsulated wires of the same cross section [6]. This increases the voltage at the end of PL, which leads to a decrease in the load losses in the line, significantly reduces the commercial losses associated with the theft of electricity, and slightly reduces the cost of operating the power line.

Initial data for calculation: length PL L = 0,5 km; annual electricity consumption at the head W_h = 600 thousand kW · h; load power factor $cos\ \varphi$ = 0,9; v $tg\ \varphi$ = 0,48; maximum load power loss time T_{max} = 5000 h; number of hours of greatest losses τ = 3500 h; wire parameters – *brand wire* A-50: r_1 = 0,578 Ohm / km, x_1 = 0,3 Ohm / km, unit cost k_1 =103 thousand rubles / km, unit cost of maintenance and repair a_o = 0,03, depreciation rate a_a = 0,06; *brand wire* SIW2 3x50 + 1x54,6: r_1 = 0,641 Ohm / km, x_1 = 0,1 Ohm / km, unit cost k_2 = 128,4 thousand rubles / km, unit cost of maintenance and repair a_o = 0,01, depreciation rate a_a = 0,06; the cost of electrical energy 4 rubles / kWh; load unevenness ratio k_{un} = 1; commercial losses take the same for both options. Determine the effectiveness of using wires brand SIW.

Calculation of private technical and economic indicators for the option of upgrading PL using A-50 brand wires:

1. Determine the maximum active power transmitted by PL:

$$P_{\max} = W_{h|} / T_{\max} = 600\,000 / 5000 = 120\ \text{kw}$$

2. Calculate the maximum reactive power load:

$$Q_{\max} = P_{\max} tg\ \phi = 120 \cdot 0{,}48 = 57{,}6$$

3. Determine the capital cost of replacing the wires of the brand A-50:

$K_1 = k_1 L$ = 103·0,5 = 51,5 thousand rubles

4. Perform the calculation of operating costs. The calculation will be carried out by the expression: $I_1 = I_a + I_o + I_n$,

where I_a – depreciation deductions;
I_o – maintenance and repair costs;
I_n – PL power loss.

Depreciation deductions:

$$I_a = K_1 \frac{a_a}{100} = 51{,}5 \frac{6}{100} = 3{,}09$$ thousand rubles

Maintenance Costs:

$I_o = a_o K_1$ = 0,03·51,5 = 1,55 thousand rubles

Cost of covering electricity losses. To calculate the load loss in PL, we use the line voltage drop method. Calculation perform the formula:

$$\Delta W_{\%} = 0,7 k_{un} \Delta U \frac{\tau}{T_{\max}},$$

where k_{un} – coefficient taking into account the uneven distribution of the load on the phases;

ΔU – loss of voltage in the network from the transformer substation to the most electrically remote electric receiver, in the mode of maximum load,%.

The value of ΔU is determined on the basis of measurements or by calculation in the mode of maximum load [7]. In this case, we will perform its calculation of the amount of electricity supply to the network, assuming that consumers are considered distributed along the line evenly.

The voltage losses in the highway with a uniform load distribution are calculated by the expression:

$$\Delta U_1 = \frac{P_{max} R + Q_{max} X}{2 U_{ном}} = \frac{P_{max} r_1 L + Q_{max} x_1 L}{2 U_{ном}} = \frac{120 \cdot 0,578 \cdot 0,5 + 57,6 \cdot 0,3 \cdot 0,5}{2 \cdot 380} = 5,7\,\%.$$

Then, the relative loss of electricity in PL will be:

$$\Delta W_{\%} = 0,7 k_{un} \Delta U \frac{\tau}{T_{\max}} = \frac{0,7 \cdot 1 \cdot 5,7 \cdot 3500}{5000} = 2,8\,\%.$$

Absolute value of the annual load loss will be equal to:

ΔW_n = 600 000·2,8/100 = 16 800 kWh

Суммарные стоимость ежегодных потерь электроэнергии составит:

$I_n = c_e \Delta W_н$ = 16,8·4 = 67,2 thousand kWh

Total annual operating costs for the maintenance of the HL during the modernization of the first option will be:

I_1 = 3,09 + 1,55 + 67,20 = 71,84 thousand rubles

Calculation of private technical and economic indicators for the option of modernization of PL using wires brand SIW-2:

1. Determine the maximum active power transmitted by PL:

$$P_{\max} = W_{h|} / T_{\max} = 600\,000/5000 = 120 \text{ kw}$$

2. Calculate the maximum reactive power load:

$$Q_{\max} = P_{\max} tg\,\phi = 120 \cdot 0,48 = 57,6\,.$$

3. Determine the capital cost of replacing the wires of the brand A-50 on the wires SIW-2:

$K_2 = k_2 L$ = 128,4·0,5 = 64,2 thousand roubles.

Excess capital costs to the first option:

$\Delta K = K_2 - K_1$ = 64,2 – 51,5 = 12,7 thousand roubles.

4. Perform the calculation of operating costs:

Depreciation deductions:

$$I_a = K_2 \frac{a_a}{100} = 64{,}2 \frac{6}{100} = 3{,}85$$ thousand roubles.

Service costs:

$I_o = a_o K_2 = 0{,}01 \cdot 64{,}2 = 0{,}64$ thousand roubles.

The cost of covering electricity losses.

The voltage losses in the highway with a uniform load distribution are calculated by the expression:

$$\Delta U_2 = \frac{P_{max} r_2 L + Q_{max} x_2 L}{2U_{ном}} = \frac{120 \cdot 0{,}641 \cdot 0{,}5 + 57{,}6 \cdot 0{,}1 \cdot 0{,}5}{2 \cdot 380} = 5{,}4\,\%.$$

Then, the relative loss of electricity in PL will be:

$$\Delta W_{\%} = 0{,}7 k_{un} \Delta U \frac{\tau}{T_{\max}} = \frac{0{,}7 \cdot 1 \cdot 5{,}4 \cdot 3500}{5000} = 2{,}65\,\%.$$

The absolute value of annual load losses will be equal to:

$\Delta W_n = 600\,000 \cdot 2{,}65/100 = 15\,900$ kWh

The total cost of annual electricity losses will be equal to:

$I_n = c_e \Delta W_n = 15{,}9 \cdot 4 = 63{,}6$ thousand kWh

Total annual operating costs for the maintenance of HL during the modernization of the second option will be:

$I_2 = 3{,}85 + 0{,}64 + 63{,}60 = 68{,}09$ thousand roubles.

The annual economic effect in the case of the use of wires brand SIW will be equal to:

$E = I_1 – I_2 = 71{,}84 – 68{,}09 = 3{,}75$ thousand roubles.

CONCLUSION

Determination of the general economic indicators of comparable options for upgrading the electrical network.

1. The net present value for the 10 years of the project's existence at a discount rate of E = 0.1 will be:

$$\text{NPV} = \sum_{m=0}^{10} \frac{Э}{(1+E)^m} - \Delta K = \sum_{m=0}^{10} \frac{3{,}75}{(1+0{,}1)^m} - 12{,}7 = 12{,}96$$ thousand roubles.

2. Internal rate of return. Using the method of successive substitutions, we determine the range of finding the IRR (Table 1):

Table 1: NPV dependence on discount rate

E	0,1	0,15	0,2	0,25	0,3
NPV, thousand roubles.	12,96	6,12	3,01	0,68	– 1,11

As follows from table 1, the project IRR is in the range of 0.25–0.30. Specify this value using the iterative method:

$$E_{ex} = E_1 + \frac{\mathrm{NPV}(E)}{\mathrm{NPV}(E_1) - \mathrm{NPV}(E_2)}(E_2 - E_1) = 0{,}25 + \frac{0{,}68}{0{,}68 - (-1{,}11)}(0{,}3 - 0{,}25) = 0{,}27.$$

Thus, the income from the reconstruction using wires brand SIW can be 27%.

3. Payback period. To calculate the payback period, we define the cash flow for the entire project term (10 years):

$$F_1 = \frac{3{,}75}{(1+0{,}1)^1} = 3{,}45$$ thousand roubles.

$$F_2 = \frac{3{,}75}{(1+0{,}1)^2} = 6{,}51$$ thousand roubles.

$$F_3 = \frac{3{,}75}{(1+0{,}1)^3} = 9{,}33$$ thousand roubles.

$$F_4 = \frac{3{,}75}{(1+0{,}1)^4} = 11{,}88$$ thousand roubles.

$$F_5 = \frac{3{,}75}{(1+0{,}1)^5} = 14{,}22$$ thousand roubles.

$$F_6 = \frac{3{,}75}{(1+0{,}1)^6} = 16{,}33$$ thousand roubles.

$$F_7 = \frac{3{,}75}{(1+0{,}1)^7} = 18{,}26$$ thousand roubles.

$$F_8 = \frac{3{,}75}{(1+0{,}1)^8} = 20{,}00$$ thousand roubles.

$$F_9 = \frac{3{,}75}{(1+0{,}1)^9} = 21{,}60$$ thousand roubles.

$$F_{10} = \frac{3{,}75}{(1+0{,}1)^{10}} = 25{,}67$$ thousand roubles.

4. It follows from the above data that in the first four years the sum of economic effects will amount to 11.88 thousand rubles, which is less than the value of additional capital investments. ΔK = 12,70 thousand roubles. For five years, cash receipts will be equal to 14.22 thousand roubles. Which is more than the value of additional capital investments. Therefore, we find that the payback period of an energy-saving project is in the range of 4 to 5 years. To find it more accurately, we use the extrapolation method using formula (2).

Assuming a linear dependence of income growth on time, the payback period will be: $4 + (12{,}7 - 11{,}88)/14{,}22 = 4{,}06$ years, which is quite acceptable for the modernization of grid facilities.

5. The calculations made it possible to establish a positive value of net discounted income acceptable for electric power facilities payback period and attractiveness of the network reconstruction project in terms of the internal rate of return (annual yield of 27% at the bank interest rate currently 10-15%), which indicates the feasibility of such an event.

REFERENCES

[1] Khorolsky V. Ya. Electricity saving in rural electrical installations / V. Ya. Khorolsky, M. A. Taranov, A. V. Efanov. - SPb: Lan, 2017.

[2] Smagina M.N. Technique of the Feasibility Study of Energy Saving Measures // Bulletin of Economics, Law and Sociology. 2015 № 4.
[3] Freydkina E.M. Methods and criteria for evaluating the effectiveness of energy conservation. - SPb: GTURP, 2013.
[4] Guidelines for assessing the effectiveness of investment projects and their selection for financing. - M: Economy, 2000.
[5] G. Shvedov. Electricity losses during its transportation through electric networks / G. V. Shvedov, O. V. Sipacheva, O. V. Savchenko. - M: Publishing house MEI, 2013.
[6] Lykin A.V. Energy saving and increase of energy efficiency in electric networks. - Novosibirsk: NSTU, 2013.
[7] Khorolsky V. Ya. Energy saving in electrical installations of enterprises, organizations and institutions / V. Ya. Khorolsky, I. V. Atanov, V. N. Shemyakin. - Stavropol: AGRUS, 2011.