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Development of a methodology for calculation of discounted costs for the distribution electric network

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ABSTRACT: To select a variant of the design solution, it is necessary to use evaluation methods. Evaluation methods make it possible to speed up the solution of the problem of choosing the optimal voltage of the distribution network. Due to the use of a simplified methodology, algorithm and computer program, the time spent on design is reduced.

KEYWORDS: Mathematical model, discounted costs, electrical network.

1. INTRODUCTION

To select a variant of the design solution, it is necessary to use evaluation methods. Evaluation methods make it possible to speed up the solution of the problem of choosing the optimal voltage of the distribution network.

The advantage of evaluation models is that they take into account the individual features of the system being designed, take into account the reliability requirements in the course of calculating each compared option. Evaluation models allow for a complete feasibility study for each of the proposed options. After such an analysis, the choice of the best of the selected options is not very difficult [1]. For a comparative economic evaluation of options for technical solutions, the total discounted costs are used, mln. soum [4],

$$З = K_t + \sum_{t=1}^{T_a} \frac{И_{o.r.t} + \Delta И_{e.t}}{(1+E)^t} \quad (1)$$

Where t - discounting step;
T_a - settlement period is taken equal to the life cycle of the project or another time period with in the life cycle;
K_t - capital investments according to the option of the power supply scheme at the step mln. soum;
$И_{o.r.t}$ - the facility maintenance and repair costs, soum ;
$\Delta И_{e..t-}$ the cost of compensating for energy losses in the scheme at the step t;
E - discount rate and comparison rate, represents the minimum required rate of return on capital;
In the article , proposed components of the formula (1) express through the parameters of the network elements and their modes of operation .

$$З = K_t + \sum_{t=1}^{T_a} \frac{\alpha_{absl} \cdot K_t + \dfrac{C_0 \cdot S^2 \cdot \tau \cdot \rho \cdot l}{U^2 \cdot F}}{(1+E)^t} \quad (2)$$

Where α_{absl} - the rate of deductions for maintenance and repair, %;
C_0-electricity cost, mln/kWh;
S-is the calculated load power;
ρ , F - resistivity and cross section of the conductive core;
U - rated voltage, kV ;
l- line length, km.

At a certain section *F*, the discounted costs for a transmission line from a given type group are a quadratic function of the calculated power.

$$З_{wl} = A + BS^2 \quad (3)$$

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$$A = K_t + \sum_{t=1}^{T_a} \frac{\alpha_{absl} \cdot K_t}{(1+E)^t} \quad (4)$$

$$B = \sum_{t=1}^{T_a} \frac{\dfrac{C_0 \cdot \tau \cdot \rho \cdot l}{U^2 \cdot F}}{(1+E)^t} \quad (5)$$

The calculation results are presented with the original expression (2) being piecewise smooth nonlinear functions of the calculated power. The presence of breaks in these functions makes it impossible to use them in technical and economic calculations. Because of this, the mathematical model of the discounted costs for a typical group of transmission lines, based on the function of economic intervals, not received significant distribution in the practice of technical and economic calculations. [1]

With a relatively small average error, these functions can be approximated by linear dependencies on the design power.

$$З = b + cS \quad (6)$$

Based on the calculated expressions of discounted costs, assumptions are formulated in accordance with which the coefficients *b* and *c* of linear functions for various elements of the electrical network can be determined.

The first term of expression (6) characterizes the discounted costs due to the presence of an electrical network element. This part of the cost does not depend on the throughput of the network element, and, therefore, on its design capacity.[4] It reflects the objective part of construction, installation and adjustment works for each network element under construction, the cost of which depends only on the fact of the construction of the element, and not on its throughput , which determines the position in the series of elements of the type group. [5]

For overhead transmission lines, this part of the discounted costs reflects the cost of preparing the route, the cost of alienated land, as well as the cost of poles, insulator strings and their installation.

The second term (6) reflects the costs due to the ability of an element of the electrical network to transmit one or another design power.[3] This part depends on the design capacity of the network element and reflects part of the construction and installation work, material values and losses of electrical energy, the cost of which depends on the required bandwidth of the network element.

For overhead lines, this part of the discounted costs characterizes part of the cost of wires and the cost of electrical energy losses in them. In accordance with the linearization method, this part of the costs depends proportionally on the rated power. [1]

Linearization of the function of discounted costs for a typical group of transmission lines can be carried out according to the well-known [2] method based on the following assumptions:

1. The scale of transmitted powers is continuous. This assumption allows us to differentiate the discounted cost function with respect to the *F* argument;
2. Capital investments K_0 in one kilometer of the line are a linear function of the cross section of the conductive core;

$$K_0 = \lambda L + \gamma F L \quad (7)$$

The coefficients λ and γ are constant for each typical group of lines and can be determined by least-squares approximation of capital investment data for various standard sections *F*.

Under the assumptions made, the economically feasible cross section of the conductive cores is determined from the condition of the minimum discounted costs.

$$\frac{dЗ}{dF} = \lambda L + \gamma F L + \sum_{t=t_0}^{T_a} \frac{\alpha_{absl}(\lambda L + \gamma F L) + \dfrac{C_0 \cdot S^2 \cdot \tau \cdot \rho \cdot l}{U^2 \cdot F}}{(1+E)^t} = 0 \quad (8)$$

$$F_{eq} = \sqrt{\frac{3 \cdot \rho \cdot \sum_{t=t_0}^{T_a} \tau \cdot \dfrac{S^2}{3U^2} \cdot C_0 (1+E)^{-t}}{\gamma (1 + \sum_{t=t_0}^{T_a} \alpha_{absl} (1+E)^{-t}}} = \sqrt{\gamma \frac{\rho \cdot \sum_{t=t_0}^{T_a} \tau \cdot \dfrac{S}{U^2} \cdot C_0 (1+E)^{-t}}{a(1 + \sum_{t=t_0}^{T_a} \alpha_{absl} (1+E)^{-t})}} \quad (9)$$

$$F_{eq} = a \cdot S$$

$$a = \sqrt{\frac{\rho \cdot \sum_{t=t_0}^{T_a} \tau \cdot \frac{1}{U^2} \cdot C_0 (1+E)^{-t}}{\gamma (1+\sum_{t=t_0}^{T_a} \alpha_{absl} (1+E)^{-t}}} = \frac{1}{U} \cdot \sqrt{\frac{\rho \cdot \sum_{t=t_0}^{T_a} \tau \cdot C_0 (1+E)^{-t}}{\gamma (1+\sum_{t=t_0}^{T_a} \alpha_{absl} (1+E)^{-t})}} \qquad (10)$$

Substituting (7) and (10) into (12), the discounted costs are:

$$З = \lambda L + \gamma L \cdot a \cdot S + \sum_{t=t_0}^{T_a} \frac{\alpha_{absl} (\lambda L + \gamma L \cdot a \cdot S) + \frac{3 \cdot C_0 \cdot S^2 \cdot \tau \cdot \rho \cdot L}{3U^2 (a \cdot S)}}{(1+E)^t} =$$

$$\lambda L + \gamma L \cdot a \cdot S + \sum_{t=t_0}^{T_a} \frac{\alpha_{absl} (\lambda L + \gamma L \cdot a \cdot S) + \frac{C_0 \cdot S \cdot \tau \cdot \rho \cdot L}{U^2 a}}{(1+E)^t} = \qquad (11)$$

$$\lambda L + \sum_{t=t_0}^{T_a} \frac{\alpha_{absl} \cdot \lambda L}{(1+E)^t} + \gamma L \cdot a \cdot S + \sum_{t=t_0}^{T_a} \frac{\gamma L \cdot a \cdot S + \frac{C_0 \cdot S \cdot \tau \cdot \rho \cdot L}{U^2 a}}{(1+E)^t}$$

$$b = \lambda L + \sum_{t=t_0}^{T_a} \frac{\alpha_{absl} \cdot \lambda L}{(1+E)^t} \qquad (12)$$

$$c = \gamma L a + \sum_{t=t_0}^{T_a} \frac{(\gamma L a + \frac{C_0 \cdot \tau \cdot \rho \cdot L}{a \cdot U^2})}{(1+E)^t} \cdot S \qquad (13)$$

II. CONCLUSION

The mathematical model of discounted costs for the elements of the electrical network, obtained on the basis of the discounted costs linearization method, is a simplified mathematical model generalized to all elements of a typical group. Simplification in it is achieved by not taking into account the deviations of the individual parameters of individual network elements from the values determined by the law of their change generalized to the entire typical group of network elements. However, this generalized law retains and reflects the main trend in discounted costs within each typical group of elements, namely: the presence of a part of the costs that does not depend on the rated capacity, and a part of the costs that increases with an increase in the calculated

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