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Technical and economic analysis of parameters of city distribution electric network up to 1000 V

M V Melikuziev[1], *L A Nematov*[4], *Novikov A N*[2], *K K Baymuratov*[3]

[1] Tashkent state technical university named after Islam Karimov, Tashkent, Uzbekistan
[2] Joint Stock Company "Scientific and Technical Center of the Federal Grid Company of the Unified Energy System", Russia
[3] Karakalpak State University
[4] Bukhara Engineering Technological Institute

Abstract. The article shows the sequence of development of mathematical expressions of the technical and economic indicators of networks whose voltage is up to 1000 V. In the development of these expressions, methods such as the smallest squares, the criterion analysis were used. From the resulting expressions, it is possible to see which sizes are significantly dependent or dependent on the costs incurred for this network processing.

1 Introduction

The same distribution of the load on the territory of the city district creates approximately the same load density in the area of the region in which it is seen. The use of the same cross-section surface cable in this area, the use of standardized elements of the specified economic indicators, allows to mathematically describe the feasibility indicators as the function of the parameters of this element (transformer power, cable cross-section surface, etc.) [1-3].

Such an ideal distributor can be expressed as a linear function, which when building an electrical network connects a comparable capital savings on cable lines up to 1000 V to the surface of the cable cross section:

$$K_{ПК} = K_{ПК0} + K_{ПКF} \cdot F_{ПК}, \qquad (1)$$

here $K_{ПК0}$ – comparative price of the part of the cable line not connected to the cross-section surface, mln.sum/km; $K_{ПКF}$ – coefficient of cost for the comparative price, which depends on the surface of the line cut, mln.sum/mm^2·km, $F_{пк}$ – low voltage network cable cutting surface, mm^2.

For 0,38 kV voltage *ABBг* branded 4-vessel cables, the coefficients of the estimating expression (1) ($K_{ПК0}$, $K_{ПКF}$) are found. At the same time, in the scheme of 0,38 kV voltage creep, the cables were obtained as if lying in one trench, two in the scheme of the trunk, and two in the scheme of the trunk. $F_{ПК}$ on two main lines – the cross-section surface of each cable vein, mm^2 [7-14].

Based on the condition of the above analysis, one transformer has the same length of the lines up to 1000 V output from the substation and conducts the same load. Here the load of each line is determined by the following expression:

$$S_{Л} = \frac{S_{ТП} \cdot \beta_{Т}}{M_{ПК}}, \qquad (2)$$

Power consumption in networks up to 1000 V can be determined as follows:

$$\Delta P_l = \frac{K_{\Delta P} \cdot S_{Л}^2 \cdot l_{ПК} \cdot 10^{-3}}{n_з \cdot \gamma \cdot U_Н^2 \cdot F_{ПК}}, \qquad (3)$$

here $K_{\Delta P}$ – coefficient taking into account the reduction in power consumption on account of the distribution of loads during the length of the line; $n_з$ – the number of parallel chains ($n_з$=1 for slab schemes and $n_з$=2 for two master schemes); $l_{ПК}$ – average distance of each line, km; γ – comparative electrical conductivity of electric conductors, km/om·mm^2. $M_{ПК}$ – number of outgoing lines from the transformer substation, $\beta_т$ – load coefficient of the transformer [4-6].

In all sections of the cable line, the cross section is unchanged and assuming that the load in it is evenly distributed, the coefficient of $K_{\Delta P}$ load is the inverse value of the coefficient K_j square. The coefficient of $K_{\Delta P}$ and the waste of electricity in the distribution power networks vary significantly with the number of connections on the line n. For example, n=1 will be equal to $K_{\Delta P}$ =1, n=5 will be equal to $K_{\Delta P}$

=0,4. Therefore, it is not necessary to give the same value of $K_{\Delta P}$ in the optimization of taqsimex of the parameters of the distribution power grid, but to use the $K_{\Delta P}$'s dependence on n. To obtain a simplified expression for $K_{\Delta P}$, the smallest squares with a degree function are approximated using the method and the following result is obtained:

$$K_{\Delta P} = 0,77 \cdot n^{-1/3}, \tag{4}$$

The number of connections in a single line up to 1000 V can be found by the following expression:

$$n = \frac{S_{ТП} \cdot \beta_T \cdot \cos\varphi_{ТП}}{K_{пр} \cdot P_{бир.} \cdot M_{ПК}}, \tag{5}$$

(5) and (3) given $P_{бир.} = \frac{2,5 \cdot 10^{-5} \cdot \sigma}{K_к \cdot K_{пр}}$, (4) the expression takes the following view:

$$K_{\Delta P} = K_{\delta P} \cdot M_{ПК}^{1/3} \cdot \sigma^{1/3} \cdot S_{ТП}^{-1/3}, \tag{6}$$

here $K_{\delta P} = \frac{0,77}{K_к} \cdot (\frac{\beta_T \cdot \cos\varphi_{ТП}}{2,5 \cdot 10^{-5}})^{-1/3}$.

Considering (6), (4) and (3), the power consumption in networks up to 1000 V within a transformer substation will be as follows:

$$\Delta P_{ПК} = \frac{K_{\delta P} \cdot \beta_{ПК}^2 \cdot \lambda_{ПК} \cdot 10^{-3}}{n_з \cdot \gamma \cdot U_H^2 \cdot \sigma^{5/12}} \cdot S_{ТП}^{29/12} \cdot M_{ПК}^{-7/6} \cdot F_{ПК}^{-1}, \tag{7}$$

The annual quoted costs of the distribution network up to 1000 V are the sum of the costs of capital expenditure and the cost of electricity energy waste, which can be found through the following expression [15-19]:

$$З_{ПК} = p_{\Sigma Л} \cdot (K_{ПК0} + K_{ПКF} \cdot F_{ПК}) \cdot l_{ПК} + \Delta P_{ПК} \cdot \tau \cdot c \cdot 10^{-5}, \tag{8}$$

$$p_{\Sigma Л} = p_н + p_{атх}, \tag{9}$$

here $p_{\Sigma Л}$ – total discount coefficient from capital expenditure; $p_н$ – normative coefficient of effective use of capital expenditure (0,12); $p_{атх}$ – discount coefficient for depreciation for repair and maintenance, 5% from capital costs for cable lines up to 10 kV; τ – maximum waste time, hour/year; c – the cost of wasted kWh of electricity, sum/kWh.

Given the expressions (3), (6) and (7), the expression of total costs (9) can be written as follows:

$$Z_{ПК} = \frac{C_1}{\sigma^{0,42}} \cdot S_{ТП}^{2,42} \cdot M_{ПК}^{-1,77} \cdot F_{ПК}^{-1} + \frac{C_2}{\sigma^{0,75}} \cdot S_{ТП}^{0,75} \cdot M_{ПК}^{0,5} + \frac{C_3}{\sigma^{0,75}} \cdot S_{ТП}^{0,75} \cdot M_{ПК}^{0,5} \cdot F_{ПК}, \tag{10}$$

here

$$C_1 = \frac{\lambda_{ПК} \cdot K_{\delta P} \cdot \beta_T^2 \cdot \tau \cdot c}{n_з \cdot \gamma \cdot U_H^2} \cdot 10^{-8},$$

$$C_2 = p_{\Sigma Л} \cdot K_{ПК0} \cdot \lambda_{ПК}, \tag{11}$$

$$C_3 = p_{\Sigma Л} \cdot K_{ПКF} \cdot \lambda_{ПК}.$$

If we multiply (10) by N_{TP} (number of TPS), we get an expression of the total costs in networks up to 1000 V within the area under consideration. here it is possible to write as follows, taking into account (11) [20-25]:

$$Z_{ПК} = A_1 \cdot S_{ТП}^{1,42} \cdot M_{ПК}^{-1,17} \cdot F_{ПК}^{-1} + A_2 \cdot S_{ТП}^{-0,25} \cdot M_{ПК}^{0,5} + A_3 \cdot S_{ТП}^{-0,25} \cdot M_{ПК}^{0,5} \cdot F_{ПК}, \tag{12}$$

here

$$A_1 = \frac{C_1}{\sigma^{0,42}} \cdot \frac{S_{TM}}{K_0}, \quad A_2 = \frac{C_2}{\sigma^{0,75}} \cdot \frac{S_{TM}}{K_0}, \quad A_3 = \frac{C_3}{\sigma^{0,75}} \cdot \frac{S_{TM}}{K_0}. \tag{13}$$

2 Conclusions

Thus, analyzing the characteristics of a complex feasibility model in networks with voltage up to 1000 V, it depends on the number of network cable lines, the cross-sectional surface and the nominal capacity of the transformer that provides this network. The determining accuracy of the parameters depends on the value of these parameters. The significant stability of the technical and economic indicators to the initial data sets creates the ground for further unification of the cross-sections of the network cables up to 1000 V.

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