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Development of standard cable cross-sections of rural electrical networks

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Abstract. For the optimal development of electric networks, not only the optimal choice of the network element parameter from the existing standard scale (parametric series) of sizes is important, but also the optimization of standard scales of equipment sizes or checking their optimality. The method of economic intervals explores the existing parametric series of standard cross-sections of 10 kV cable cores and establishes that the existing series does not satisfy the conditions for optimizing the use of cable lines in rural areas. Since cable lines have not yet found wide distribution in rural areas, there are conditions not only to verify the optimality of the existing scale of cable conductor cross-sections but also to establish an optimal scale of 10 kV cable conductor cross-sections, intended for the construction of cable power transmission lines in rural areas (if the existing scale does not meet optimality conditions). For rural distribution electric networks, the initial and final sections in a parametric series (25 and 120 mm^2) are determined and the optimal for rural areas parametric series of cable cross-sections of 10 kV (25; 50; 120 mm^2) is recommended.

1. Introduction

Following the requirements set forth in [1], scale sizes constructed with a constant step according to the principle of arithmetic or geometric progression are currently preferred. The existing standard scale of standard sizes of nominal sections of cable conductors, as well as wires of overhead power lines, has an uneven pitch between adjacent sections. According to [2], for cables with a voltage of 10 kV, as well as for overhead power line wires, the following standard cross-sectional scale was adopted in Uzbekistan: 16; 25; 35; fifty; 70; 95; 120; 150; 185; 240 mm^2. The ratio between adjacent sections ranges from 1.56 to 1.23. Thus, the standard scale of cable conductor cross-sections does not meet the requirements [2] and therefore the question arises of whether the existing scale of cable conductor cross-sections corresponds to optimality requirements.

It should be noted that recently the question has been raised about the optimality of the existing scale of cable conductor cross-sections for urban networks [3]. The issue of the unification of electrical equipment (including cables) is considered abroad [4].

The purpose of the research is to develop a methodology for selecting optimal parameters of typical cable sections in rural areas

Research problem:

overview of the state of the problem and methods for selecting optimal parameters of cable sections of rural electric networks;
selection of parameters of distribution electric networks of rural power supply systems;
creating a mathematical basis for the formation of models in the development of typical cable sections.
The object of research is rural electric networks.
The subject of the research is the search for optimal parameters of low-voltage rural electric networks.

2. Methods

Based on an analysis of methods for constructing optimal parametric series of electrical equipment for constructing a parametric series of cable core sections for 10 kV cable power lines in rural areas, it is proposed to use an approach that uses the principle of limiting the allowable cost increase from optimal. Moreover, as a criterion of optimality, the use of a minimum of reduced costs is assumed[5,6].

3 Results and Discussion

When establishing the optimal scale of equipment sizes, it is important to determine the initial and final values of the scale size.

The specificity of rural distribution networks is that relatively small loads are encountered in them. Therefore, for rural networks, the initial cross-section may be somewhat smaller than for urban ones. However, in the end, it should be determined on the basis of economic indicators. In studies, it is advisable to consider options for various initial sections, for example, 10, 16, 25 mm^2.

The final cross-section of the cable cores of the parametric series of their nominal values is determined practically by the greatest possible current loads and the maximum possible short circuit currents. The largest section of the range of rated must satisfy the condition of long-term permissible currents and thermal stability at possible values of the above currents. For long-term current loads, the final section can be selected at least 75 mm^2. According to the conditions of thermal stability, the cross-section must be at least 100 mm^2.

According to the PUE, with a maximum load of up to 5000 hours, the economic current density for 10 kV cables with impregnated paper insulation is 1.4 A/mm^2. Based on this current density and the possible maximum current, the final section of the parametric series should be at least 80 mm^2.
Thus, as can be seen from the analysis, the condition for the thermal stability of cables is the determining factor for choosing the final section in the scale, since this condition gives the greatest value of the cross-section of the cable conductors. Based on this condition, the final section must be taken equal to at least 100 mm^2.

If we take into account that the maximum cross-section for power transmission lines of 10 kV for agricultural purposes is currently taken to be 120 mm^2, then, taking into account possible changes in short-circuit currents in the future, the final section in the scale of nominal cross-sections of cable cores can be taken to be 120 mm^2 [7-9].
If we arbitrarily take several cross-sections of cable conductors as continuous, then for any given load, we can find the optimal cable cross-section $F_{\text{э}}$ for it, the use of which would ensure a minimum of reduced costs. This section is determined from the fact that the partial derivative of the function of reduced costs over the section [10] is equal to zero, i.e.

$$\frac{\partial \text{З}}{\partial F} = (E_{\text{н}} + p_a)k - \frac{U_{\Pi} S_T^2 A 10^{-5}}{U_{\text{н}}^2 \gamma F^2} = 0 \qquad (1)$$

Where from

$$F_{э} = S_T \sqrt{\frac{U_{П} A 10^{-5}}{U_{н}^2 \gamma (E_{н} + p_a) k}} \qquad (2)$$

After the corresponding transformation, we get

$$З_{э} = (E_{н} + p_a) K_0 + 2 S_T \sqrt{\frac{k A U_{П} 10^{-5}}{U_{н}^2 \gamma}} \qquad (3)$$

Expression (3) represents a linear function of the costs of the load and is the envelope of the family of curves of reduced costs for any selected section from the accepted continuous series (line 1 in Figure1).

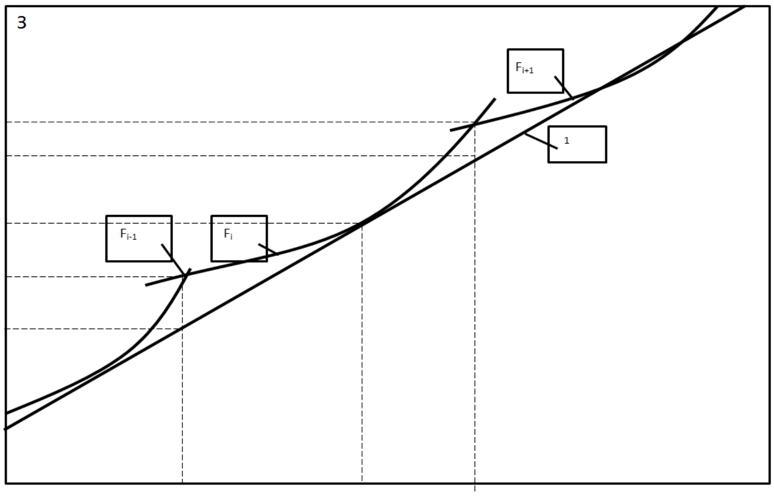

Figure 1. Economic load intervals.

The point of contact of the straight line with the curves of reduced costs for specific sections corresponds to the condition $F_i = F_{iэ}$, which corresponds to the minimum reduced costs for a given load. At this point, when considering the standard cross-section, the actual costs will be equal to the optimal $З_{iэ}$. For other values of the load, the reduced costs for the section under consideration will be greater than optimal; and the maximum deviation will occur at the intersection points of the curves at the borders of the economic load intervals (see Fig. 1). In the practice of design and scientific and technical research, it is accepted that the two compared options are considered economically equivalent if their indicators differ by no more than 5%. This condition underlies one of the approaches to determining the optimal parametric series [11], which consists in the fact that the deviation of the actual costs when using a section from the standard scale from the optimal is 5%, i.e.

$$З_{ф} = (1 + \delta) З_{э} \qquad (4)$$

where δ - deviation of actual costs from optimal, accepted equal to 0.05.

We initially investigate the actual cost deviations for the existing parametric series of cable core sections. Based on the economic intervals of the load, the relative change in reduced costs when deviating from the economic section to a larger or smaller standard is defined as

$$\delta_i^{\text{н}} = \frac{\text{З}_i^{\text{н}} - \text{З}_{i\text{э}}^{\text{н}}}{\text{З}_{i\text{э}}^{\text{н}}} \quad \text{and} \quad \delta_i^{\text{в}} = \frac{\text{З}_i^{\text{в}} - \text{З}_{i\text{э}}^{\text{в}}}{\text{З}_{i\text{э}}^{\text{в}}} \tag{5}$$

The values of the reduced costs $\text{З}_i^{\text{н}}$ and $\text{З}_i^{\text{в}}$ are determined

$$\begin{gathered} \text{З}_i^{\text{н}} = (E_{\text{н}} + p_a)[K_0 + k(F_{i-1} + F_i)] \\ \text{З}_i^{\text{в}} = (E_{\text{н}} + p_a)[K_0 + k(F_i + F_{i+1})] \end{gathered} \tag{6}$$

When substituting the boundary values of the load by the expression (2), we obtain the economic sections corresponding to the boundary capacities $\text{З}_{\text{гр}i}^{\text{н}}$ and $\text{З}_{\text{гр}i}^{\text{в}}$.

$$F_{i\text{э}}^{\text{н}} = \sqrt{F_{i-1}F_i}\,, \quad F_{i\text{э}}^{\text{в}} = \sqrt{F_iF_{i+1}} \tag{7}$$

The values of the reduced costs $\text{З}_i^{\text{н}}$ and $\text{З}_i^{\text{в}}$ are determined

$$\begin{gathered} \text{З}_i^{\text{н}} = (E_{\text{н}} + p_a)\left[K_0 + 2k\sqrt{F_{i-1}F_i}\right] \\ \text{З}_i^{\text{в}} = (E_{\text{н}} + p_a)\left[K_0 + 2k\sqrt{F_iF_{i+1}}\right] \end{gathered} \tag{8}$$

Taking into account expressions (6) and (8), we find

$$\delta_i^{\text{н}} = \frac{\left(\sqrt{F_i} - \sqrt{F_{i-1}}\right)^2}{\frac{K_0}{k} + 2\sqrt{F_{i-1}F_i}} \quad \text{and} \quad \delta_i^{\text{в}} = \frac{\left(\sqrt{F_{i+1}} - \sqrt{F_i}\right)^2}{\frac{K_0}{k} + 2\sqrt{F_iF_{i+1}}} \tag{9}$$

From (9) it follows that the value of the relative deviation of the reduced costs when deviating from the economic section is determined only by the ratio of replaceable standard sections and the ratio of the constant component of the cost of the power line K_0, independent of the section, to the cost factor k [12, 13, 14].

Data analysis table. 1 shows that the value of the ratio K_0/k varies in a narrow range – from 92.73 to 124.02 with an arithmetic mean of 116.62 and a mean square of 112.27.

Table 1 The magnitude of the relative changes in reduced costs when deviating from the economic section

Section	Relative change in reduced costs at K_0/k							
mm^2	97.22	118.90	92.73	115.92	124.02	120.91	112.27	116.62
16	0.0073	0.0063	0.0075	0.0064	0.0061	0.0062	0.0066	0.0064
25	0.0054	0.0047	0.0055	0.0048	0.0046	0.0047	0.0049	0.0048
35	0.0074	0.0066	0.0076	0.0067	0.0064	0.0065	0.0068	0.0067
50	0.0078	0.0071	0.0080	0.0072	0.0069	0.0070	0.0073	0.0071
70	0.0073	0.0068	0.0074	0.0068	0.0066	0.0067	0.0069	0.0068
95	0.0047	0.0044	0.0048	0.0044	0.0043	0.0044	0.0045	0.0044
120	0.0046	0.0043	0.0046	0.0044	0.0043	0.0043	0.0044	0.0043
150	0.0043	0.0041	0.0043	0.0041	0.0040	0.0040	0.0041	0.0041
185	0.0069	0.0066	0.0070	0.0067	0.0066	0.0066	0.0067	0.0066

From table 1 it is seen that the deviation of actual costs from economic allows you to abandon the use of some sections from the standard series. This confirms the relevance and legitimacy of raising the question of the appropriateness of the existing scale of nominal cable cross-sections and the need to develop a new scale [15].

As mentioned above, it is currently recommended to build a standard series of sizes with a constant step according to the principle of arithmetic or geometric progression [1]. Then you can write

$$\frac{F_{i+1}}{F_i} = q \qquad (10)$$

Then, substituting the value F_{i+1} from (10) into (9) and assuming the initial value of the section of the scale F_0, after simple transformations, we obtain

$$q = \left[(1+\delta) + \sqrt{(1+\delta)^2 - \left(1 + \frac{K_0\delta}{kF_0}\right)}\right]^2 \qquad (11)$$

From the obtained expression (11) it can be seen that the scale step size is determined only by the relative change in the reduced costs when deviating from the economic section and the ratio of the constant component of the cost of the power line, independent of the section, to the line rise rate, as well as from the initial section of the scale [15].

It should be noted that the scale can be built not only from bottom to top, but also from top to bottom, i.e. as the base section, set not only the first, but also the last section of the scale. Moreover, the dependence between the members of several sections can be expressed by the following expression

$$F_{i-1} = \left[(1+\delta)\sqrt{F_i} - \sqrt{(1+\delta)^2 F_i - F_i + \delta\frac{K_0}{k}}\right]^2 \qquad (12)$$

With the last section of the row equal to 120 mm^2, the scale constructed according to expression (12) is a row (after rounding): 3; 19; fifty; 120 mm. Thus; having excluded from this series a section of 3 mm^2, which is unacceptable for reasons of mechanical strength and cable throughput, we obtain a scale of sections of cable cores, consisting of 3 sections: 16 (25); fifty; 120 mm^2.

4. Conclusions

1. The existing parametric range of nominal cross-sections of 10 kV cable cores does not satisfy the conditions for optimizing the use of cable lines in rural areas and contains an overestimated number of cross-sections.
2. For distribution networks of power supply, the initial and final sections in the parametric row should be equally equal to 25 and 120 mm^2, and depending on the terrain, the parametric row of 10 kV cables is – 25; fifty; 120 mm^2.
3. it is possible to study the regularity of the formation of a complex of parameters of typical cables of rural electric networks, taking into account the unification in multi-criteria conditions.
4. it was found that the number and values of standard cable sections are most sensitive to changes in the generalized coefficients that determine the errors in the cost indicators of cable lines in rural areas.

References

[1] Dzeventsky A Ya, Hoshimov F A and Zahidov R A 1994 Energy saving in industry *J Problems of Informatics and energy* **1** pp 18-21

[2] Hoshimov FA, Rahmonov I U 2014 Rationing of electricity production in the rolling of ferrous metallurgy *J European Science review* **11-12** pp 56-59

[3] Rafikova G R, Ruzinazarov M R and Makhmutkhonov S K 2019 Features stabilization of the consumer current using electro-ferromagnetic circuits E3S Web Conf 139 doi:10.1051/e3sconf/201913901075

[4] Taslimov A D, Rakhmonov I U 2019 Optimization of complex parameters of urban distribution electric networks *Journal of Physics: Conference Series* **1399** doi:10.1088/1742-6596/1399/5/055046

[5] Hoshimov F A, Rahmonov I U 2015 Analysis of the optimal energy indicators of electric arc furnace *Austrian Journal of Technical and Natural Sciences* **3-4** pp 52-55

[6] Rakhmonov I U, Niyozov N N 2019 Optimization setting of steel-smelting industry in the issue of alloy steels *E3S Web Conf* **139** doi:10.1051/e3sconf/201913901077

[7] Rakhmonov I U, Reymov K M and Shayumova Z M 2019 The role information in power management tasks. *E3S Web Conf* **139** doi:10.1051/e3sconf/201913901080

[8] Rasulov A N, Usmanov E G, Bobojanov M K and Karimov R Ch 2019 Non –contact voltage relay for switching windings of a boost transformer *E3S Web Conf* **139** doi:10.1051/e3sconf/201913901079

[9] Rakhmonov I U, Reymov K M 2019 Mathematical Models and Algorithms of Optimal Load Management of Electricity Consumers *J ENERGETIKA. Proceedings of CIS higher education institutions and power engineering association* **62(6)** pp 528-535 doi:10.21122/1029-7448-2019-62-6-528-535

[10] Rakhmonov I U, Tovbaev A N, Nematov L A and Alibekova T Sh 2020 Development of forecasted values of specific norms for the issues of produced products in industrial enterprises *Journal of Physics: Conference Series* **1515** doi:10.1088/1742-6596/1515/2/022050

[11] Rakhmonov I U, Nematov L A, Niyozov N N, Reymov K M and Yuldoshev T M 2020 Power consumption management from the positions of the general system theory *Journal of Physics: Conference Series* **1515** doi:10.1088/1742-6596/1515/2/022054

[12] Rakhmonov I U, Reymov K M 2019 Regularities of change of energy indicators of the basic technological equipment of the cotton-cleaning industry *Journal of Physics: Conference Series* **1399** doi:10.1088/1742-6596/1399/5/055038

[13] Rakhmonov I U, Reymov K M, Najimova A M, Uzakov B T and Seytmuratov BT 2019 Analysis and calculation of optimum parameters of electric arc furnace *Journal of Physics: Conference Series* **1399** doi:10.1088/1742-6596/1399/5/055048

[14] Taslimov A D, Berdishev A S, Melikuzuev M V and Rakhimov F M 2019 Method of selecting parameters of cable lines distributive networks 10 kv in uncertainty conditions *E3S Web Conf* **139** doi:10.1051/e3sconf/201913901082

[15] Taslimov A D, Berdishev A S, Melikuziyev M V and Rakhimov F M 2019 Method of choosing the unification of cable sections of electric network cables under conditions of load development uncertainty *E3S Web Conf* **139** doi:10.1051/e3sconf/201913901081