Economic Load Intervals for Selecting 10 Kv Cable Cross-Sections for Agricultural Consumers

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ECONOMIC LOAD INTERVALS FOR SELECTING 10 KV CABLE CROSS-SECTIONS FOR AGRICULTURAL CONSUMERS

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Annotation. The article considers the problem of choosing the number and values of standard cross-sections of cable cores of rural distribution electric networks by the method of economic load intervals based on an optimization model for various values of the calculation period taking into account limiting conditions and the influence of various factors and defines the boundaries of the economic load intervals for standard cable cross-sections.

Keywords: optimization model, sections, load growth, economic intervals, estimated period.

Introduction. Currently, agricultural distribution electric networks have a constant increase in load. In these conditions, the correct choice of the parameters of cable lines and residential cable line is of great importance. Due to the complexity of increasing the throughput of cable lines and dynamic networks, problems arise with the choice of optimal paths for wires and residential cables for agricultural lines.

Methods. Recognition and the greatest application for solving this problem has received the method of economic intervals [1,2]. However, it should be noted that mainly the economic load intervals were calculated and widely used to select the wires of overhead power lines. To select the cross-sections of cable cores of cable power lines, economic current density is widely used to date, which does not meet the minimum cost condition. In this regard, it became necessary to determine the economic load intervals for the choice of cross-sections of cable conductors and related tasks.

Results and Discussion. When applying the method of economic intervals, boundaries of the economic intervals of the load are determined from the condition

$$З_i = З_{i+1} \quad (1)$$

where $З_i$ –is the cost of a cable line with a cross-section of cable conductors F_i; $З_{i+1}$ - the same, with the cross-section of the cable veins F_{i+1}.

With regard to the definition of economic load intervals, the costs of cable power lines can be determined as follows [3]

$$З = (E_н + p_a)K \frac{U_П 10^{-5}}{U_н^2 \gamma F}\left[S_1^2 + \sum_{t=2}^{T} (S_t^2 - S_{t-1}^2)(1+E_{нп})^{1-t}\right] \quad (4)$$

An analysis of the technical and economic indicators of 10 kV cable power lines in rural areas showed that, in accordance with the conditions for the existence of economic intervals [2], all standard cable core sections have economic load intervals.

If the load throughout the entire period under review is constant and does not change in time, i.e.

$$S_t = S_{t-1} = S$$

then $З_i$ and $З_{i+1}$ in the expression (1) in accordance with (4) will take the form

$$З_i = (E_н + p_a)K_i + \frac{U_П S^2 10^{-5}}{U_н^2 \gamma F_i} \quad (5)$$

$$З_{i+1} = (E_н + p_a)K_{i+1} + \frac{U_П S^2 10^{-5}}{U_н^2 \gamma F_{i+1}} \quad (6)$$

Equating expressions (5) and (6) in accordance with condition (1) and solving the obtained equation with respect to the load, we obtain an expression for determining the boundaries of economic intervals for adjacent sections for the case that does not take into account the dynamics of load growth

$$S_{гр} = \sqrt{\frac{(E_н + p_a)(K_{i+1} - K_i)U_н^2 \gamma F_{i+1} F_i 10^5}{U_П (F_{i+1} - F_i)}} \quad (7)$$

From the expression (7) it can be seen that the sectors that determine the boundaries of the economic intervals of the load can be divided into two groups: constant and variable. The former include conductivity and standard sections F_i and F_{i+1}. The group of constant factors can also conditionally include the standard efficiency coefficient $E_н$, the rate of depreciation deductions pa and the stress $U_н$.

A completely different effect on the economic intervals of the load has a change in load over time. If the load growth is expressed relative to its value at the end of the billing period, then the boundary values of the economic loading intervals can be determined by the following expression

$$S_{\text{гр}} = \sqrt{\frac{(E_{\text{н}} + p_a)(K_{i+1} - K_i)U_{\text{н}}^2 \gamma F_i F_{i+1} 10^5}{U_{\Pi}(F_{i+1} - F_i)A}} \quad (11)$$

where A - is the coefficient determined by the law of load growth.

The coefficient A is determined for the exponential, linear laws of load growth and load growth according to the law of a simple modified exponent.

When using coefficient A, the expression for the reduced costs of the power line for any law of load growth can be written as

$$З_i = (E_{\text{н}} + p_a)(K_0 + kF_i) + \frac{U_{\Pi} S_T^2 A 10^{-5}}{U_{\text{н}}^2 \gamma F_i} \quad (12)$$

To determine the effect of various laws of load growth, the compared options should be comparable. Comparability conditions are provided if the compared growth laws give the same multiplicity of load growth. Therefore, the previously mentioned laws of load growth must be expressed in terms of the growth rate.

At $t = T$, the load growth factor for the exponential growth law is defined as

$$K_T^{\text{Э}} = \frac{S_T}{S_0}\left(1 + k_{\text{пр}}^{\text{Э}}\right)^2 \quad (13)$$

for the linear law of load growth as

$$K_T^{\text{Л}} = \frac{S_T}{S_0}\left(1 + k_{\text{пр}}^{\text{Л}}\right)^2 \quad (14)$$

Comparability conditions will be met if the load growth factors are determined from expressions (13) and (14) for a given magnitude of the load growth ratio as

$$k_{\text{pr}}^{e} = exp\left(\frac{ln\, ln\, k_T}{T}\right) - 1 \quad (15)$$

$$k_{\text{pr}}^{l} = \frac{k_T - 1}{T} \quad (16)$$

Thus, changes in the boundaries of the economic intervals of the load are studied, depending on possible changes in the source information.

Therefore, having determined the value of $S_{\text{гр}}$ between the first and second sections from a series of nominal sections, there is a real opportunity to determine the boundaries of the economic load intervals for all other standard sections. The value of the coefficient ΔS_i^* **and** $\Delta З_i^*$ are given in table. 1.

Table 1.

The values of the coefficients ΔS_i^* and $\Delta З_i^*$

	Cable cross section F_i, mm²								
	16	25	35	50	70	95	120	150	185
ΔS_i^*	1,00	0,48	0,61	0,87	1,12	1,26	1,37	1,62	2,21
$\Delta З_i^*$	1,00	0,76	1,00	1,40	1,80	2,00	2,20	2,60	3,60

Let us consider the relationship between the difference in reduced costs not within the boundaries of the economic interval of the load for an arbitrary section of cable strands of the cable line and the difference in the reduced costs at the borders of the economic interval of the load for the first standard section of cable strands from the scale of nominal sections Mathematically, this can be expressed as follows

$$\Delta З_i^* = \frac{З_{\text{гр}i}^{\text{в}} - З_{\text{гр}i}^{\text{н}}}{З_{\text{гр}1}^{\text{в}} - З_{\text{гр}1}^{\text{н}}} \quad (17)$$

Substituting the corresponding values into the expression (17) after the simplest transformations, we obtain

$$\Delta З_i^* = \\ = \frac{[F_{i+1}(K_{i+1} - K_i)(F_i - F_{i-1}) - F_{i-1}(K_i - K_{i-1})(F_{i+1} - F_i)](F_2 - F_1)}{F_2(K_2 - K_1)(F_{i+1} - F_i)(F_i - F_{i-1})} \quad (18)$$

Or, given expression (8), after the transformations, we can write

$$\Delta З_i^* = \frac{F_{i+1} - F_{i-1}}{F_2} \quad (19)$$

Thus, it can be seen from expression (19) that the value $\Delta З_i^*$ is determined only by the ratio of the cross sections from the scale of the nominal cross sections of cable cores. The coefficient$\Delta З_i^*$ is given in table. 1.

Studies have shown that the results obtained on the dynamic optimization model can also be considered as economic load intervals for the choice of cable conductor cross-sections. The only difference is that the model allows you to take into account the influence of limiting conditions.

A comparison of the load boundaries obtained on the optimization model with the economic load intervals showed the following. When removing restrictions on long-term permissible current loads and allowable voltage loss, the load boundaries determined by almost coincide with the economic intervals of the load, the optimization model, for any duration of the calculation period. This is clearly seen from the data table. 2, 3.

Table 2.

The upper bounds of the economic intervals of the calculation load

Section, mm²	Billing period, years			
	10	15	20	30
16	269	310	363	513
25	441	507	594	839
35	569	655	767	1086

50	944	1087	1272	1798
70	1169	1346	1575	2227
95	1456	1675	1954	2772
120	2009	2312	2707	3826
150	2417	2782	3257	4604
185	2856	3291	3853	5445

The tables 2 and 3 show the calculation results for the following initial data$l$ = 1 km; $\cos\cos\varphi = 0{,}85$; $U_{п} = 295\ \mathrm{sum\ /\ kW \cdot h}$; $x = 0{,}08$ ohm / km; $U_{н}$ = 10 kV. The amount of investment was taken according to [5-8]. For calculations, an average relative annual load increase of $k_{пр}$ = 0.075 (the law of load growth is exponential) was adopted.

Table 3.

The upper boundaries of the economic intervals of the load model

Section, mm^2	Billing period, years			
	10	15	20	30
16	268	311	361	525
25	443	503	594	831
35	567	658	765	1051
50	948	1095	1274	1795
70	1170	1346	1572	2232
95	1453	1672	1954	2801
120	2009	2315	2718	3852
150	-	2781	3250	4596
185	-	-	3865	5472

Table 4.

Economic load intervals according to the optimization model, taking into account limiting conditions

Section, mm^2	Billing period, years			
	10	15	20	30
16	268	311	361	394
25	443	503	595	613
35	567	651	765	832
50	948	1095	1189	1269
70	1175	1346	1572	1751
95	1453	1672	1954	2145
120	-	2308	2570	5122
150	-	2781	3101	6347
185	-	-	3674	7310

From the data table. 2, 3 it can be seen that for any billing period, the boundaries of economic intervals coincide. The existing discrepancies are explained by the accuracy of the calculations, since when calculating on the optimization model the load boundaries in order to save machine time were determined with an accuracy of 5 kVA. Based on this comparison, we can conclude that the proposed optimization model is correct [9-12].

Conclusions. 1. For the calculation periods of 10 and 15 years, the economic load intervals determined by the method of economic intervals and optimization models, taking into account the limiting conditions, are practically irrelevant (the relative error does not exceed 1%).

2. With a calculation period of 20 years, no upper limits of the economic load intervals were presented for the cross-section of residential cables of 50, 120, 150 and 185 mm2. For the intervals between the boundaries of economic intervals, the loads practically coincide.

3. If the calculation period is 30 years, the boundaries of the economic intervals of the load are not found for all sections. This is due to the influence of limiting conditions.

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