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Optimal tendency of selecting cable cross-sections for agricultural electrical networks

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Optimal tendency of selecting cable cross-sections for agricultural electrical networks

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Abstract. The article determines the optimal development trend of rural distribution electric networks on the basis of a dynamic optimization model taking into account limiting conditions under various laws of load growth using the method of economic intervals and establishes the optimal trend for choosing cable cross-sections for different durations of the calculation period - 10, 15, 20 and 30 years.

Currently, agricultural distribution electric networks are characterized by a constant increase in loads. Under these conditions, the correct choice of the parameters of power lines and, above all, the cross-sections of the wires of overhead lines (OL) and cable strands of cable lines (CL) is of great importance. At the same time, there are technical possibilities to increase the throughput capacity of overhead and cable power lines [1,2,3,4]. However, of all the possible ways to increase the throughput for cable lines, only disaggregation of the load (construction of an additional line or an enlarging substation) can be considered practically acceptable.

In connection with the difficulties of increasing the transmission capacity of cable lines and dynamically developing networks, the problem of choosing the optimal cross-section of cable conductors for lines with an ever-increasing load is aggravated. Based on the foregoing, two options for the development of a cable network are theoretically possible. The first option is to choose the cross section of the cable cores based on the load at the end of the billing period, equal to the cable line service life, in order to ensure the necessary line capacity without reconstruction during the entire cable service life. The second option is that the cross section of the cable conductors is selected based on the load at the end of the billing period, which is less than the cable service life, and then the throughput is increased by laying a parallel cable.

Moreover, based on the conditions of comparability of comparison of possible development options taking into account the specifics of CL the full billing period should be taken equal to the life of the cable line. However, in real conditions there is no necessary reliable information about the change in load for such a long period. Therefore, it is necessary to initially determine the optimal development trend of cable lines under a dynamically changing load, which would allow making the right decisions regarding cable networks based on information for a shorter period than the life of cable lines. In studies, it is advisable to consider the load growth according to the laws of exponential

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(exponential), linear and simple modified exponential [5]. Graphically, the laws of load growth are shown in figure 1.

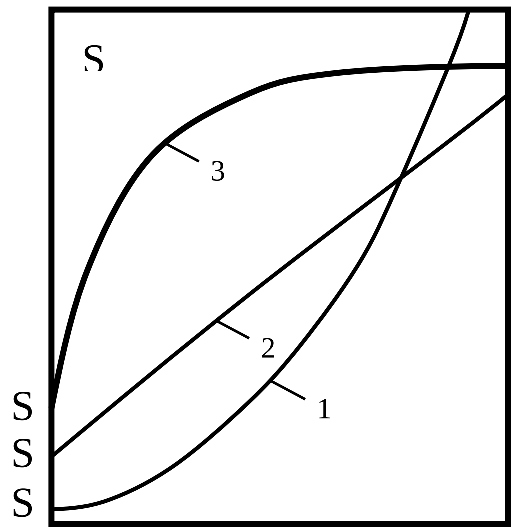

Figure 1. Laws of load growth
1 - exponential; 2 - linear; 3 - modified exponential.

Using the exponential function of load growth allows you to conduct research for the conditions of constant specific annual load growth. The load at any time is determined by the expression

$$S_t = S_T(1+k_{load})^{t-\tau} \tag{1}$$

where S_T– load at the end; k_{load} – load growth factor.

Studies with a linear increase in load allowed us to study the trends in building a cable network with constant absolute load increments. With the linear law of growth, the load at any time is determined by the formula

$$S_t = S_T(1+k_{load}T)^{-1}(1+k_{load}t) \tag{2}$$

A simple modified exponential function allows us to study the development of CL in the conditions of a decrease in the annual relative load increase to zero and further load constancy. This model of load growth made it possible to study the optimal trend in close to operational conditions, when the load in the line reaches a certain limit and remains constant in the future due to its redistribution. In this case, the load is determined by the formula

$$S_o = S_T - (S_T - S_0)m^t \tag{3}$$

where *m* - is a coefficient that determines the dynamics of load growth.

where *m* - is a coefficient that determines the dynamics of load growth.

To optimize the choice of the CL initial cross-section and increase its throughput with a further increase in load, a model has been developed (figure 2), which corresponds to the following possible in real-life situations.

Initially, laying of one cable of each of *N* sections or two parallel cables of any of N sections, including equal ones, is considered. During operation, with an increase in consumer load, the following options are considered every year: the cable originally accepted (or parallel cables) remains or an additional second cable is laid in parallel with the existing cable. In this case, options with all *N* nominal cross-sections of cable conductors are considered.

Thus, a sufficiently large number of options for power supply to the consumer are considered (with the existing standard scale of nominal cross-sections of cable conductors, there are 65 each year of development of the network).

In the first case, the cross-section of the cable conductors is selected according to the nearest load, and then when the load reaches the maximum permissible value, the line throughput is increased by laying a parallel cable. With this approach, the initial investment is small, but the cost of covering the losses of electricity in the line is greater and there are additional investments for reconstruction.

In the second case, the cross-section of the cable conductors of the cable line is immediately selected of such a magnitude (or two parallel cables with the corresponding cross-sections of the wires are immediately laid) so that it is not necessary to increase the transmission capacity of the transmission line in question within the accepted period. At the same time, there will be large initial investments, but relatively lower costs for reimbursing electricity losses. Therefore, the choice of consumer power supply option must be made in an optimal way. The optimization criterion accepted total costs [6,7,8].

Studies on the proposed dynamic optimization model were carried out for all the laws of load growth considered above. In this case, a change in the initial load was set in the range from 20 to 1000 kW.

It is important to establish the influence on the optimal trend of limiting factors - long-term allowable current loads and allowable voltage losses. As for the long-term permissible current loads, they are strictly regulated for cables of a certain brand, while the magnitude of the allowable voltage loss can, depending on specific conditions, fluctuate quite significantly [9,10].

Studies on the optimization model were carried out with the following initial data: E_H = 0.12; p_a = 0.043; l = 1 km; T_m = 1900 h / year; = 0.032 km / ohm $\cdot mm^2$; $cos\ cos\ \varphi$ = 0.85; U_H = 10 kV; x = 0.08 ohm / km. The amount of investment was taken according to [1] for cables of the AAShv brand when laying in a trench. The values of long-term permissible current loads for cables with impregnated paper insulation were adopted according to [11], and the value of permissible voltage loss is 0.8% / km. In the initial calculations, the exponential law of load growth was considered. At the same time, the average value of the load growth coefficient k_{pr} equal to 0,075 was taken. The optimal tendency to choose the cross-section of cable conductors was studied at different durations of the calculation period - 10, 15, 20 and 30 years. The calculation results are graphically presented in figure 3.

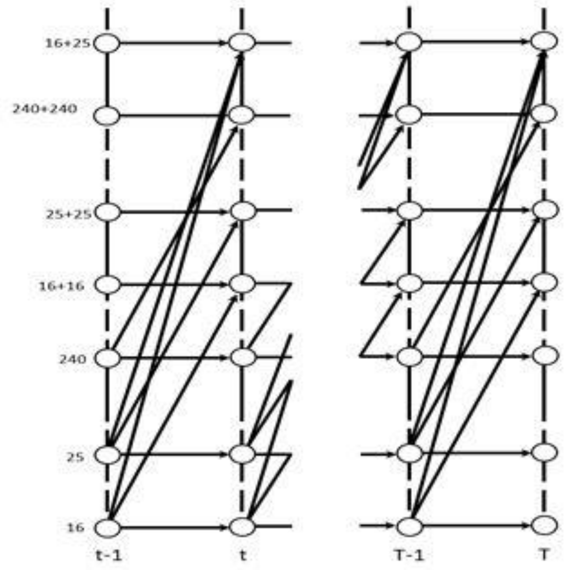

Figure 2. Fragment of the optimization model.

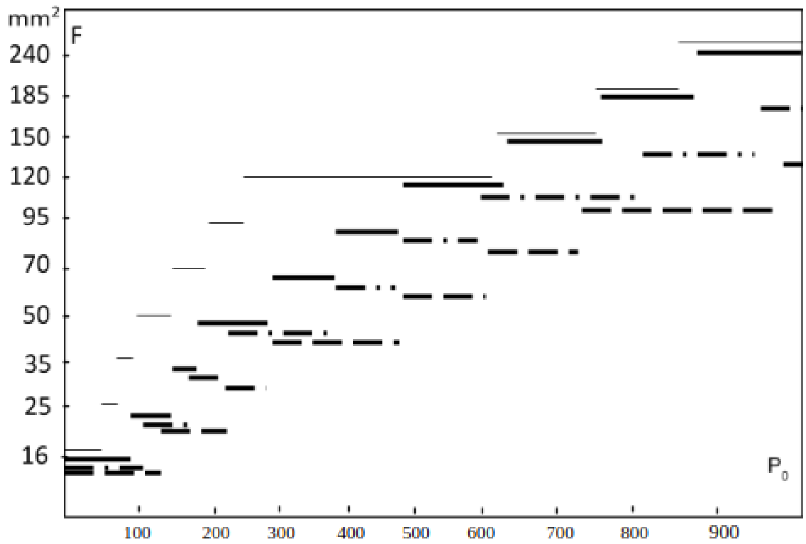

Figure 3. The choice of cross-sections of cable conductors, taking into account restrictions for different billing periods
Estimated period T: — — — - 10 years; — · — - 15 years; ——— - 20 years; ----- - 30 yearsю

Studies on the optimization model, taking into account the limiting conditions, have shown that for a calculation period of up to 20 years, the tendency for an optimal choice of cable cross-sections is that a cable with an optimal cross-section of wires depending on the initial load is immediately selected for the entire period, and during operation line throughput is not performed. With an increase in the duration of the billing period *T*, the tendency to choose cross-sections of cable cores changes slightly. Depending on the magnitude of the initial load, either power lines with one cable for the entire billing period (with small initial loads) can be selected, or a cable with the required cross-section of conductors can be initially selected, and then for a certain year (usually no less than 20 years) parallel to the first cable is laid the second. Moreover, the construction at the beginning of the operation of the cable line with two parallel cables is not economically feasible [12].

With an increase in the initial load, the cross-sections of the cable conductors that are planned for laying at the beginning of the billing period are selected almost sequentially on the scale of the nominal cross-sections of the cable conductors in increasing order (see figure 3).

Thus, with a settlement period of up to 15 years, the optimal tendency is to choose a cross-section of cable conductors based on the loads of this period. With an increase in the settlement period to the service life of cable lines (30 years), the established optimal trend for the choice of cable conductor cross-sections remains generally. However, at the same time, the influence of the adopted restrictions is already observed, due to which, in a number of cases and mainly with sufficiently large initial loads (i.e., when choosing large cross-sections of cable conductors), it is optimal to lay parallel to the existing second cable after 20 or more years of operation.

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