Method of selecting parameters of cable lines distributive networks 10 kv in uncertainty conditions

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Abstract. The article discusses the task of selecting the optimal number of types and values of standard cable sections of urban distribution electric power supply systems under conditions of uncertainty of electric load development using zoning method and proves the expediency of using a very limited number of standard cable sections (application of one or two standard cable sections at wide range of load DNcity variation).

The construction and development of distributive networks(DN) in time is determined by the influence of a number of factors and the choice of parameters of the elements of DN is carried out taking into account the uncertainty of a complex of factors characterizing the development of the load in the considered time period.

Construction and development of distributive networks(DNs) in time are caused by the influence of a number of factors and selection of parameters of DN's elements is carried out taking into account uncertainty of the set of factors characterizing the development of load in the considered period of time. At the same time, such factors are usually considered: normative coefficient of efficiency of capital investments, coefficient of initial load in shaDN of the project, laws of increase of load over time; Annual uniform and uneven load growth; Year of achieving design load from the moment of transformer substation (TS) commissioning; Considered period of time, for example, estimated operation time of the designed network before its reconstruction [1].

Selection of parameters values of avionics cables shall be performed on the basis of optimization criterion under conditions of uncertainty of initial information [2]. At the same time, depending on whether the information belongs to a certain information situation, it is necessary to use one or another criterion of decision selection [3,4]: Bayes criterion, Bernoulli - Laplace criterion, Wald and Savage criterion, Gurwitz criterion.

The general disadvantage of choosing a solution according to these criteria is that the obtained solutions are little sensitive to additional information about uncertain factors [4]. And if the DNults of selecting the optimal number of cable sections according to the Wald, Savage, and zoning criteria are the same, the final decision is applied. Otherwise, different criteria [5,6] are used.

The main disadvantage of choosing a solution according to Wald and Savage's criteria is the subjective

evaluation of the optimal solutions obtained, which leads to different DNults. Thus, at a given value of electrical load DNcity, the quantity sections of SES cables found on the Wald criterion are less than those obtained on the Savage criterion or equal to them. This is due to the fact that the use of the Wald principle is oriented to the maximum value of the DNulting undefined factor, and on the Savage criterion the DNult depends on both the maximum and minimum values of its values. In this case, the values of the undefined factors given by the intervals must be supplemented by reasonable assumptions about the reliable values of the undefined factors. An illustration of such an addition is the method of zoning a plurality of vectors of the state of nature [1,9].

For the task of selecting the number of cable sections, the zoning method [1,9] consists in dividing the set S of possible values of the DNulting undefined factor F into areas, in each of which a certain strategy is optimal (in our case, some number of cable sections from the set N under consideration).

The zoning method is based on the operation of dividing the set S into subclasses of two NF1NF1 strategies.

The pairwise boundary equation is defined by the equality of optimization criteria for the NF1NF1 strategy, i.e.:

$$Z(N_F, \Phi) = Z(N_F + 1, \Phi). \quad (1)$$

If the paired boundary is outside the state vector field [4], i.e.

$$\max_{\Phi} \Delta Z(\Phi) < 0, \quad \min_{\Phi} \Delta Z(\Phi) \geq 0,$$

Where $\Delta Z(\Phi) = Z(N_F, \Phi) - Z(N_F + 1, \Phi)$,

Then one of the strategies cannot be optimal under any circumstances and is excluded from consideration. If the

paired boundary intersects the field of nature state vectors, i.e.

$$\max_{\Phi} \Delta Z(\Phi) \geq 0, \quad \min_{\Phi} \Delta Z(\Phi) < 0$$

then the pair boundary equation (1) is compiled, the solution of which with respect to Φ determines the optimality zone of a certain strategy, i.e. a certain number of used cable sections.

In the problem under consideration, due to the linear dependence of the optimization criterion on the resulting uncertain factor Φ outside the pair boundary, one strategy is strictly optimized over another. To select the number of cable sections, in accordance with [1], the equation of the pair boundary (1) takes the form:

$$\delta_1 + \delta_2 + \delta_3 N_F^{-1} + \delta_4 \Phi_{nap} N_F^{-0.3} = \delta_1 + \delta_2 + \delta_3 (N_F + 1)^{-1} + \delta_4 \Phi_{nap} (N_F + 1)^{0.3}, \quad (2)$$

Where F_{par} - characterizes the boundaries of the area by an uncertain factor in which a certain strategy is optimal.

Decision (2) concerning F_{par} determines the area of optimum application of a certain number of cable sections:

$$\Phi_{nap} = \frac{\delta_3}{\delta_4} \frac{(N_F + 1)^{-1} - N_F^{-1}}{N_F^{0.3} - (N_F + 1)^{0.3}}.$$

An algorithm for selecting the optimum number of cable sections under conditions of uncertainty by zoning method has been developed and a program for selecting the optimum number of cable sections under conditions of uncertainty by zoning method has been created based on the algorithm [7].

At the received initial data [1], Figure 1 shows the zoning of the DNulting undefined factor F by the number of sections of electrical distribution cables 10kV, at that for each power value of transformer substation (TS) the uncertainty zone corDNponding to the maximum and minimum value is defined.

With the accepted initial data [1], in Fig. Figure 1 shows the zoning of the resulting indeterminate factor Φ by the number of cable cross-sections of 10 kV distribution electric networks, and for each power value of the transformer substation (TS), an uncertainty zone corresponding to the maximum and minimum values of the uncertain factor is determined. The zones between the curves determine the optimal number of used cross-sections of 10 kV DN cables.

If, in the uncertainty zone $\Phi_{min} \div \Phi_{max}$, the optimality zones of several numbers of cable sections fall, then it's impossible to get a definite solution. As can be seen from fig. 1a, such a case arises of the capacities of transformer substations (400-2000kVA) when loop circuits of 10kV networks are used. For example, at 630 kVA, two optimality zones of different numbers of cable cross-sections $N_F = 2$ and 3 immediately fall into the uncertainty zone $\Phi_{min} = 1.7 \div \Phi_{max} = 2.8$.

Fig. 1. Zoning of an uncertain factor in the number of used cable cross-sections of DN 10kV.

If the uncertainty interval $\Phi_{min} \div \Phi_{max}$ found for specific conditions falls into the optimality zone of only one value of the number of cable cross-sections, then we can obtain an unambiguous solution to the problem. As can be seen from fig. 1b, such an unambiguous choice is possible with a power of TS 20000kVA or more, when two-beam schemes of 10kV networks are used. In this case, the uncertainty zone $\Phi_{min} \div \Phi_{max}$ falls only in the optimality zone for the use of one cable section for any TS power.

In the above cases, it is recommended to partially or by density remove the uncertainty based on additional information on the values of the uncertainty based on additional information on the values of the uncertain factors [1]. Expert information is used as additional information about the values of uncertain factors.

To determine the most probable (real) values of the considered uncertain factors, a survey of leading specialists in the design and operation of urban DN.

The ratios of weighting coefficients of additional criteria obtained from experts were processed by the direct assessment method [8]. The total ranks for all ratios are determined and the ratios are adjusted. In this case, the ratio corresponding to the lowest rank, i.e.

$$X_{min} = \min(x_1, x_2, \dots, x_n),$$

where $x_1, x_2, \dots, x_n$ are different ratios of weighting coefficients of additional criteria.

In this case, the minimum and maximum values of the resulting uncertain factor were determined according to [1]; moreover, Φ_{min} corresponded to the values $\beta_{2min}(v) = 1.01$ (0.6), $tpr(min) = 2$ years, $Tp(min) =$

10 years, and at $\Phi_{\max} - \beta_{2\min}(\nu) = 1.1 (0.6)$, $t_{pr}(\max) = 10$ years, $T_r(\max) = 25$ years

Using expert assessments, the minimum and maximum values of the normative coefficient of efficiency of capital investments, the initial load coefficient in fractions of the design factor, the factor of uniform (uneven) increase in load $\beta(\nu)$, the values of the estimated period T_r and the value of the time to reach the project load t_{pr} are determined, and also determined their most likely values. As a result, the most likely (average) values of the factors are:

$\kappa_{np} = 0.8$; $p_u = 0.2$; $\beta_{cp}(\nu_{cp}) = 1.02 (0.4)$, $t_{np.cp} = 5$ years, $T_{p.cp} = 25$ years, and then the value of the resulting indeterminate factor $\Phi_{cp} = 1.7 (2.8)$.

As can be seen from fig. 1a, for small capacities of TS for loop network circuits ($\sigma < 10 \text{ mVA} / \text{km}^2$), at $F_{sr} = 1.7$, which corresponds to the uniform law of load growth, it is optimal to use one or two cable sections in 10 kV DN, and at $F_{sr} = 2, 8$, which corresponds to the uneven law of load growth, one cable section is optimal. Thus, the results confirm the advisability of using a very limited number of cable cross-sections of urban 10 kV DN and lead to the same quantitative results: it is optimal to use one and two standard cable cross-sections in the networks under consideration. At the same time, it is recommended that at high load densities and double-beam network circuits - use a section of 120 mm^2 ; at low load densities, when loop circuits are used, one section is 120 mm^2 or two sections 185 and 70 mm^2 . In addition, the results obtained in terms of the number of cable cross-sections used in RES correspond to similar foreign technical solutions (France, Germany, Poland, Russia, etc.), which is a certain confirmation of the reliability of the results.

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