Optimization of electric networks modes under conditions of partial uncertainty of initial information

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Abstract. One of the problems of modern power systems management regimes associated with the probabilistic nature of the starting information. In such circumstances, the decision of relevant control tasks based on deterministic methods lead to unacceptable or non-optimal results. Therefore, this article questions optimization of energy systems based on functional limitations in terms of probability of the initial information

1 Introduction

Currently, most of the methods and algorithms for calculating and analyzing the modes of electric power systems are based on the use of deterministic models. In this case, the nature of the ongoing process is determined unambiguously for the given schemes and operating parameters. Such models are characterized by high accuracy and speed, all influencing factors are taken into account as much and accurately as possible. However, to assess any one or several parameters based on this model, each time it is required to carry out calculations according to the full scheme with the appropriate preparation of the initial data and a greater cost of estimated time. At the same time, it does not seem possible to take into account all influencing factors, especially the probabilistic nature of the initial information. Therefore, the calculation result with the corresponding error reduces the effect of solving the problem [1-7].

In this regard, the issues of synthesis of control laws for limited information are topical. To solve these questions, regression models can be effectively used, the features of which are the establishment of statistical links between the controlled parameters and the factors influencing them.. In the tasks of optimizing the modes of electrical networks, such parameters are most often taken to be the optimized parameters - the voltages of the reference nodes, the reactive powers of the controlled sources and the transformation ratios of the controlled transformers [8-15].

2 The mathematical statement of the problem

In such problems, the coefficients of the regression equations are determined in advance on the basis of regression analysis and the use of an appropriate approximation method, most often the least squares method. This paper presents the results of research on the modes of electrical networks under conditions of partial uncertainty of the initial information. A quadratic equation is taken as a regression equation. The factors were the loads of the nodes. Optimized parameters - voltages of nodes with adjustable reactive powers - are accepted as responses. The regression equation for the optimized node stress is as follows:

$$U_i = a_{io} + \sum_{j=1}^{n} ij\, P_j + \sum_{j=1}^{n} \sum_{k=j}^{n} a_{ijk}\, P_j P_k$$

Where n is the number of nodes in the electrical network, a_{i0}, a_{ij}, a_{ijk} –the coefficients of the regression equation, which determines the coefficients of the regression equations, the values of the load factors of the nodes were set in a certain range by a random number generator. And the correspondence of the response value was determined on the basis of optimization by the deterministic method [16-24].

The work investigated the dependence of the accuracy of the regression model on the number of experiments (number of samples). The results of the experimental calculations for various typical schemes of electrical networks showed that to determine the coefficients of the regression equations, at which the process under study is modeled with sufficient accuracy for practical purposes, it is advisable to use experimental planning methods with the adoption for each factor in a given range of three values - minimum, average and maximum. In this case, the number of necessary experiments is equal to 3n, where n is the number of factors (nodes with partially undefined loads) .

3 Modelling of redundant scheme of energy source structure

The studies, in particular, were carried out for the electrical network, the diagram of which is shown in Pic. 1.

The loads of nodes 1, 4 and 7 are partially undefined. The minimum and maximum possible active loads and tgφ for these nodes are given in Table 1.

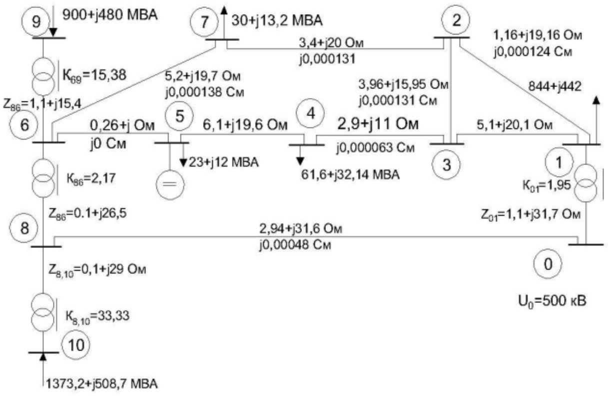

Fig. 1. Electrical network diagram

Table 1. Load of nodes

	P_1, MW	P_4, MW	P_7, MW
Minimum	801,8	55,4	27
Average	844,0	61,6	30
Maximum	886,2	67,76	33
tgφ	0,5236	0,5217	0,4403

Optimization of the electrical network mode is carried out according to the voltages of nodes 5 and 9 where there are adjustable sources of reactive power.

Below are the regression equations, the coefficients of which were obtained on the basis of a statistical experiment with the number of samples of 500 and the method of experiment planning.

1) based on a statistical experiment with 500 samples:

$U_5 = 220{,}83 + 0{,}0413 \cdot P_1 + 0{,}3582 \cdot P_4 - 0{,}0343 \cdot P_7 - 0{,}00011074 \cdot {P_1}^2 + 0{,}00078887 \cdot P_1 P_4 + +0{,}00087082 \cdot P_1 P_7 - 0{,}00574887 \cdot {P_4}^2 + 0{,}00182516 \cdot P_4 P_7 - 0{,}0119837 \cdot {P_7}^2.$

$U_9 = 15{,}2 - 0{,}000004 \cdot P_1 - 0{,}00001 \cdot P_4 - 0{,}000023 \cdot P_7 + 0{,}000000002 \cdot P_1^2 + 0{,}000000006 \cdot P_1 P_4 + 0.000000017 \cdot P_1 P_7 + 0{,}000000031 \cdot P_4^2 + 0{,}000000059 \cdot P_4 P_7 + 0{,}000000086 \cdot P_4^2.$

2) experiment planning method:

$U_5 = 112{,}72 + 0{,}775 \cdot P_1 + 17{,}63 \cdot P_4 - 0{,}7584 \cdot P_7 - 0{,}00055488 \cdot {P_1}^2 + 0{,}00097513 \cdot P_1 P_4 + +0{,}000776 \cdot P_1 P_7 - 0{,}01980088 \cdot {P_4}^2 + 0{,}00428843 \cdot P_4 P_7 - 0{,}0023226 \cdot {P_7}^2.$

$U_9 = 15{,}2 - 0{,}000001 \cdot P_1 - 0{,}0000004 \cdot P_4 - 0{,}0000005 \cdot P_7 + 6{,}65 \cdot P_1^2 + 0{,}000000006 \cdot P_1 P_4 + 0.000000017\ P_1 P_7 + 0{,}000000031\ P_4^2 + 0{,}000000059\ P_4 P_7 + 0{,}000000086 \cdot 10^{11} \cdot P_1^2 + 2{,}3 \cdot 10^{-10} \cdot P_1 P_4 + 2{,}6 \cdot 10^{-10} \cdot P_1 P_7 + +1{,}46 \cdot 10^{-9} \cdot P_4^2 + 1{,}3 \cdot 10^{-9} \cdot P_4 P_7 + 3{,}55 \cdot 10^{-9} \cdot P_7^2.$

The verification of the adequacy of the regression equations was carried out on the basis of calculating the total losses in the networks by carrying out optimization according to the complete scheme of the electrical network and determining the optimal voltages for the nodes by the obtained regression equations for various values of the loads of nodes 1, 4, and 7.

The root-mean-square deviation of the total losses of active power in the networks when using the regression equations turned out to be less than 0.1%, which quite satisfies the requirements of practical calculations.

Table 2 contains the results of optimization of the modes of electrical networks for some specific values of the loads of nodes 1, 4, and 7 according to the full scheme based on a deterministic algorithm and using regression equations with coefficients obtained when planning an experiment [25-37].

Table 2. Optimization results

Loads of nodes, MW			Full-scheme optimization			Optimization based on a regression model		
P_1	P_4	P_7	U_5, kV	U_9, kV	π MW	U_5, kV	U_9 kV	π MW
801,8	61,6	33,0	235,50	15,2	80,892	235,28	15,2	80,944
886,2	61,6	27,0	228,82	15,2	84,195	228,54	15,2	84,316
844,0	67,76	30,0	235,16	15,2	81,486	223,96	15,2	81,791

4 Conclusions

Thus, the results obtained confirm that the adopted regression model has a sufficiently high calculation accuracy and allows one to determine the optimal values of the controlled parameters (in this case, the voltages of nodes 5 and 9), even in conditions of insufficient information required for optimization according to the complete circuit of the electrical network.

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