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APPLICATION OF THE METHOD OF INDETERMINATE LAGRANGE MULTIPLIERS FOR OPTIMAL POWER DISTRIBUTION OF COMPENSATING DEVICES BETWEEN CONSUMERS

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Abstract:

This article discusses the calculations of determining the optimal value of the reactive power among consumers in terms of the lowest costs and compensation for active power losses using Excel. The most optimal option is to calculate by coordinates, and the results obtained using nonlinear programming methods are compared with each other.

Keywords: power supply schemes, optimization, Lagrange method, nonlinear problem, constraint, objective function.

INTRODUCTION. In the production of electricity at power plants and consumption in the national economy of Uzbekistan, special attention is paid to improving its quality and rational use.

Optimization is usually understood as a purposeful activity, which consists in obtaining the best results under appropriate conditions. The formulation of an optimization problem implies the presence of its object, the presence of independent parameters (variables) that describe this problem, as well as conditions (often called restrictions) that characterize the acceptable values of independent variables. An obligatory component of the description of the optimization problem is a scalar measure of "quality", called the criterion of optimality or the objective function, which depends on the optimization variables. The solution of the optimization problem is the search for a certain set of values of variables, which corresponds to the optimal value of the optimality criterion.

When designing a power supply scheme, as a rule, the monetary costs of this scheme are minimized. Reducing power losses due to the installation of compensating devices reduces the costs of the circuit, however, compensating devices also require monetary costs.

METHODS. In this regard, the problem arises of determining the optimal power of compensating devices that meets the minimum of total costs. Such a problem belongs to the problem of unconditional optimization and can be solved, for example, by gradient methods.

Consider such a problem for a radial power supply circuit (Fig. 2.). The power supply has a voltage of U. N consumers with reactive capacities Q1, Q2, ... Qn are powered from this source. The active resistances of the lines between the source and consumers are R1, R2, ... Rn. Each i-th consumer can have a Qki compensating device installed [1].

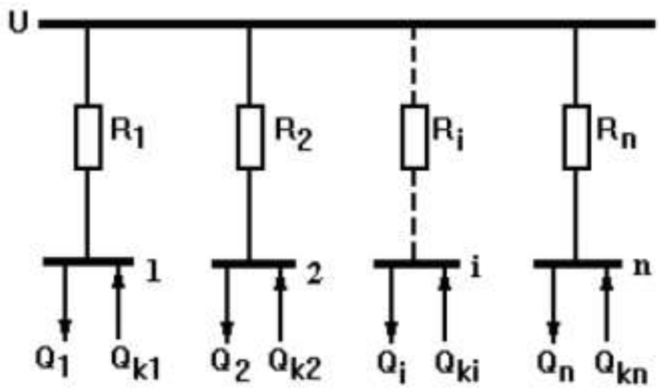

Fig. 2. Radial power supply scheme

It is required to find the optimal distribution between consumers 1,6 2, ... n of the given total power of compensating devices Q_k.

The optimality criterion is the minimum loss of active power in the circuit [1, 2, 3].

The objective function to be minimized, which is the loss of active power in the circuit, has the following form [7], [9]:

$$\Delta P = (Q_i - \sum_{i=1}^{n} Q_k)^2 R_i / U^2 \to min. \qquad (1)$$

The relative minimum of the objective function is sought under the constraint:

$$Q_{ki} = \sum_{i=1}^{n} Q_k \quad \text{или} \quad Q_{ki} - \sum_{i=1}^{n} Q_k = 0. \qquad (2)$$

Let 's write down the Lagrange function:

$$L = \frac{(Q_i - \sum_{i=1}^{n} Q_{ki})^2 R_i}{U^2} + \lambda(\sum_{i=1}^{n} Q_{ki} - Q_k) \to min. \qquad (3)$$

To find the minimum of the function L, we calculate its partial derivatives and equate them to zero:

$$\frac{dL}{dQ_{k1}} = -\frac{2R_1(Q_1 - Q_{k1})}{U^2} + \lambda = 0,$$

$$\frac{dL}{dQ_{k2}} = -\frac{2R_2(Q_2 - Q_{k2})}{U^2} + \lambda = 0, \qquad (4)$$

....

$$\frac{dL}{dQ_{ki}} = -\frac{2R_i(Q_i - Q_{ki})}{U^2} + \lambda = 0,$$

$$\frac{dL}{dQ_{kn}} = -\frac{2R_n(Q_n - Q_{kn})}{U^2} + \lambda = 0,$$

$$\frac{dL}{d\lambda} = \sum_{i=1}^{n} Q_{ki} - Q_k = 0.$$

RESULTS. The analysis of system (4) shows that the optimal distribution of the given total value of the Qk compensating devices in the radial power supply scheme obeys the equality [6], [8], [10]:

$$R_1\, Q_1 - Q_{k1} = R_2\, Q_2 - Q_{k2} = \cdots = R_i\, Q_i - Q_{ki} = \cdots = R_n\, Q_n - Q_{n1}. \qquad (5)$$

Let's consider the solution of optimization problems in the example of Fig. 2.

The working field for entering initial information is shown in Fig. 1. In cells B2...B10 there is numerical initial information. The desired values of the variables Q_{k1} and Q_{k2} are in cells F1 and F2. The initial values of these variables are assumed to be zero [11], [12].

	A	B	C	D	E	F
1	**исходные данные:**				**переменные**	
2	Q1=	600			Qk1=	0,0
3	Q2=	800			Qk2=	0,0
4	R1=	6				
5	R2=	4				
6	U=	10			**Целевая функция**	
7	z0=	0,5			Z=	1432,0
8	c0=	10				
9	a1=R1*c0*10^-3/U^2=	0,0006				
10	a2=R2*c0*10^-3/U^2=	0,0004				
11						
12	**Ограничения:**					
13	Qk1>=0					
14	Qk2>=0					
15						

Fig. 1. Initial information of a nonlinear problem on the working field

Table 1
Bringing the coordinate descent with a constant step

Step Number	Q_{k1}	Q_{k2}	Z	Note
At the beginning	0	0	1432	In the direction of Qk2 and start the descent
The first step	0	400	864	
The second step	0	800	616	
The third step	0	1200	689	Obviously, it is advisable to stop the descent along the Q_{k2} coordinate, and return to the values of the second step
A new third step	400	800	624	

The solution of this nonlinear problem using Excel software is given [13].

The objective function of fig. 2. using (1) has the form:

Z=z0(Qk1+Qk2)+a1(Q1+Q2–Qk1–Qk2)2+a2(Q2–Qk2)2,

where a1=R1*c0*10-3/U2=0,0006, a2=R2*c0*10-3/U2=0,0004.

An expression is entered in cell F7 to calculate the value of this objective function:

= B7*(F2+F3)+B9*(B2+B3-F2-F3)^2+B10*(B3-F3)^2.

In the dialog box "Search for a solution" (Fig. 2.), the address of the cell of the objective function F7 [4], [5] is set, it is noted that the minimum value of the objective function is being searched; the addresses of cells with the desired variables F2, F3 are indicated; boundary conditions of non-negativity of the desired variables $Q_{k1} \geq 0$ $Q_{k2} \leq 0$are introduced as constraints.

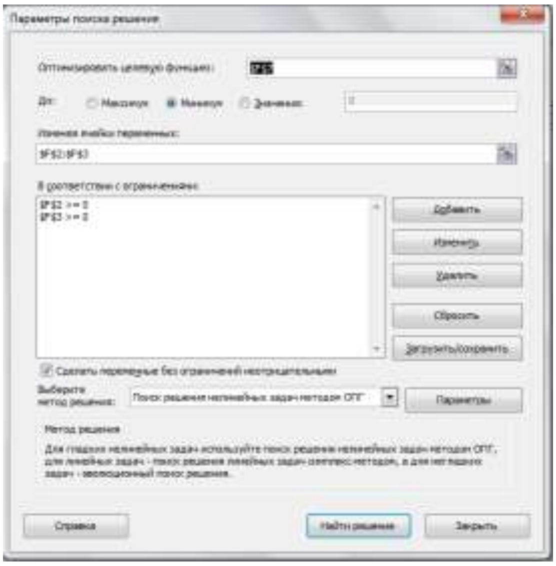

Fig. 2. The "Solution Search" dialog box

CONCLUSION. The results of solving a nonlinear problem, issued by a computer to the working field, are shown in Fig. 3.

The results of the solution are as follows: Q_{k1}=183.3 kVAr, Q_{k2}=800 kVAr, Z=596 Y.e.

This solution is more accurate, the value of the objective function is 28 y.e. less than in the method of coordinate descent with a constant step.

	A	B	C	D	E	F
1	**исходные данные:**				**переменные**	
2	Q1=	600			Qk1=	183,3
3	Q2=	800			Qk2=	800,0
4	R1=	6				
5	R2=	4				
6	U=	10			**Целевая функция**	
7	z0=	0,5			Z=	595,8
8	c0=	10				
9	a1=R1*c0*10^-3/U^2=	0,0006				
10	a2=R2*c0*10^-3/U^2=	0,0004				
11						
12	**Ограничения:**					
13	Qk1>=0					
14	Qk2>=0					

Fig. 3. Results of solving a nonlinear problem on the working field

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