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OPTIMIZATION OF OVERHEAD LINE PARAMETRES BY CRITERIAL METHOD USING FUZZY MODELING

The algorithm of optimum values of wires cross-sections and overhead lines voltages calculation by criterial method using fuzzy modeling in conditions of uncertainty is offered.

***Keywords**: criterial method, fuzzy modeling, Mamdani's model, parameters of overhead lines.*

Importance of the problem

Prior to building of new electrical network, expansion or reconstruction of existing one, design and research are performed. At designing the most rational alternative of problem solution is chosen. For profitability quantitative assessment the value of economic charges for operation meanings and maintenance of its separate elements is used. In practice of electrical networks designing the method of alternative comparison is used. At its application not one, but several possible alternatives of design solution are elaborated , each of them is studied in details to determine its basic engineering properties, technical and economic performances. The important problem in designing is determination of economically expedient voltage and cross-sections of wires of overhead lines (OL) [1, 2].

While solution of optimization problem aimed at obtaining minimum value of expenditures for construction and operation of overhead lines the following problems occur [1, 2]:

- necessity to solve equations systems with complexity degree more than zero;
- very sloping criterion function.

Goal of the work is working out of the algorithm of optimum values of wires cross-section and power lines voltages calculation by criterial method using fuzzy modeling in conditions of uncertainty.

Transformation of expenditures function from absolute units into relative and creation of system of similarity criteria

Choosing optimum parameters of overhead line, the resulted expenditures can be presented [1, 2]:

$$З=\left[\left(k_1+k_2U-k_3F\right)l+k_4\left(\frac{P}{l}\right)^2\frac{l}{F}\right]+\left[k_5+k_6P+k_7PU+k_8Ul+k_9\frac{Pl}{U}\right], \quad (1)$$

where $k_1 ... k_9$ – cost indexes; U – overhead line voltage; F – cross-sectional area of current carrying parts; l – OL length.

Voltage U and cross-sectional area of wires F of overhead line are variables which are optimized. We will take advantage of criteria method for determination of their values.

Having studied only variable component and having introduced such designations:

$$\begin{aligned} a_1&=k_2l+k_7P+k_8l; \\ a_2&=k_9Pl; \\ a_3&=k_4P^2l; \\ a_4&=k_3l, \end{aligned} \quad (2)$$

let us rewrite (1):

$$З_* = a_1U+a_2U^{-1}+a_3U^{-2}F^{-1}+a_4F. \quad (3)$$

Let us determine minimum value of these charges and corresponding optimum values U_0 and F_0, as well as vector of similarity criteria π. The degree of complexity of this problem is equal to unit.

Proceeding from orthogonality conditions and rationing, we will write the equations system for similarity criteria [2]:

$$\left.\begin{array}{r} \pi_1 - \pi_2 - 2\pi_3 = 0; \\ -\pi_3 + \pi_4 = 0; \\ \pi_1 + \pi_2 + \pi_3 + \pi_4 = 1 \end{array}\right\}. \qquad (4)$$

Formation of dual problem

Functions $d(\pi)$ and $y(x)$ are in such relation:

$$y(x) \geq d(\pi).$$

It means, that if variables x and π are given any values we will obtain y(x) and d(π) such, that the optimum solution of the problem will lay between them (Fig. 1). The specified property of dual problems can be used for construction of iteration process of optimum solution determination.

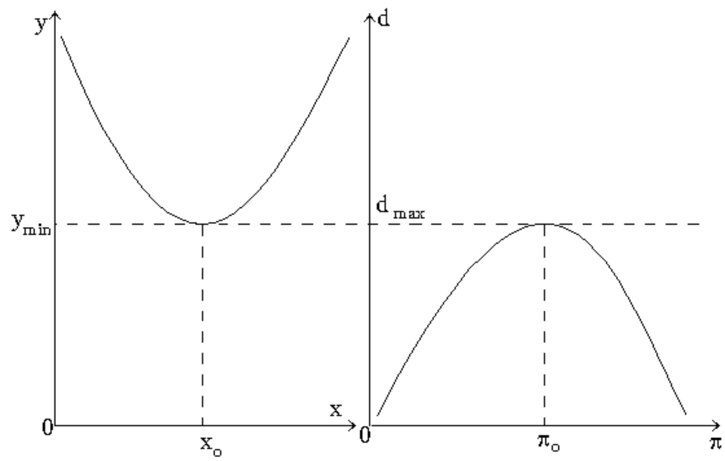

Fig. 1. Minimax principle

Let us write dual function to expression (3)

$$d(\pi) = \left(\frac{a_1}{\pi_{10}}\right)^{\pi_{10}} \left(\frac{a_2}{\pi_{20}}\right)^{\pi_{20}} \left(\frac{a_3}{\pi_{30}}\right)^{\pi_{30}} \left(\frac{a_4}{\pi_{40}}\right)^{\pi_{40}}. \qquad (5)$$

where π_{10}, π_{20}, π_{30}, π_{40} – similarity criteria.

Algorithm of optimization problem solution by criteria method

Algorithm of optimization problem solution by criteria method [1, 2].

1. Nonlinear direct problem is replaced by dual problem with nonlinear criterion function and restrictions in the form of orthogonal system of simple equations. In direct problem variables are physical or economic parameters x, but in dual function similarity criteria π are variables, that is dimensionless combinations of parameters x.

2. Optimum values of similarity criteria are calculated by solution of orthonormal equations system.

3. Obtained similarity criteria are substituted in criterion function of dual problem, and its optimum value is calculated.

At the same time it is optimum solution and direct problem of criteria programming, as relation between direct and dual problems is such, that $d(\pi_0) = y(x_0)$. Characteristic feature is that optimal value of optimum criterion y_0 is calculated without determination of optimal values of variables x_0.

The basic complexity of resulted algorithm is calculation of optimizing vector of similarity criteria.

For determination of system (4) solution fuzzy modeling is expedient to apply because existing methods do not always yield authentic results.

Application of the method of dichotomy is illustrated in Fig. 2. At condition if function d(π) is very sloping, to obtain exact result is impossible; often there appears a problem of method convergence.

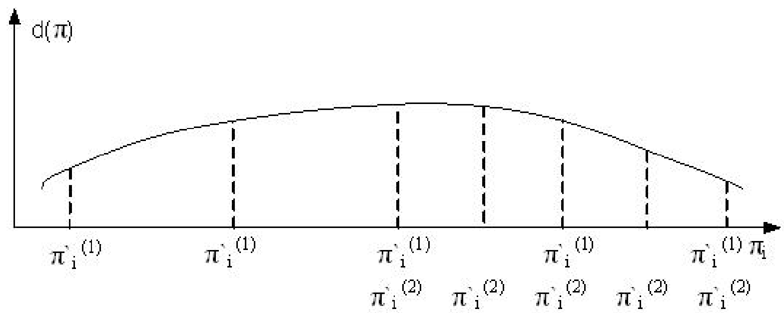

Fig. 2. Determination of maxima of function by dichotomy method

Table 1

Disadvantages of method of function minimum search at degree of complexity of equations systems restrictions more than 1

№	Method	Disadvantages
1	Degree of complexity decrease	
1.1	Delay of optimal values of variables selection	Expedient to use only for separable functions
2	Dual problem linearization	
2.1	Gradient method	Poor convergence at sloping function
2.2	Dichotomy method	Low efficiency at sloping function, require large quantityof iterations
2.3	Method of gold section	Low accuracy
2.4	Method of quadratic interpolation	Appropriate to use only for strongly marked parabolic function

For solution of optimizing problems of functions search and arguments maxima at which this maximum is attained, the method of fuzzy modeling is offered to use. The algorithm is presented in Fig. 3.

Algorithm of optimum values of OL parameters search by critarial method using fuzzy modeling

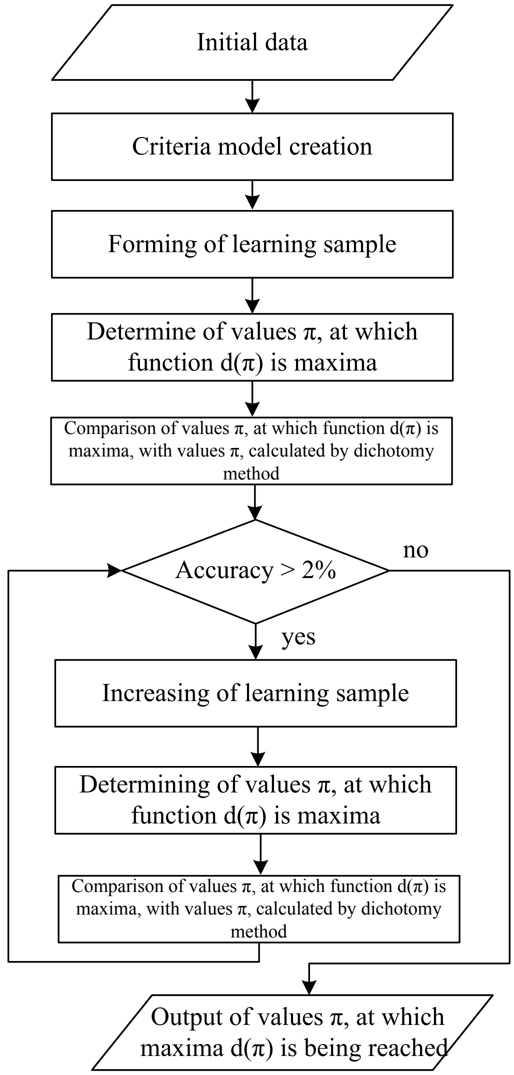

Fig. 3. Algorithm of problem solution

Description of the algorithm optimum values of OL parameters

1. Formation of criteria model provides passage from direct problem of searching minimum of function y(x) to search of maximum of dual function d(π) at set restrictions.

2. Formation of learning sample consists in compilation of logic equations of the type:

if π_1 - large, π_2 - average, π_3 - average, π_4 - average, d(π) - large.

3. Determination of π values at which function d(π) is maximum, is performed in 2 stages:

3.1. Dependences d(π) on π_1, π_2, π_3, π_4 in the form of surfaces are constructed.

3.2. Approximate values of π_1, π_2, π_3, π_4 at which function d(π) reaches maximum , are introduced into the model and more exact calculation is carried out.

4. Obtained result is checked on accuracy (by comparison with calculation results obtained by other methods).

5. When accuracy does not satisfy conditions then learning sample is increased, namely: amount of logic equations is increased and membership function of input values is changed .

Model making

For network creation a multivariant approach was used, namely: alternatives with membership functions of the type trimf, trapmf, gbellmf, gaussmf, pimf, dsigmf, psigmf [3] were considered. The least error is attained in the model with membership function gaussmf.

Having taken advantage of program complex MatLab, the minimum value of function of expenditures for a line of 70 km and transmitted power 300 MW was determined. Mamdani's model was used. 47 rules for obtaining the desired accuracy were formulated. The obtained criterial model has such view:

$$З_{*}=0{,}5U_{*}+0{,}27U_{*}^{-1}+0{,}115U_{*}^{-2}F_{*}^{-1}+0{,}115F_{*}\,. \tag{6}$$

Fig. 4. Calculation results

This model is convenient for analysis of resulted expenditures dependence at deviation of line voltage or cross-sectional area of wires from their optimum values.

Conclusions

The algorithm of OL parameters determination by criterial method with application of fuzzy modeling methods is offered. Usage the developed algorithm will allow to calculate optimum values of voltage and cross-sections of overhead lines in uncertainty conditions. Application of fuzzy modeling tools is perspective direction for the solution of the important problems of power engineering by criterial method.

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