METHODS OF POWER SYSTEMS OPTIMIZATION

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Abstract. The modern power systems have complex elements with complex schema of technological connections. In such complexes the processes of transport and transformation of various kinds of energy with change of parameters of condition and charges of working fluids are proceeded. The decision of optimization problems of power systems is impossible without mathematical modeling. Now are used some mathematical models by virtue of complexity and varieties of power systems structure. We shall briefly estimate some approaches of greatest interest. Method of choice of optimum parameters of system is based on research of spaces of parameters R_n by their uniform filling by points x_j, j = 1, 2...N in all space. In each x_j the value of criterion function Z is calculated. This information is used for procedure of problem perfection and choice of the optimal solution.
Keywords: power systems, processes of energy transport and transformation, mathematical models, optimization problems of power systems.

Rezumat. Sistemele electrice moderne au elemente complexe, cu scheme complexe de conexiuni tehnologice. În astfel de complexe au loc procese de transport şi de transformare a diferitelor tipuri de energie, cu schimbare de parametri de stare şi sarcină ai fluidelor de lucru. Deciziile primvind optimizarea sistemelor electroenergetice sunt imposibile fără modelare matematică. În prezent sunt utilizate unele modele matematice în temeiul complexității şi varietății structurii sistemelor electrice. Vom estima pe scurt unele abordări de mai mare interes. Metoda de alegere a parametrilor optimi ai sistemului se bazează pe cercetarea unor spații ale parametrilor R_n prin umplerea uniformă cu puncte x_j, j = 1, 2 ... N a întregului spațiu. În fiecare x_j se calculează valoarea funcției criteriu Z. Aceste informatii sunt folosite pentru procedura de perfecționare a problemei şi alegerea soluției optime.
Cuvinte cheie: sisteme electrice, procesele de transformare şi de transport al energiei, modele matematice, probleme de optimizare a sistemelor de alimentare.

The modern power systems are complex of difference (and don't similar) elements with complex schema of technological connections. In such complexes the processes of transport and transformation of various kinds of energy with change of parameters of condition and charges of working fluids are proceeded.

The decision of optimization problems of power systems is impossible without mathematical modeling. Now are used some mathematical models by virtue of complexity and varieties of power systems structure. Briefly we shall estimate some approaches that representing of greatest interest.

Method of choice of optimum parameters of system is based on research of spaces of parameters R_n by its uniform filling by points x_j, j = 1, 2...N in all space. In each x_j the value of criterion function Z is calculated. This information is used for procedure of problem perfection and choice of the optimal solution.

For estimation of distributed sequences uniformity degree it is expedient to address to method of multi-dimensional points.

Multi- dimensional point $xj = \{x_{1j}, ..., x_{nj}\}$ of sequences are by ratio $x_{ij} = x_1^b + q_{ij}(x_i^t - x_i^b)$, $i = 1, 2, ... n; j = 1,2, ..., N,$ where x_i^t, x_i^b – top and bottom border of i-th parameter variation, N – number of trial points of regular intervals distributed of sequence $x_1 ... x_n$; $0 < q_{ij} < 1$.

Further it is recommended to pass consistently in vicinity of points where the best results are received by gradually specifying borders of x_i^t and x_i^b. It is necessary to use additional information received by research of simplified dependence or the approached decisions for narrowing space of search.

If it is necessary to express as well only parameters and also block-scheme of the machine (one or some variants) that this optimization method is applied to each structures consecutive.

The similar conclusion can be made for optimization method using multi-dimensional tables of experiments (analogue of statistical method).

The perspective has methods based on ideologies of "branches and borders".

The essence of these methods consists in maintenance of the most economic means of search of the optimum decisions of various optimum problems for synthesis and reduction of look over of multi-dimensional set of the possible solutions $\{P\}$.

The principles of optimal synthesis of technical systems include the basic technological, heuristic and mathematical rules of theory of optimum solution search.

It is supposed that is an optimum synthesis decision for each initial problem of optimum $P^* \in \{P\}$, where $\{p\}$ - a lot of all sense solutions.

The solution P^* is such optimum technological scheme for which the value of efficiency criterion Z is extremal.

There are some principles of optimal technical systems synthesis [1]:

Decomposition-Flow (DF-principle). Basic of this principle is:

• search of optimal technological scheme $P^* \in \{P\}$ is carried out by decomposition of multi-dimensional initial problem on set of more simple problems, or

• element-decomposition look over only of perspective or effective decision variants of initial problem of synthesis.

Heuristic-decomposition principle (HD-principle). Basic of this principle is:

• by elements search of optimum technological scheme is made by ordered look over of a lot of technological scheme on the basis of some numbers of a heuristic rules using.

Integral-hypothetical principle (IG-principle). Basic of this principle is:

• the creation of the optimum technological scheme of system $P^* \in \{P\}$ by to give off any scheme from some generalized technological structure that is formed by association of the various alternative variants of possible technological schemes of the given system.

Evolutionary principle (E-principle). Basic of this principle is:

• the creation of optimum technological scheme of system by step-by step evolutionary updating of separate elements and subsystems of initial technological scheme of the given system.

Note, the most effective methods of optimum systems synthesis can be achieved on the basis of complex use of several principles of researched systems synthesis.

One of versions of method of branches and borders is the method of optimum synthesis by tree decisions. In this case the decision of problem is made by way of search with returning based on "α- and β-cutting off". This method is following [2],

The possible variants of system are nominated heuristically. We construct the tree of decisions by method of search on width giving the bottom estimations of all chosen variants. The basis of this decision stage is one of variant of branches and borders method (α - cutting off) of cutting off of each top with the least value and escalating of perspective branches so long as the list of alternative variants will not be exhausted. Let's estimate each top of the graph as result of branching on width.

Further, the method of search on depth is used. The tree received at the previous stage is develops in depth by perspective branches. Unpromising branches don't develop by β-cutting-off.

The estimated characteristics of analyzed system are deduced as result of search on depth. Thus, the transition from top to top is carried out on least meaning of border, i.e. by minimal value of function Z. The unpromising branches (schematic solution of system) are rejected.

Unfortunately, the ideologists of "branches and borders" gives only general recommendations or strategy of the problem decision [2] while the optimization of real technical systems demands real construction of computing procedures.

Use the graph theory method is one of effective methods of such concrete definition.

Generally, the variants of the schemes we shall present as parametrical graphs consisting from n difference-parametrical arches $S = (S_1, S_2, ..., S_n)$ and m simple contours $(L_1, L_2, ..., L_m)$. The optimization problem consists in determining in initial parametrical-flow graph a set of parametrical arches $S^* = (S_1, S_2, ..., S_n)$, $S^* \in S$, $p \leq m$ with minimal sum of parametric.

The column of the given technical system is correspond the equation matrix of tops made for flows on graph arches.

If the equations of connection of examined flow-graph in common closed equations system that receive the cyclic information graph of balances equations system of examined system.

For the analysis of the complex counter-directed technical systems it is necessary to use other strategy of the analysis. The algorithm of the optimum analysis of complex system displayed by multi-planimetric parametrical-flow graph is ordered on layers of tops equivalent acyclic parametrical-flow graph. The equivalent acyclic graph is receiving from multiplanimetric initial graph by break of the minimal set of the special arches.

The most perspective method, by authors' opinion, is method based on the concepts of exergo-economic optimization.

The application of thermo-economic (exergo-economic) principle of optimization [4-10] is based on estimation of exergy losses in system by money. In this case use the economic characteristics incorporated in exergy estimation of system. Such approach unites energy and economic estimation and does not concede on objectivity of generality technico-economic optimization.

Let's consider homogeneous system consisting of various elements where one flow h_1 consistently and unitary cooperates with n flows (Fig. 1) [3],

In this case of optimum synthesis problem can be formulated as: it is necessary to distribute the set of flows C_1, $i = 1, 2, ..., n$ along the flow h_j, $j = 1$ that the flow parameters h_j after system were in given interval of meanings, and the chosen optimization criterion accepted the minimal value [4],

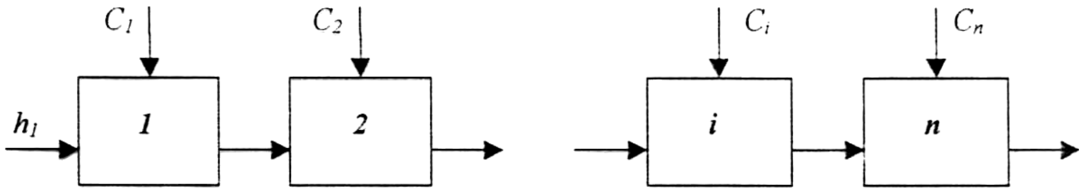

Fig. 1. The linear scheme of power system.

Let's accept expression of total thermo-economic expenses in system as optimization criterion

$$\sum_i \sum_j Z_{ij} = Z_{\Sigma}^{\min} \tag{1}$$

where Z_{ij} – thermoeconomic expenses in i-th element of system (as = l)

$$Z\left\{Z_{i_p}^{(p)}\right\}; \quad p = 1,2,...,k;$$
$$i_p = 1,2, ..., [n - \{p - 1)] \tag{2}$$

The set $Z\left\{Z_{i_p}^{(p)}\right\}$ can be broken on k subsets

$$Z\left\{Z_{i_p}^{(p)}\right\} = \bigcup_{p=1}^{k} Z\left\{Z_{i_p}^{(p)}\right\}$$

Here subset

$$Z\left\{Z_{i_p}^{(p)}\right\} = \\ = \left\{Z_1^{(p)},\ Z_2^{(p)},\ ...,\ Z_{i_p}^{(p)},\ ...,\ Z_{[n-(p-1)]}^{(p)}\right\} \tag{3}$$

is possible meanings of thermo-economic expenses on some stage p, $p < k$.

Then on each intermediate stage p it is necessary to choose such flow for which

$$Z_{i_p}^{(p)} \in Z\left\{Z_{i_p}^{(p)}\right\} \\ Z_{i_p}^{(p)} = Z_{\min}^{(p)},\ i_p = 1,\ 2,\ ...,\ [n-(p-1)] \tag{4}$$

where $Z_{\min}^{(p)}$ is minimal thermo-economic expense for stage p. Then the chosen flow is excluded from the further consideration. Hence, for numbers of elements p-th and $(p - 1)$-th subset the ratio is fair

$$Z\left\{Z_{i_p}^{(p)}\right\} = Z_{(p+1)}^{(p)} Z\left\{Z_{i_{(p+1)}}^{(p+1)}\right\} \tag{5}$$

Then from eq. (4) with eq. (5) the number of elements of set $Z\left\{Z_{i_p}^{(p)}\right\}$ is equal to number of possible variants of distribution of cooperating flows

$$Z\left\{Z_{i_p}^{(p)}\right\} = \prod_{p=1}^{k} Z\left\{Z_{i_p}^{(p)}\right\} = \frac{n!}{[n-(k-1)]} \tag{6}$$

For achievement given parameters for flow h_j it is necessary $k \le n$ elements, i.e. necessary to find the set of flows $C_k \in C$ for eq. (l) was carried out.

Generally thermo-economic criterion of optimality is

$$Z_{\Sigma} = \left(\frac{\sum_n C_n \Pi_n + \overline{K_n}}{\sum_k e_k} \right) \tag{7}$$

where C_n, Π_n are the cost and annual exergy consumption from external sources; $\overline{K_n}$ – annual capital and other expenses associated with n-th element; e_k – annual exergy charge for k-th product reception.

Eq. (7) has more simple kind for special cases. For example, for installation with one product

$$Z_{\Sigma} = \min \left(\frac{\sum_n C_n \Pi_n + \overline{K_n}}{B} \right) \tag{8}$$

where B – output of product.

Thus, the optimization problem can be generally shown to search extremum of function

$$Z_{opt} = \ \min Z_{\Sigma} \tag{9}$$

or for parametrical optimization

$$\eta_{opt} = max \eta_e^{\Sigma} \tag{10}$$

The special interest represents the geometrical device of exergo-economic optimization. This method is clear consequently it is convenient for decision of optimization problems [8-10], Let's examinate basis of the theory C-curve. For example, optimization criterion is exergy expenses. Function Z = $f(EX)$ has minimums to each axes: EX_{min} and Z_{min} (Fig. 2).

The optimum meaning (point A) can be determined by assuming linear dependence between exergy expenses ΔEX and expenses ΔZ

$$\Delta Z = k\Delta EX \tag{11}$$

where k is the capital investment for gain of primary energy.

At multi-criterion optimization use method C-surface [10]. In Fig. 3 the surface formed with C-curve on two-criterion analysis: thermo-economics and thermo-ecology. Thus the ecologo-economics projection is received as closing between thermo-economics and thermo-ecology.

The optimum meaning by C-curve and C-surface methods can be determined by graphic differentiation in borders of examined site. The graphic way is easily translated in analytical.

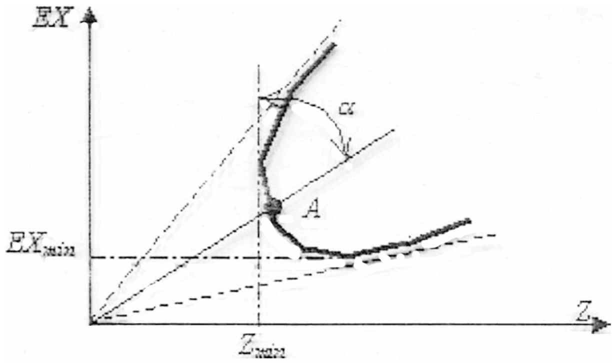

Fig. 2. Thermoeconomic model of system as C-curve.

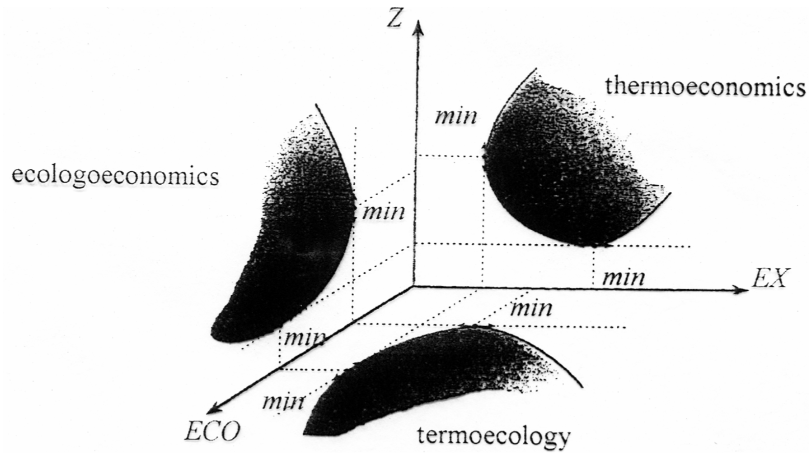

Fig. 3. C-surface.

NOMENCLATURE

e_k	annual exergy charge;
{P}	set of the semantic decisions
x	coordinate
L	graph contour
S	graph arcs
Z	efficiency criterion
Z_{ij}	thermo-economic expenses
η	performance
c_n	exergy costs
Π_n	annual exergy consumption
K_n	annual capital expenses

index

b	botton
e	exergy
min	minimal
opt	optimal
t	top