UDC 519.7:519.85

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Analytical design of energy-efficient management of complex energetic power systems

The proposed work presents the process of energy-efficient analytical design of energetic electric power systems. It is noted that it is advisable to solve the optimization problems of managing complex energy systems using stochastic programming methods using the aggregative-decomposition approach.

A probabilistic statement of the problem of managing complex energy power systems is proposed if the environment with the influence on the system has statistical characteristics. At the same time, for each implementation of the control process with the control algorithm the target function is a probabilistic function. As a result, the mathematical expectation of the objective function, which characterizes the quality of the process of managing the energetic electric power system, which is a controlled Markov process, should be extreme. A probabilistic process is Markov if:

$$p(x(t+1)|x(t), x(t-1), \dots, x(0)) = p(x(t+1)|x(t)),$$

where $p(x(t+1)|x(t), x(t-1), \dots, x(0))$ - probability density of the system state at time t+1;
$x(t)$ - the state of the electric power system, which represents a probabilistic process.

The state of the system at the moment of time t is described by a vector - a column of probabilities:

$$p(t) = (\,p_1(t), p_2(t), \dots, p_r(t))^{\,T},$$

where element I of $p_i(t), i = \overline{1,r}$ represents the probability of finding the electric power system in a state $x_i(t), i = \overline{1,r}$ at a point in time $t, t \in \{0, 1, 2, \dots, t_{iN}\}$.

The search for a solution to the probabilistic optimization problem of energy-efficient management of a complex power system is a process of analytical design of power systems. Ergatic electric power systems represent multi-level aggregates of man-machine systems of varying degrees of significance, which are proposed to be managed on the basis of finding solutions to stochastic programming problems using an aggregative-decompositional approach. Regarding the modeling of complex energy systems, it is suggested to use vertical decomposition procedures.

At each hierarchical level of a complex system, it is recommended to study the process of extremization of the objective function taking into account the system of probabilistic constraints. Complex energetic power systems are multi-level multi-objective probabilistic systems. So, the multidimensional model of the electric power system is described by equations:

$$y_i = f_i(x_i), i = \overline{1,n},$$

where x= $\{x_i\}$, $i = \overline{1,n}$ – model inputs;
$y = \{y_i), i = \overline{1,n}$ – model outputs.

The optimization approach to the study of complex energy systems is a search for a solution to the problem of minimizing the loss function, which ensures the energy efficiency of these systems. Thus, the modeling of complex power systems at the upper levels of the hierarchy is described by aggregated processes.

The structure of these processes is determined by spatio-temporal aggregation of the initial management task into a task of lower dimensionality relative to the upper level [1,2]. The purpose of the process of spatial aggregation and decomposition is to reduce the dimension of the optimization problem and to divide the power system into subsystems.

The time aggregation process is a transition to other discretization intervals of power supply processes; the process of time decomposition consists in the analysis of the problem of probabilistic control of a complex power system in different time intervals as a set of different tasks of power system structure control.

Regarding linearized complex systems, to obtain an aggregated control problem, as well as local control problems, the controllability of the initial complex energy system and the construction of a probabilistic structure of a compatible aggregation system are sufficient. The implementation of these procedures implies the expediency of applying a system analysis of the management processes of complex electric power systems.

A systematic approach to solving applied problems of managing these systems leads to the need to find a solution to problems of heuristic programming of man-machine procedures. At the same time, it is advisable to create a system of simulation models, the software of which represents the basis for making optimal decisions in dialog mode.

The process of modeling decision-making procedures according to the specified level of aggregation is the basis of the algorithmization of the procedure for finding a set of admissible alternative plan options $\{\gamma(u)\}$, where u - is the controlling parameter, as well as the algorithmization of the optimal plan selection operator γ^*:

$$\gamma^* = extr\{ F(\gamma(u))\}$$

In the process of finding a solution to non-linear optimization problems of the electric power industry, it is suggested to use the method of approximating programming. At the same time, an iterative process of using linear programming procedures is carried out.

This iterative process ensures the convergence of the sequence of solutions of linear programming problems to the solution of a nonlinear programming problem, the mathematical model of which takes the form:

$$f(\mathrm{x}) \rightarrow min, \mathrm{x} \in E^n$$

for restrictions

$$h_i(\mathrm{x}) = 0, i = \overline{1, m},$$

$$g_i(\mathrm{x}) \geq 0, i = \overline{m+1, p}$$

When applying the approximate programming method, a procedure for linearizing the constraints of the nonlinear programming problem is assumed; the target function is a nonlinear function in the process of its minimization.

In the process of researching complex ergatic electric power systems, problems of nonlinear programming with zonal uncertainty arise. In the structures of mathematical models of these problems, the objective function, as well as some of the constraints, are uncertain.

Regarding the search for a solution to such optimization problems, it is suggested to remove those vectors x for which the objective function f(x), as well as the constraints are uncertain. In the case when only the objective function is uncertain in some zones of the domain of changes of the vector x, it is recommended to apply an auxiliary constraint - the inequality:

$$F_{p+i}(\mathrm{x}) - \Phi^{(\kappa)} \geq 0, i = \overline{p+1, p+q},$$

where $F_{p+i}(\mathrm{x}) -$ component of the structure of the target function, in which the target function f(x) loses its determination in separate zones E^n;
q - the number of such components of the objective function f(x);
$\Phi^{(\kappa)} -$ the component of the objective function.

Conclusions

Ergatic electric power systems represent multi-level aggregates of man-machine systems of varying degrees of significance, which are proposed to be managed on the basis of finding solutions to stochastic programming problems using an aggregative-decompositional approach. In the process of finding a solution to non-linear optimization problems of the electric power industry, it is suggested to use the method of approximating programming. When applying the approximate programming method, a procedure for linearizing the constraints of the nonlinear programming problem is assumed.

References

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