Conclusions

The analysis showed the following:

1. software systems for analyzing electrical modes have minor differences related to the representation of source data, output parameters, and export/import capabilities;

2. software systems manufactured in the CIS, as a rule, have a narrow focus on specific technological tasks;

3) foreign-made systems are positioned as comprehensive tools that can solve all operational tasks, as well as problems of economic optimization or choosing the optimal strategy in the electricity market;

4) software systems manufactured by CIS can work with the format of the dispatching control center, which allows importing and exporting data from one software and computing complex to another for solving various tasks.

Currently, there are problems in the energy system of Kazakhstan with the installation of an electricity dispatching system, especially the work on the distribution of electricity in some local power networks, and the issues are still very significant. Many power dispatching systems use distributed software systems. Each software has large differences and does not have a system. The program "Digital of Kazakhstan" proposed construction goals and requirements for the functionalization, automation, dispatching and control of the integrated power grid. In accordance with national requirements for monitoring and managing power system capacity, it is necessary to use information digital graphics technology. To improve the architecture of the dispatching of power supply and to provide high quality services supply.

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SYNTHESIS OF ADAPTIVE SYSTEMS BY METHOD OF FUNCTIONS OF LYAPUNOV

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Adaptive control systems are called systems that determine the desired control law based on an analysis of the behavior of an object when its characteristics change and disturbances acting on it [6]. There are a number of methods for the synthesis of parameter adaptation algorithms [4], [5], [7] - [10]. Some of them are simple to implement, but they can only be stable in the small. Moreover, since when constructing adaptive systems its structure is nonlinear, it is rather difficult to solve the stability problem [1], [2]. The considered method of synthesis of an adaptive system with direct adaptation using the Lyapunov function method allows us to obtain conditions for the stability of the system in large, therefore, the stability problem does not arise.

Let a control object be described by the following equation of state

$$\dot{x} = Ax + Bu, \tag{1}$$

where $x \in R$ is the state vector of the object,

$u \in R$ is the control vector,

A, B - (n x n) and (n x m) - matrix of parameters of the control object.

It is necessary to provide the control object of the desired dynamics. We set this dynamics using the reference model.

$$\dot{y} = A_M\, y + B_M\, g, \tag{2}$$

where $y \in R^n$ is the state vector of the reference model, $g \in R^m$ is the setting action,

A_M, B_M - (n x n) and (n x m) are given constant matrices.

The issue of choosing a reference model is not considered here. It is assumed that it is stable, i.e. A_M - Hurwitz matrix.

We assume that the parameter vector $\alpha \in \Omega_\alpha$ of the control object, consisting of coefficients of the matrices A, B is not predefined. The space Ω_α can be set, for example, using the maximum and minimum values that can take the parameters of the control object. We put further for the reference model n = m. Signal mismatch error

$$e = x - y. \tag{3}$$

We solve the problem in two stages: at the first stage, we build the main circuit, and at the second stage, the adaptation circuit.

The object is controlled using the vector signal x_k, which compensates signal and parametric disturbances. The input of the main circuit and the reference model receives the same signal with a fairly rich spectrum. Then

$$u = g - x_k. \tag{4}$$

We write the parametric perturbations in the form:

$$A(t) = A_M + \Delta A,\ B(t) = B_M + \Delta B. \tag{5}$$

Substituting (5) in the equation of the object (1), we obtain:

$$\dot{x} = A_M x + B_M g - B_M x_k + \Delta A x + \Delta B u, \tag{6}$$

The resulting equation (6) describes the dynamics of the main closed system. The compensation condition for parametric and signal perturbations can be written as:

$$\Delta A x + \Delta B u - B_M x_k = 0.$$

From here

$$x_k = B_M^{-1}(\Delta A x + \Delta B u). \tag{7}$$

Here $detB_M \neq 0$.

Identification of matrices of current parametric disturbances is a difficult task. Therefore, the direct adaptive control method is used. We will form an estimate of $\wp$ as follows:

$$\wp_k = B_M^{-1}(\Delta K x + \Delta L u), \tag{8}$$

where ΔK and ΔL are adjustable parameters, which at the end of the adaptation process will be equal respectively

$\Delta K = \Delta A$ and $\Delta L = \Delta B$.

In this case, the processes occurring in the generalized custom object will be described, as in the model (2). The task in the second stage is to find the adjustment ΔK and ΔL, which provide Lyapunov-stable adaptation processes to the reference model. Substituting estimate (8) into equation (6), we obtain:

$$\dot{x} = A_M x + B_M g + (\Delta A - \Delta K)x + (\Delta B - \Delta L)u. \tag{9}$$

The parametric mismatch of the main circuit with respect to its reference model is characterized by the matrices K=$\Delta A - \Delta K$ and L=$\Delta B - \Delta L$. In this case, (9) is written in form

$$\dot{x} = A_M x + B_M g + Kx + Lu, \tag{10}$$

Comparing (10), (2), we conclude that the coincidence with the reference model will be for K=0 and L=0 ubtract the equation of model (2) from equation (9); we obtain, taking into account (3):

$$\dot{e} = A_M e + Kx + Lu, \tag{11}$$

This shows that for K=L=0 $\dot{e} = A_M e$ and, therefore, $\lim_{t\to\infty} e = 0$, because matrix A_M- Hurwitz.

We choose integrating links to ensure the restructuring coefficients of the matrices K and L as follows:

$$\dot{K} = -\varphi; \;\; \dot{L} = -\psi, \tag{12}$$

where φ and ψ are the desired adaptation algorithms. According to the second Lyapunov method, we construct a positive definite Lyapunov function in the form:

$V = e^T P e + \lambda_1 tr\left(K^T \dot{K}\right) + \lambda_2 tr\left(L^T \dot{L}\right)$,

$P = P^T > 0,\ \lambda_1 > 0, \lambda_2 > 0$.

The full derivative will look like:

$\dot{V} = 2e^T P \dot{e} + 2\lambda_1 tr\left(K^T \dot{K}\right) + 2\lambda_2 tr\left(L^T \dot{L}\right)$,

or, taking into account (11), (12) and using a circular permutation under the trace sign [3]

$\dot{V} = 2e^T P A_M e + 2tr[e^T P(Kx + Lu) - (\lambda_1 K^T \varphi + \lambda_2 L^T \psi)]$,

Because $PA_M = \frac{1}{2}(PA_M + A_M P)$, then, denoting -Q= $PA_M + A_M P$, we obtain:

$$\dot{V} = -e^T Q e + 2tr[K^T(Pex^T - \lambda_1 \varphi) + L^T(Peu^T - \lambda_2 \psi). \tag{13}$$

The first term is the sign-definite negative quadratic form of the signal mismatch vector. The second term gives tuning algorithms.

$\varphi = \dfrac{1}{\lambda_1} Pex^T, \qquad \psi = \dfrac{1}{\lambda_2} Peu^T,$

By virtue of (12), we have:

$\dot{K} = \dfrac{1}{\lambda_1} Pex^T, \qquad \dot{L} = \dfrac{1}{\lambda_2} Peu^T,$

Since the matrices A, B change slowly, i.e., approximately $\Delta\dot{A} = 0, \Delta\dot{B} = 0$, then adaptation algorithms (8) are defined as follows:

$$\Delta\dot{K} = \tfrac{1}{\lambda_1} Pex^T,\ \Delta\dot{L} = \tfrac{1}{\lambda_2} Peu^T, \tag{14}$$

In this case, it follows from (13) that $\dot{V} = e^T P e$, i.e. in the signal space of mismatches, the full derivative of the Lyapunov function is a sign-definite negative function and, therefore, there is asymptotic stability of the system with respect to signal mismatch. In full phase space, full derivative of the Lyapunov function is a negative constant function. Because $\lim_{t\to\infty} e = 0$, then it follows from (11) that Kx+Lu→0. Therefore, if the signals x, u are linear independent then K→0, L→0 and the constructed system is asymptotically stable \ in the full phase space.

Thus, an adaptive system with the reference model (1), (2), (14) was synthesized by the Lyapunov function method. This system is asymptotically stable in the full phase space.

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