ALGORITHMS OF STEADY CALCULATION OF THE VECTOR OF PARAMETERS OF THE REGULATOR IN LINEAR SYSTEMS ON THE BASIS OF MODAL MANAGEMENT

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Abstract: *algorithms of steady calculation of a vector of parameters of the regulator are given in linear systems on the basis of modal management. The wording of requirements to system is carried out by a task of desirable distribution on the complex plane of own numbers of a matrix of the closed system. The required vector of coefficients of the regulator decides on the basis of an iterative algorithm on averaging. The given algorithm provides convergence to one of solutions of the considered matrix operator equation.*
Keywords: *linear system, modal management, regulator parameters, iterative algorithm.*

АЛГОРИТМЫ УСТОЙЧИВОГО ВЫЧИСЛЕНИЯ ВЕКТОРА ПАРАМЕТРОВ РЕГУЛЯТОРА В ЛИНЕЙНЫХ СИСТЕМАХ НА ОСНОВЕ МОДАЛЬНОГО УПРАВЛЕНИЯ

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Аннотация: *приводятся алгоритмы устойчивого вычисления вектора параметров регулятора в линейных системах на основе модального управления. Формулировка требований к системе осуществляется путем задания желаемого распределения на комплексной плоскости собственных чисел матрицы замкнутой системы. Искомый вектор коэффициентов регулятора определяется на основе итерационного алгоритма с усреднением. Приведенный алгоритм обеспечивает сходимость к одному из решений рассматриваемого матричного операторного уравнения.*
Ключевые слова: *линейная система, модальное управление, параметры регулятора, итерационный алгоритм.*

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Synthesis of regulators of the linear systems of automatic control (SAC) is understood as finding of the operating influences (managements) allowing to solve optimum the engineering task set for developers. At the same time it is supposed that the solution of a task will meet all requirements of the specification. At synthesis of regulators solve usually two problems. The first task consists in providing necessary dynamic indicators of quality of the projected system. The second task consists in achievement of the required accuracy of this system [1-8].

The first task is a difficult task as increase in high-speed performance of system: leads to increase in oscillatory nature of transient phenomena. It in turn carries to use of more expensive element basis allowing to take place in SAU to signals with great values of amplitudes. Use of the rectifier filters eliminating surges of signals leads to reduction of high-speed performance and, respectively, to increase in duration of transient phenomenon and also to complication of system. Therefore usually try to find an optimum ratio between high-speed performance and the oscillatory nature of the proceeding processes, being at the same time within the specification.

The second task in comparison with the first is simpler. As support of required accuracy can be reached due to change of transmission ratio of an open-ended circuit or due to increase in an order of astatism, or due to introduction to the control algorithm of the compensating communications on the setting or perturbing influences.

It is necessary to mark that the majority the contemporary of SAU are constructed on the basis of microprocessor technique as this technique allows to realize any complexity the control algorithm, to provide compactness and simplicity of SAU. However use of digital regulators sets the tasks connected to memory allocation and determination of a format of data representation for the developer, participating in administrative process. And this choice influences the accuracy of operation of SAU. Therefore one of available means of check of operability of the projected system and the determination of a format of data representation participating in administrative process is computer simulation. Thanks to such simulation the conclusion about compliance of figures of merit of SAU received as a result of synthesis to requirements of the specification is drawn and also the most suitable format of representation melon the synthesized controlling influence is selected. Recently big distribution was gained by a method of modal control [7, 8] which allows to solve most effectively problems of synthesis of management systems dynamic objects.

We will set model of an object in a look:

$$\dot{x}(t) = A \cdot x(t) + b \cdot u(t), \qquad (1)$$

where $x(t)$ – n- measured vector of a state, $u(t)$ –scalar management,

b – n- measured vector of management, A– $n \times n$ -transitional matrix.

The law of management is looked for in a look

$$u(t) = k \cdot x(t), \qquad (2)$$

where k – a size n vector line with material coefficients.

The characteristic equation of the closed "object (1), regulator (2)" system has an appearance [8]:

$$-\frac{k \cdot adj(Is - A) \cdot b}{d(s)} + 1 = 0,$$

where I – a single matrix of the size n;

$adj(Is - A)$ – attached to a $(Is - A)$ matrix;

$d(s) = \det(Is - A)$ – characteristic polynom of an object;

s – a transformation symbol according to Laplace under zero entry conditions (further it is also understood as a differentiation symbol on t).

We will reduce it to a common denominator and we will enter designation

$$\Delta(s) = -k \cdot adj(Is - A) \cdot b + d(s) = 0, \qquad (3)$$

Where $\Delta(s)$ represents analytical expression of a characteristic polynom of the considered closed system through parameters of an object and coefficients of the regulator.

The wording of requirements to system can be carried out or by a task of desirable distribution on the complex plane of own numbers of a matrix of the closed system, or method of standard coefficients of a characteristic polynom [7,8].

In case the system has zero, preference is given to the first way of a task of requirements as it allows to consider somewhat influence of these zero on dynamics by the rational choice of poles. If to designate through the $\beta_1, \beta_2, ..., \beta_n$ desirable poles (complex interfaced or real numbers), then the polynom can be written down in the form of [9]:

$$(s - \beta_1) \cdot (s - \beta_2) ... (s - \beta_n) = s^n + \Delta_1 \cdot s^{n-1} + \Delta_2 \cdot s^{n-2} + ... + \Delta_n, \qquad (4)$$

where coefficients $\Delta_\gamma (\gamma = \overline{1, n})$ are defined by multiplication of the simplest factors in the left part and group of members at identical degrees s.

At a numerical task $\beta_1, \beta_2, ..., \beta_n$ sizes $\Delta_1, \Delta_2, ..., \Delta_n$ are also numbers.

Expression (3) can be written down as follows

$$s^n + \Delta_1(a_{ij}, b_i, k_j) \cdot s^{n-1} + \Delta_2(a_{ij}, b_i, k_j) \cdot s^{n-2} + ... + \Delta_n(a_{ij}, b_i, k_j) = 0, \qquad (5)$$

where designation $\Delta_\gamma(a_{ij}, b_i, k_j) \ (\gamma = \overline{1, n})$ shows that coefficients of a polynom are functions of parameters of an object and the regulator.

The type of these functions is defined by structure of a matrix A and yes b vector. Generally these functions aren't a_{ij}, b_i, linear on, but are always linear on $k_j (i, j = \overline{1, n})$ [10].

Equating of coefficients of polynoms (4) and (5) at equal degrees of s receive the system of the algebraic equations

$$\begin{cases} \Delta_1(a_{ij}, b_i, k_j) = \Delta_1, \\ \Delta_2(a_{ij}, b_i, k_j) = \Delta_2, \\ \dots\dots\dots\dots\dots\dots \\ \Delta_n(a_{ij}, b_i, k_j) = \Delta_n, \end{cases} \qquad (6)$$

Owing to linearity of functions $\Delta_\gamma(a_{ij}, b_i, k_j)$ on k_j system (6) it can be written down in the following look

$$\begin{cases} P_{11}(a_{ij}, b_i)\cdot k_1 + P_{12}(a_{ij}, b_i)\cdot k_2 + \dots + P_{1n}(a_{ij}, b_i)\cdot k_n + d_1(a_{ij}) = \Delta_1, \\ P_{21}(a_{ij}, b_i)\cdot k_1 + P_{22}(a_{ij}, b_i)\cdot k_2 + \dots + P_{2n}(a_{ij}, b_i)\cdot k_n + d_2(a_{ij}) = \Delta_2, \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ P_{n1}(a_{ij}, b_i)\cdot k_1 + P_{n2}(a_{ij}, b_i)\cdot k_2 + \dots + P_{nn}(a_{ij}, b_i)\cdot k_n + d_n(a_{ij}) = \Delta_n, \end{cases} \qquad (7)$$

where, $P_{ij}(a_{ij}, b_i)$, $(i, j = \overline{1, n})$ – generally nonlinear functions of parameters of an object, and $d_\gamma(a_{ij})\ (\gamma = \overline{1, n})$ – coefficients of a characteristic polynom of an object (generally nonlinear functions of parameters of a matrix of A).

In a matrix look the system (7) registers as follows

$$P\cdot k + d = \Delta, \qquad (8)$$

where k – the transposed vector of required coefficients of the regulator (vector column), the sign of transposing further for simplification of designations we lower, $P = \left\| P_{\gamma l}(a_{ij}, b_i) \right\|\ (\gamma, l = \overline{1, n}) - n \times n$ matrix of the relevant structure; $d = \left\| d_\gamma(a_{ij}) \right\|\ (\gamma = \overline{1, n})$ – the vector column made of coefficients of a characteristic polynom of an object; $\Delta = \left\| \Delta_\gamma \right\|\ (\gamma = \overline{1, n})$ – the vector column made of coefficients of a desirable characteristic polynom of the closed system.

As sizes represent $a_{ij}, b_i\ (i, j = \overline{1, n})$ real numbers, the matrix of P and a vector of d are numerical. Then the system (8) is given to a look

$$P\cdot k = h, \qquad (9)$$

where h is by the rule of subtraction of vectors

$h = \Delta - d$,

that is $h_\gamma = \Delta_\gamma - d_\gamma\ \ (\gamma = \overline{1, n})$.

Thus, if an object doesn't contain uncertain parameters and quite we operate, then the problem of synthesis of the regulator providing desirable any arrangement of poles of the closed system comes down to calculation of coefficients of a polynom (4), matrix of P, d vector, and then – to the solution of system of the linear algebraic equations (9).

The solution of system (9) unstably for the reason that the matrix P can be badly caused. We will believe that the linear operator P acts in space of H and meets conditions

$\|P\| = 1, \ \ \|P - I\| = 1.$

We will accept conditions of approximation in a look to conditions $\|h - \bar{h}\| \le \delta$, where $\bar{h}$ – exact value of the right member of equation (9). For the solution of the equation (9) we will use a method of iterations with averaging [11].

We will consider the sequence

$$\bar{d}_m = \frac{1}{m+1}\sum_{k=0}^{m} d_k, \quad m = 0,1,2,..., \qquad (10)$$

where are defined by the following iterations:

$$\left.\begin{aligned} & d_0 \in H, \\ & d_k = d_{k-1} + h - Pd_{k-1},\ k = 1,2,... \end{aligned}\right\} \qquad (11)$$

As shown in [11,12], the sequence (10) meets to one of solutions d of the equation (9) at $\delta = 0$ i.e.

$$\lim_{m\to\infty}\left\|\bar{d}_m - d\right\|_{\delta=0} = 0.$$

If $\delta \neq 0$, that

$$\left\|\bar{d}_m - d\right\| \leq \left\|\bar{d}_m - d\right\|_{\delta=0} + \frac{m}{2}\delta.$$

At $m = m(\delta)$ it that

$$\frac{m(\delta)}{2}\delta \to 0 \quad \text{at} \quad \delta \to 0, \qquad (12)$$

we have $\left\|\bar{d}_m - d\right\| \to 0$ at $\delta \to 0$,

i.e. the scheme (10) – (11) when performing (12) generates a regulating algorithm.

The given algorithms allow to make steady calculation of a vector of parameters of regulators on the basis of modal management.

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