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Automation of calculation of dynamic characteristics of elements of information-measuring and control systems of smart house

I Petrova, Yu A Snegireva, K A Shumak

Department of CAD Systems and Modeling, Astrakhan State University of Architecture and Civil Engineering, 18, Tatishchev Str., Astrakhan 414056, Russia

E-mail: lejninau@gmail.com

Abstract. Using energy-information models for describing the chains of different physical nature and apparatus PSS, it is possible to represent the entire variety of interrelations between quantities and parameters in the form of a complex graph. In this paper, the elements that reflect the dynamic processes in the operator form (parameters and quantities) are introduced into this graph for the first time. With the advent of powerful computing tools, it became possible to automate a purposeful process of synthesizing structural schemes. In this paper, an important task is solved to automate the investigation of the dynamic characteristics of both existing and synthesized parametric structural schemes (PSS). The calculation part effectively provides a qualitative and quantitative assessment of the PSS. The developed system makes it possible to create a structural diagram, perform the calculation of the time, amplitude of the frequency, phase frequency and complex frequency characteristics.

1. Introduction

Currently, there are a number of tools designed for full or partial automation of labor Developer technical devices [1]. Only a few of these systems allow the synthesis of technical solutions, each of these systems has an original theoretical basis.

The efficiency of automated data banks used by developers of new technical solutions depends significantly on the choice of the conceptual model of the database. The task of the conceptual model is to describe the data as a whole and make this description independent of specific technical problems. Therefore, when developing data banks for the Physico-Technical Effect, it is advisable to use the theory of analogy and similarity to develop a conceptual model that allows describing processes and phenomena of a different physical nature with the help of a single mathematical apparatus. As such a conceptual model of data banks for the Physico-Technical Effect, it is advisable to use energy-information models of chains of various physical nature [2-5].

Using the operator's calculation method, it is possible to investigate the dynamic characteristics of the projected elements of control systems of various physical nature. However, at the same time, the task of automating the calculation of the dynamic characteristics of the elements of information-measuring and control systems remains urgent.It is vital that you do not add any headers, footers or page numbers to your paper; these will be added during the production process at IOP Publishing (this is why the Header and Footer margins are set to 0 cm in table 1).

2. Formulation of the problem

Solving the problem of searching for new principles for the operation of elements and devices Information Measuring and Control Systems (IMCS) with dynamic characteristics reduces to searching for variants of the physical principle of action (FPA) of an element or IMCS based on structural and parametric synthesis on the basis of information in the DB (Data Base) of physical and technical effects and The choice of the best options for a combination of performance characteristics. It is necessary to develop a subroutine for estimating the dynamic characteristics of this device. It is necessary to develop a subroutine for estimating the dynamic characteristics of this device.

Using energy-information models for describing chains of different physical nature and the PSS apparatus, it is possible to represent the entire variety of interrelations between quantities and parameters in the form of a complex graph (Figure 1). In this graph elements are introduced that reflect the dynamic processes in the operator form (parameters and quantities). The vertices of the graph are the values of chains of different physical nature, and the edges are parameters or effects. In general, we can assume that they are all represented by their images in the operator form. With the help of the graph, it is possible to determine from the input and output values of the element or device IMCS the possible versions of the FPA (ie, the way through the graph) and to select the most optimal one based on the set of requirements for performance characteristics and to estimate the dynamic characteristics of the received PSS. The general properties of the problem are as follows:

- the final set of choices - a family of PSS, reflecting the variants of the FPA sensor with the given input and output;
- each set of PSS is compared with a set of quantitative operational characteristics (sensitivity, reliability, error, range of input and output variables, the degree of nonlinearity of the output characteristic, speed, etc.), calculated from the values of the characteristics of individual links (FPA or parameters);
- it is required to choose the variant of the sensor FPA for a set of performance characteristics that satisfies certain predetermined requirements.

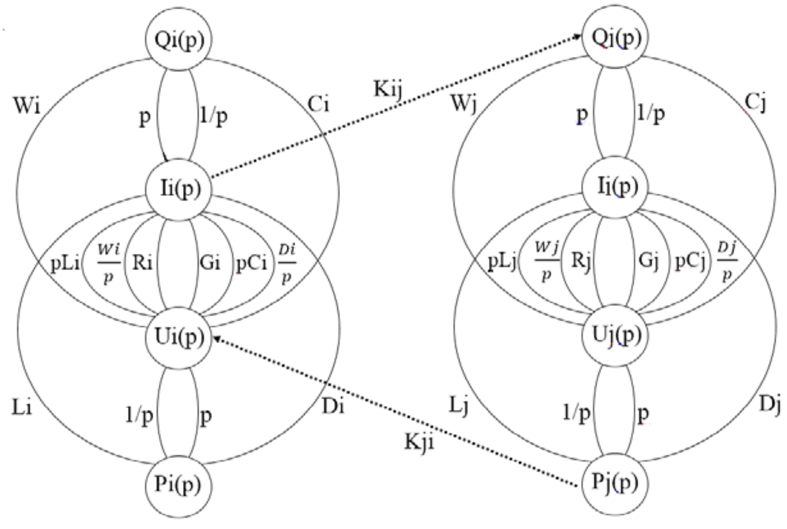

Figure 1. Graph of interrelations between quantities and parameters in operator form for chains of different physical nature (i-th and j-th nature)

Thus, the task is reduced to the problem of a complete search using the return strategy. As a result, we obtain chains of successive transformations, reflecting the dynamics of the processes occurring.

3. Solution method

To evaluate the dynamic characteristics, it is first necessary to find the analytical form of the transfer function in the parametric structural scheme in the operator form, and then from the image go to the original function and obtain a time dependence.

Therefore, a method was chosen based on obtaining the Laplace mapping of the desired transfer function of the PSS and transferring it to the original region [6].

Consider, for example, the structural diagram shown in Figure 2.

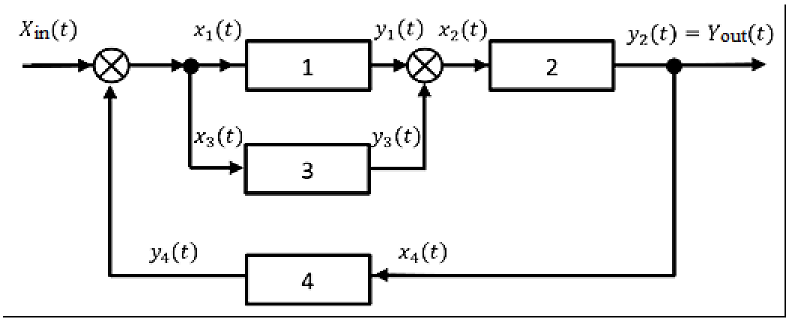

Figure 2. An example of a complex parametric structural scheme.

The universal algorithm for finding the transfer functions of block diagrams using Mason formula [7,8]. The main idea of this method is that the system is represented in the form of an oriented graph in which the arcs are equivalent to elementary links and are characterized by the transfer function of this link (block), and the vertices to the signal transmission lines.

An oriented graph (digraph) can be constructed from a parametric structural scheme. When constructing a digraph according to the structural scheme, it is necessary to adhere to the following rules: x_{in}

- We modify the structural scheme so that in the links of summation all variables add up with a positive sign, negative signs are introduced into the transfer functions of the links.
- Each summing element of the structural scheme is replaced by a vertex, which corresponds to the output variable of this link.
- Each elementary element of the structural diagram is replaced by an arc with an operator equal to the transfer function of this link.
- Each size, including the input one, has its own vertex.

After the block diagram is transformed into an oriented graph, you can use the Mason formula (1) to find the image of the complex transfer function of the entire structural scheme.

$$W(p) = Y(p)/X(p) = 1/\Delta(p) \sum_{i=1}^{n} W_{npi}(p)\Delta_i(p) \qquad (1)$$

where *W(p)* - transfer function for output value by input; W_{npi} - the transfer function of the *i*-th separate direct path from *X* (*p*) to *Y* (*p*) is calculated as a result of multiplying the transfer functions of the individual arcs entering this path; $\Delta(p)$ - determinant directed graph, which is defined by the formula

$$\Delta(p) = 1 - \sum_j W_j(p) + \sum_{jk} W_j(p)\cdot W_k(p) + \sum_{jkm} W_j(p)\cdot W_k(p)\cdot W_m(p) + \dots$$

where $W_j(p)$ - transfer function of the *j*-th closed loop, calculated as the product of the transfer functions of the arcs included in this contour; $\Delta(p)$ - the determinant of the graph obtained when removing the arcs and vertices of the *i*-th separate direct path is determined by the formula.

4. Algorithms for the implementation of the problem of finding the transfer function of the IM and CS elements with dynamic links

For calculating the transfer characteristic of the block diagram of the parametric formula Mason in this work a next set of algorithms with graph representing the pattern:

4.1. Algorithm for finding all simple paths in the graph (Algorithm of search all single ways in graph)

The algorithm is essentially a search algorithm in the graph in depth, supplemented by restrictions on the selection from the direct correspondence list of the next vertex when it is attached to the path at the current step. When the arc is switched on, the arc and its initial vertex included in the path are marked in the path. In the future, marked vertices in the current path are not included (which ensures the construction of simple paths, ie paths that do not contain the same vertices a, and hence arcs). The notation of arcs is used to not re-enable the already considered arc in the current path at the return step.

4.2. Algorithm of search all single cycles

The idea of the algorithm is as follows: sequentially, for each vertex of the graph there are all the contours passing through it, then it is marked and the search process continues similarly for the next vertex, and so on for all the vertices of the graph.

4.3. The algorithm for finding the set of all "disjoint" contours (simple cycles) (Algorithm of search all sets of “untouchment” cycles)

The set of simple cycles is the set of "disjoint" contours. We represent each contour as the vertex of some graph. Any two vertices of this graph will be joined by an edge if the contours have at least one common vertex. Then the problem reduces to the search for all sets of internal stability of a graph. For solve this problem, this algorithm is developed, which is a modification of the known algorithms for finding the maximal independent sets and search algorithms in a graph in depth using the branch and boundary method.

4.4. An algorithm for finding the set of all simple contours in a subgraph formed from the original graph by eliminating a simple path from it with arcs incident to the vertices entering this path (Algorithm of search all single cycles in subgraph).

The subgraph is formed from the original graph by eliminating a simple path from it with arcs incident to the vertices entering this path. If you exclude the i-th simple path from the graph, all cycles that contain at least one vertex in this path "disappear" in it. Thus, the required set of all simple contours in the subgraph is the set of cycles of the original graph, excluding the set of contours that are in contact with the i-th simple path.

To solve the problem of transition from the image of the transfer function to its original, algorithms for decomposing a rational function into elementary fractions are developed:

4.5. The algorithm for finding all the roots of a polynomial (Algorithm Find_Roots),

This algorithm looks for a minimum of the function by the conjugate gradient method, which is equivalent to searching for the root of the equation. This algorithm is performed until all the roots of the denominator of the transfer function are found, they are excluded as the roots are found. At the input of the algorithm is transmitted an object that contains lists of coefficients of the numerator and denominator of the transfer function, and setting parameters. At the output of the procedure realizing this algorithm, a list of all the roots of the denominator of the transfer function is output. Unreliable places in this algorithm are finding the tuning parameter and the criterion for ending the root search.

4.6. The algorithm for calculating the coefficients of elementary fractions (Algorithm Solve_Matrix),

Realizes the decomposition of the transfer function into elementary fractions. This algorithm has a serious limitation: it is only valid if the denominator of the transfer function has no multiple roots.

4.7. The algorithm for calculating the coefficients of the functions of the originals (Algorithm Solve_Koef).

The input of the algorithm is a list of the roots of the denominator of the transfer function and the result of the SolveMatrix algorithm, which contains the coefficients of the decomposition of the transfer function into elementary fractions. At the output of the algorithm, we obtain the coefficients of the original functions and the function type sign. Moreover, the summands corresponding to complex conjugate roots are combined. Then you go to the original area.

5. Experimental part of the developed system

Footnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text.

The developed algorithms make it possible to construct dynamically the characteristics of sensitive elements by parametric structural schemes. Consider, for example, the structural scheme in Figure 2, transforming it into an operator form (Figure 3).

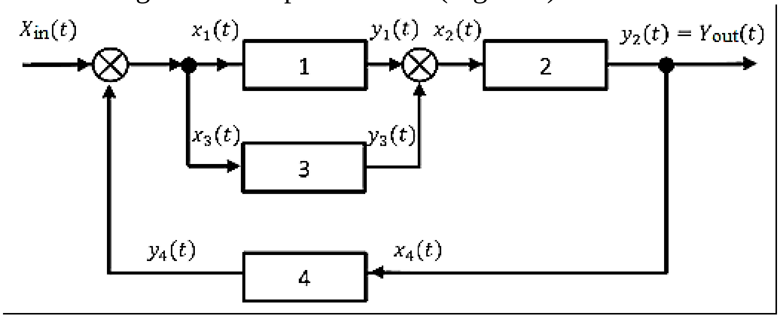

Figure 3. An example of a complex parametric structural scheme in the operator form of recording.

The complex transfer function of the system, calculated by the Mason formula (1), has the form

$$W(p) = (W_1(p) \cdot W_2(p) + W_2(p) \cdot W_3(p)) / (1 + W_1(p) \cdot W_2(p) \cdot W_4(p) + W_2(p) \cdot W_3(p) \cdot W_4(p))$$

The verification of the obtained expression (3.9) can be carried out on the basis of the calculation of the transfer function of this parametric structural scheme, performed according to the formulas of link connections.

For test the system's performance, consider an example that corresponds to a parametric structural diagram (Figure 4). We select the elementary links of the PSS in the operator form so that the condition of the correspondence of the signals at the inputs and outputs is fulfilled (Figure 4).

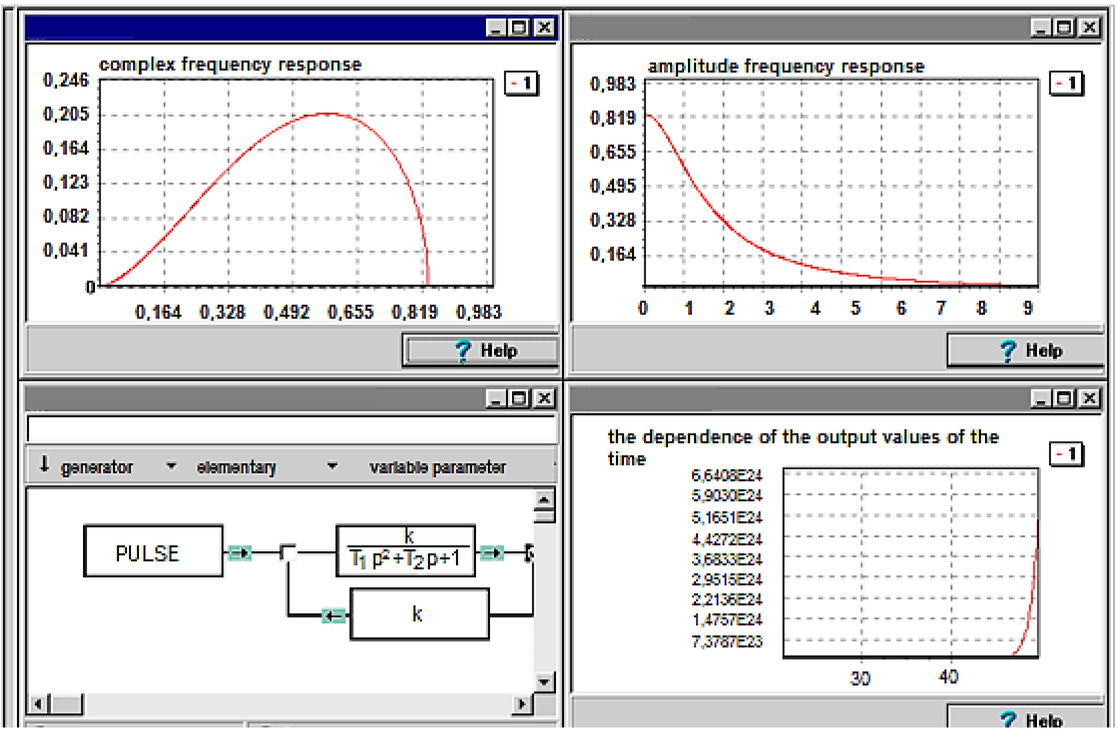

Figure 4. An example of a complex parametric structural scheme in terms of EIMC.

The system calculates the corresponding dynamic characteristic of the parametric structural diagram and calculates the calculated results in a newly created or existing chart window (Figure 4). Analytic expression for a particular graph can be obtained in the chart window and selecting the title of the graph in the dialog box that appears.

6. Conclusion

The system provides for the conversion of parametric structural schemes created with the help of a program for the synthesis of new technical solutions. In the dialog box that opens, select the file name of the synthesized structure diagram. After specifying the file name, the window of the parametric structural diagram editor is automatically created with the schema converted into it. To create and calculate the PSS, you must set the signal generator and signal control point for the converted circuit, connect them to the circuit, and perform the dynamic performance calculation described above.

The technique for calculating dynamic characteristics of automated sensors to the parametric block diagrams. The automated system allows you to explore circuits built on the basis of elementary blocks and blocks of the "Variable parameter" type of the energy information model.

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