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IDENTIFICATION TRANSIENTS IN DOUBLE-LEVEL INDUSTRIAL SYSTEMS (DIS)

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In the report DIS with sectional structure which is a typical element of multilevel industrial systems (MIS) with hierarchical structure is observed. DIS with sectional structure is used as means of representation of single-level complexes in MIS which consists of the sectional centre (SC) and the elements subordinated (SE) to it. SC is the aggregated representation of an observed single-level complex in MIS with the interconnections between its elements and SE are the elements of this complex, connections between which are carried out only through SC.

The report is devoted a problem of identification of transients of typical complexes with the general structures as installations of MIS.

The solution of such problem is carried out in two stages:

1) autocorrelation functions of input variables and mutual correlation functions between some variables, including output and input variables of separate elements of an observed complex on which basis in the beginning are defined their pulsing, and then transfer functions are under construction.

2) with use of the transfer functions gained in the first point by their clustering the complex transfer function of SC is defined.

At construction of correlation functions and DIS identification is accepted, that SE stationary, are subject to stationary casual affectings and within normal regimes they with an sufficient accuracy are represented linear. Last precondition is based on that within normal regimes input variables SE vary in narrow limits.

Realization of tasks of the first and second stages is observed on an instance of DIS, a single-level complex being representation with consecutive structure of MIS, shown on fig. 1, a.

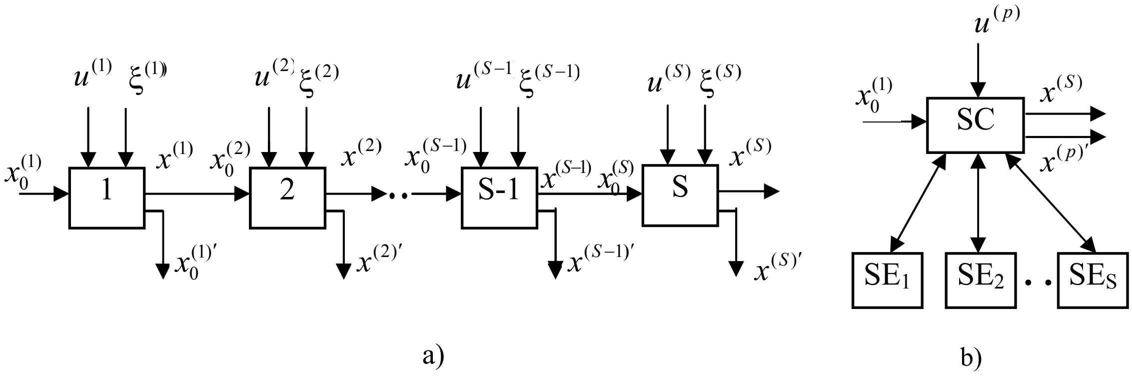

Fig. 1

On fig. 1, a $x_0^{(p)}, x^{(p)}, x^{(p)'}$ - accordingly a base raw resource, base and collateral products of element p; $u^{(p)}, \xi^{(p)}$ - operating and unchecked disturbing affecting of element p.

Generally $x^{(p)}$, $u^{(p)}$ - vector variables, on an entry of each element p move also auxiliary resources which, as a rule, are rationed or on $x_0^{(p)}$, or $x^{(s)}$ and connection between consecutive elements is carried out through an element reservation (ER), in particular, through capacities, platforms, warehouses etc. However for simplification the specified sizes are accepted scalar and auxiliary resources and reservation elements are not considered.

Applying an integral of Duhamel ([1], p.60) expressions of association of each of output variables of element p : $x^{(p)}, x^{(p)'}$ from its input variables: $x_0^{(p)}, u^{(p)}$. Such dependence for $x^{(p)}$ looks like:

$$x^{(p)} = \int_0^{\infty} k_1(\tau_1) x_0^{(p)}(t-\tau_1)d\tau_1 + \int_0^{\infty} k_2(\tau_1) u^{(p)}(t-\tau_1)d\tau_1 . \quad (1)$$

Multiplying consistently this equation on $x_0^{(p)}(t-\tau_2)$ and $u^{(p)}(t-\tau_2)$ and integrating it is received:

$$\begin{aligned} R_{x^{(p)},1}(\tau_2) &= \int_0^{T} k_1^{(p)}(\tau_1)R_1(\tau_2-\tau_1)d\tau_1 + \int_0^{T} k_2^{(p)}(\tau_1)R_{12}(\tau_2-\tau_1)d\tau_1 , \\ R_{x^{(p)},2}(\tau_2) &= \int_0^{T} k_1^{(p)}(\tau_1)R_{21}(\tau_2-\tau_1)d\tau_1 + \int_0^{T} k_2^{(p)}(\tau_1)R_2(\tau_2-\tau_1)d\tau_1 , \end{aligned} \quad (2)$$

where $R_{x^{(p)},1}(\tau_2)$, $R_{x^{(p)},2}(\tau_2)$, $R_{12}(\tau_2-\tau_1)$, $R_{21}(\tau_2-\tau_1)$ - cross-correlation and $R_1(\tau_2-\tau_1)$, $R_2(\tau_2-\tau_1)$ autocorrelation functions. The bottom indexes 1,2 at correlation functions express input variables $x_0 u$ of element p accordingly; $k(\tau)$ - a pulsing transfer function on corresponding channel; T - a time of observation of random variables.

The received expressions represent the integral equations Zadeh - Ragazini for object with two entries under condition of a physical realizability of pulsing functions: $k(\tau) = 0$ for $t < 0$. Analogous expressions are fair and for $x_0^{(p)'}$.

From the solution of integral equations (2) pulsing functions on which with application of direct Laplace transform there are transfer functions of element *p* on corresponding channels are defined:

$$G_i^{(p)}(\nu) = \int_0^{\infty} k_i^{(p)}(\tau)e^{-\nu t}dt, \; i = 1,2 , \quad (3)$$

where ν - a complex variable; $i = 1$ corresponds to the first channel - channel $x_0^{(p)}, x^{(p)}$ and $i = 2$ to the second channel to channel $u^{(p)}, x^{(p)}$.

The integral equations (2) are easily generalized and for elements with many inputs. But thus computing difficulties sweepingly grow with growth of number of inputs. As it is possible to notice, thus growth of computing difficulties is connected with presence of statistical dependences between input variables of element. At a noncorrelatness input variables calculation considerably become simpler: pulsing functions on each channel are defined independently.

On the basis of the found transfer functions of each element *p* the observed a single-level complex according to its structure transfer functions of the sectional centre are defined. For this purpose in view of connections between elements of a complex:

$$x_0^{(p)} = x_0^{(p+1)} , \quad (4)$$

since *p=s* intermediate variables are consistently excluded as a result explicit expressions of output variables of a complex are received: $x^{(s)}, x^{(p)'}, \; p = \overline{1,s}$ from its input variables: $x_0^{(1)}, u^{(p)}, \; p = \overline{1,s}$:

$$x^{(s)} = \left(\prod_{p=1}^{s} G_1^{(p)}\right) x_0^{(1)} + \sum_{p=1}^{s}\left(\prod_{\ell=p+1}^{s} G_1^{\ell}\right) G_2^{(p)} u^{(p)};$$
$$x^{(p)'} = \left(\prod_{p=1}^{p} G_3^{(p)'}\right) x_0^{(1)} + \sum_{p'=1}^{p}\left(\prod_{\ell=p+1}^{p} G_3^{\ell}\right) G_4^{(p)} u^{(p)}. \tag{5}$$

Accepting labels:

$$G_1 = \left(\prod_{p=1}^{s} G_1^{(p)}\right);\; G_2 = \left(\prod_{\ell=p+1}^{s} G_1^{\ell}\right) G_2^{(p)};\; \widetilde{G}_3^{(p)} = \left(\prod_{p'=1}^{p} G_3^{(p)}\right),\; \widetilde{G}_4^{(p)} = \sum_{p'=1}^{p}\left(\prod_{\ell=p+1}^{s} G_3^{\ell}\right) G_4^{(p)'}, \tag{6}$$

expressions (5) can be noted in an aspect:

$$x^{(s)} = G_1 x_0^{(1)} + \sum_{p=1}^{s} G_2 u^{(p)};\; x^{(p)'} = \widetilde{G}_3^{(p)} x_0^{(1)} + \sum_{p'=1}^{p} \widetilde{G}_4^{(p)'} u^{(p)'} \quad . \tag{7}$$

In expressions (6) G_1, G_2, $\widetilde{G}_3^{(p)}$, $\widetilde{G}_4^{(p)}$ make the aggregated transfer functions presented on fig.1,a a single-level complex, the same, that transfer functions SC on corresponding channels. And expressions (7) make the aggregated model of the given complex, hence, model SC as element of a higher bush of MIS.

Accepting $\nu = j\omega$ in models (3) and (7) them it is possible to present in frequency area.

It is necessary to note, that made models (3) and (7) besides a prediction, also carry out functions of filters in ranges of frequencies $\omega \le \omega_e$ and $\omega_э \le \omega \le \omega_c$, where ω_e, ω_c - frequencies of a gating through of elements and SC. Quite often for identification of complexes (SC) they are represented and investigated as black boxes. However, as show researches of the author, such approach often leads to incorrect model and rather big dimensions ([2], p.386-395).

The model of a kind (7), basically, is used for sectional control of complexes of the bottom levels of MIS. Its use at the top levels of MIS causes the big computing difficulties. Therefore in existing practice in model (7) instead of $u^{(p)}$ resources on their realization normalized rather x_0 or $x^{(s)}$ are considered. As are normalized $x_0^{(p)'}$. Such normalization is one of elements of decentralization controls of MIS. Thus model (7) considerably becomes simpler and takes a form:

$$x^{(s)} = G_1 x_0^{(1)}, x^{(p)'} = \ell^{(p)'} x_0^{(1)}, \tag{8}$$

where $\ell^{(p)'}$ - factor of normalization $x^{(p)'}$ on $x_0^{(p)}$.

For vectors $x_0^{(p)}$, $x^{(s)}$, $x^{(p)'}$ model (8) is matrix.

At presence ER - capacities between consecutive elements of a complex instead of the equation of communication (4) is used the equation of a kind $\frac{dy}{dt} = x_{(t)}^{(p)} - x_{0(t)}^{(p+1)}$ in continuous and $y(k+1) = y(k) + (x^{(p)}(k) - x_0^{(p+1)})\Delta$ in a discrete time. Here $y(t)(y(k))$ -quantity of a store of a resource in capacity in moment $t(k)$; Δ is a discrete interval. Thus consecutive exclusion $x_0^{(p)}$ for the formulation of model SC is carried out with use relation $x_0^{(p+1)} = \frac{dy}{\partial t} + x^{(p)}$, $x_0^{(p+1)} = (y(k) - y(k-1)) + x^{(p)}$.

It is easily generalized and for a case of inflow of the resource with the same name from the side in each capacity and leaving from it on a side.

The problem of control of transients in DIS with use of the made model is carried out as follows:

1. In SC within limits of frequencies $\frac{2\pi}{T_c} \div \frac{2\pi}{T_e}$ is solved and for period T_c with discrete time Δ_c, $\Delta_c \geq T_e$ taking into account restrictions on resources, including on resources for realization of control actions of elements of a complex, the problem of discrete optimum control at this phase, MIS appointed top level or defined from strategic reasons. Here T_c, T_e - the maximum time of transients in SC and elements accordingly. From the problem solution representations for entering and output resources of elements on the interval Δ_c are defined.

2. The analogous problem within frequencies $\frac{2\pi}{T_e} \div \frac{2\pi}{\Delta_e}$ is solved and for T_e with discrete time Δ_e for separate elements taking into account restrictions on the resources appointed SC on this period. From the problem solution optimum values of control actions, hence, optimum values of resources are defined.

The control system of DIS realizing above presented scheme functions by a principle of a feedback by results of realization of tasks (strategic restrictions) of elements during $T_e = \Delta_c$. Thus frequency of a retroaction makes $\frac{2\pi}{T_e}$.

In the report the received models are in detail analyzed and on example are analyzed and on an instance are shown their filtrating capacities.

Literature

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