The account of influence of time delays of processing of signals in digital control systems

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Abstract: Output signals of digital control systems have an essential delay concerning input signals. This delay is the reason of an additional error of control. Influence of a delay of the information is offered to be considered in the form of a component of dynamic error of process of digitization - restoration. At such approach the delay increase leads to increase in demanded frequency of digitization or to increase in an error of control.

Keywords: digital control systems, delay, dynamic error, control error

Each device, management systems being in a chain (fig. 1), can be characterised:

- The magnitude of error brought in control procedure (γ);
- Time of a delay of information (t).

Thus, it allows to mark for:

- Sensors $\gamma_{д}$ *and* $t_{д}$;
- Antialiasing filter $\gamma_{ф}$ *and* $t_{ф}$;
- The analogue multiplexer (AMX) γ_{MX} *and* t_{MX};
- The analogue -digital transducer (A/D) γ_{AD} *and* t_{AD};
- Digital control systems $\gamma_{CУ}$ *and* $t_{CУ}$;
- Programm recovery of information $\gamma_{MП}$ *and* $t_{MП}$;
- Digital-analogue transduser (D/A) γ_{DA} *and* t_{DA};
- Devices of apparatus recovery γ_{MA} *and* t_{MA}.
- Actuating mechanisms $\gamma_{ИМ}$ *and* $t_{ИМ}$

Besides, in a management system it is necessary to allow for an error imposing of spectra (γ_{H}) and a methodical error of recovery of the information (γ_{M}). Errors γ_{H} *u* γ_{M} set sampling rate of analogue signals. In system fig. 1 sampling rate is installed by means of master clock G.

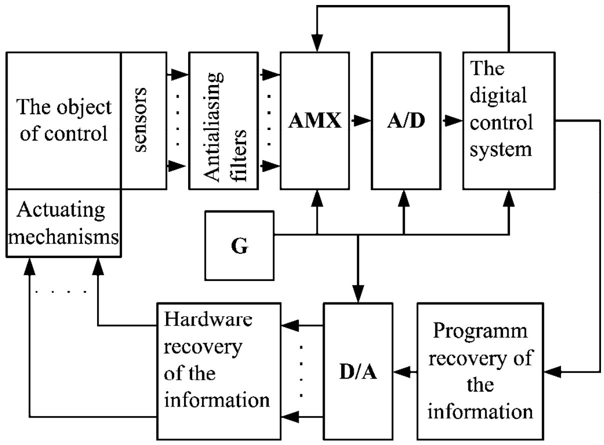

Figure 1.

Then for a common error of a control system ($\gamma_{\text{ОБ}}$) it is possible to record

$$\gamma_{\text{ОБ}}^2 = \gamma_{\text{д}}^2 + \gamma_{\text{ф}}^2 + \gamma_{MX}^2 + \gamma_{\text{AD}}^2 + \gamma_{\text{СУ}}^2 + \gamma_{\text{МП}}^2 + \gamma_{\text{DA}}^2 + \gamma_{\text{МА}}^2 + \gamma_{\text{ИМ}}^2 + \gamma_{H}^2 + \gamma_{M}^2 \,. \quad (1)$$

Summarised time of a delay of information (t_Σ) will be equal:

$$t_\Sigma = t_{\text{д}} + t_{\text{ф}} + t_{\text{MX}} + t_{AD} + t_{\text{СУ}} + t_{\text{МП}} + t_{\text{DA}} + t_{\text{МА}} + t_{\text{ИМ}} \,. \quad (2)$$

Summarised time of a delay of information is the reason of an additional essential error which we will mark as γ_t .

Assemblage of sensors the starting signals determine a control object state. On the basis of signals of sensors the digital management system works out signals on actuating units. But these actuating signals come with delay when the object is already in other state. Such situation is the complementary error reason.

Among assemblage of sensors of a management system always it is possible to select the sensor with maximum fast operation. Signals of sensors are characterised by spectral density function ($S(\omega)$). On drawing $S(\omega)$ for a low-frequency signal it is possible to select so-called frequency limit $\omega_{\text{гр}}$ outside of which agency of spectral components can be neglected. The sensor with maximum fast operation will have maximum frequency limit $\omega_{\text{гр}}^{\text{мах}}$. Bernstein's known inequality [1] allows to determine a maximum derivative of a low-frequency signal of the observed sensor ($M^1_{мax}$) in a kind:

$$M^1_{мax} = A\omega^{мax}_{гр} , \tag{3}$$

Where A - signal amplitude.
The maximum resulted error of a state estimation of the object of control at the expense of hold time (γ_t) can be gained in a kind:

$$\gamma_t = \frac{M^1_{мax} * t_\Sigma}{A} = \omega^{мax}_{гр} * t_\Sigma . \tag{4}$$

Then the summarised error of a management system (γ_Σ) will be equal

$$\gamma^2_\Sigma = \gamma^2_{ОБ} + \gamma^2_t . \tag{5}$$

The offered algorithm of engineering of a digital management system consists in the following (fig. 2).

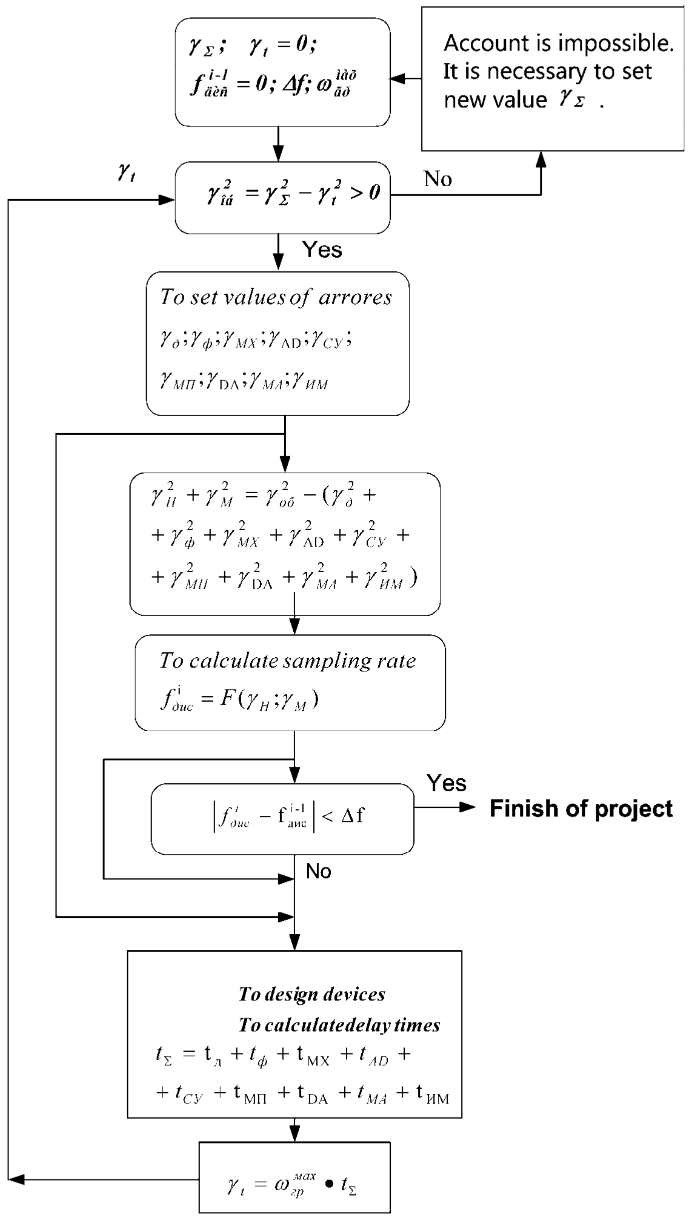
Account is impossible. It is necessary to set new value γ_Σ .
No
Yes
To set values of arrores
To calculate sampling rate
Yes
Finish of project
No
To design devices
To calculatedelay times

Figure 2

At the first stage the summarised error of management system γ_{Σ} is set. Value $\gamma_{t} = 0$.

At the second stage the value of error $\gamma_{ОБ}^2$ is computed.

$$\gamma_{ОБ}^2 = \gamma_{\Sigma}^2 - \gamma_{t}^2 > 0 . \quad (5)$$

If error $\gamma_{ОБ}$ is more than null calculation proceeds. If this error less or is equal to null calculation is impossible. It is necessary to set major value of a summarised error of system γ_{Σ} .

At the third stage the direct allocation problem of error $\gamma_{ОБ}$ between separate devices of a management system is decided. As a result each of errors from (1) is set.

At the fourth stage on the basis of the sum of error $\gamma_{H}^2 + \gamma_{M}^2$

The demanded sampling rate ($f_{дис}^{i}$) is computed. This frequency rate of discretization is compared to the sampling rate gained on the previous step of scalings $f_{дис}^{i-1}$.

$$\left| f_{дис}^{i} - f_{дис}^{i-1} \right| < \Delta f . \quad (6)$$

If the outcome of matching is less than specified value Δf calculation is considered executed. Otherwise calculation proceeds.

At the fifth stage, having errors of each device and sampling rate, it is possible to make engineering of each device and system as a whole. Engineering will allow to determine a signal delay in each device and summarized delay t_{Σ} (2).

At the sixth stage the error from delay of signal γ_{t} (4) is determined and the new cycle of calculation of a digital management system starts.

As it was marked above, calculation is ended when in the next cycle the inequality (6) will be executed.