USING OSCILLATORY DYNAMICS OF THE MEASURING CIRCUIT IN THE INTERVAL CRITERION OF THE STEADY-STATE VALUE ESTIMATOR

Y.S. Bekhtin, A.A. Lupachev, P.K. Makarychev, N.A. Serov, V.S. Khodyreva, A.R. Petsinyarzh

Abstract: In the report the standardized interval criteria (IC) of the end of transition process in the measuring circuit (MC) in the on-line mode are considered. These criteria assume the use of the aperiodic first order link as a model of MC. However, there are a number of comments on their use. One of the reasons for this may be inadequate real dynamic model of MC. The numerical simulation confirmed the presence of a critical value of the time constant for the MC model in the form of a second-order oscillatory link.

Key words: measuring circuit, second order link, interval criteria for the end of the transition process, the critical duration of the interval of observation of the process.

1. Introduction

The basis for the optimization of modern measuring instruments is the use of current information about the transition process (TP) in the measuring circuit (MC) [1]. An important role in the analysis of such information is given to the criteria of the end of the TP in MC is presented group empirical interval criteria (IC) [2, 3]. Standardized IC assume the use of the first order aperiodic link as a model of MC [4, 5]. However, there are a number of restrictions on its use.

In [6] it was shown that the IC functions correctly in a narrow range of possible values of the time constants of the MC model in the form of a first-order link. One of the reasons for this may be inadequate dynamic model of MC.

In [2] it is noted that significant systematic dynamic errors of the first kind (up to tens of percent) are observed due to the use of inadequate criterion for determining the thermal steady state during testing of power transformers.

In the work [7] the samples of intelligent measuring devices, the errors of which are caused by incorrect (earlier) determination of the end of the transition process in the measuring circuit during thermal measurements and the use of the Auto Hold function, are considered.

The essence of the interval criterion is described in [2, 6, 8-10]. It consists in the fact that the TP signal is analyzed and the relative increment of the $\rho_к$ of this signal is calculated on the observation interval of the ΔT_O in the on-line mode. Set the value of TP occurs when the execution interval criterion $B_{\%} \geq \rho_к$ in the current interval monitoring signal TP. For example, the following values are assigned as IC parameters in the current standard [11]:

- allowed relative increments of $B_{\%}$, $B_{\%}$=1%;
- the specified duration of the observation interval ΔT_O, ΔT_O = 30 s.

2. Measuring circuit model

MC is considered as a linear system with concenetrated constant parameters and is aperiodically stable. Usually MC is represented by a first order aperiodic link (ALFO), which belongs to the class of simple dynamic systems [12].

In the practice of measurements, the quasi-deterministic model of the measuring process in the form of a transient characteristic represented by the sum of the exponents has an important role. So, in the work [13] *"two important cases are highlighted: when the time constants of the exponents are close enough and when they differ 5-10 times or more"*.

It is known that many of the structures of transducers (MT) are dynamic characteristics, are presented in the form of the oscillation link of the second order (OLSO). As the main parameter of the OLSO, with respect to which the IC studies will be conducted, the damping parameter [14] or the relative damping coefficient [1] ζ is selected. The most practical value for MT is the case when the attenuation parameter lies in the range of $0.8 < \zeta < 1.0$ [15], since the duration of the transition process in this case is the smallest. In this case, the overshoot σ, which characterizes the maximum deviation of the relative transient characteristic of MT from the steady-state unit level, does not exceed 1% at $\zeta > 0.826$ [1].

3. Status of the research issue

In [10] was found the presence of restrictions on the use of interval criterion with respect to model MC ALFO in the form of the critical time constant τCR.1O circuit, exceeding which the IC gives the wrong decision on the achievement of the MC transient steady-state value with a permissible dynamic error of the first kind.

In [16], the analysis of the interval criterion for the output signal MC presented by the second order aperiodic link (ALSO), equivalent to the sequential inclusion of two ALSO with time constants T1 and T2, was carried out. The ratio of time constants (TC) K = T1/T2 was chosen as the parameter ALSO, with T1 being the maximum among them, with respect to which IC studies were conducted.

It was found that with the growth of the ratio of the time constants ALSO critical value of $\tau_{CR.2O}$ for the IC to MC the second order seek to $\tau_{CR.1O}$ = 43.9 s. it should be noted that the module of difference ($\tau_{CR.1O}$ - $\tau_{CR.2O}$) does not depend on the model parameter MC at K ≥ 1.5 and this difference does not exceed the discreteness of modeling TP in time equal to 1 s, i.e. with a relative error of not more than 2.5%.

The change of critical values within the possible range of T1/T2 = {1.0 ... 20.0} lies within the limits of $\tau_{CR.2O}$ = {38.7 s ... 45.0 s} for the following parameters of the IC under study [11]: {ΔT_O = 30 s; $B_{\%}$ = 1%}, i.e. the relative change does not exceed 15%.

This work is the development of the provisions set out in the report [7], since the nature of the change in the critical value of the time constant $\tau_{CR.OL}$ MC with a dynamic model in the form of a second-order oscillatory link is not known today.

4. MC study in the form of a second-order oscillatory link

The relationship between the K parameter for ALSO and the ζ damping parameter for SOLO can be obtained using the following expression: $\zeta = (K + 1)/(2\sqrt{K})$. For K = 1 we have ζ = 1.

The simulation results of the MC in the form of aperiodic and oscillatory links of the second order for the investigated IC [11]: {ΔT_O = 30 s; $B_{\%}$ = 1%} are shown in Fig.1. Above the curve is an area with parameters that do not provide finding the moment of the beginning of the steady-state TP process with the given parameters for the dynamic error.

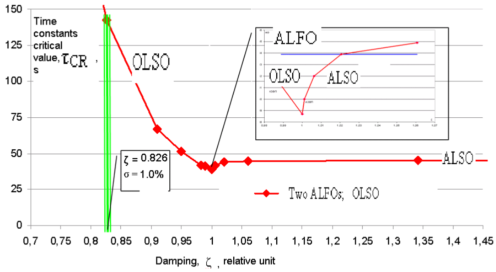

Fig. 1 - Critical time constant for the model under study MC in comparison with the model ALSO

The $\tau_{CR.OL}$ is based on the data of numerical simulation of TP at the output of OLSO with the use of spreadsheets. These data are presented in the table 1 for durations of observation of TP equal to $\Delta T_{O.1}$ = 30 s, $\Delta T_{O.2}$ = 60 s and $\Delta T_{O.3}$ =90 s for attenuation parameters ζ = {1/√2; 0,826; ..., 0.99}.

Table 1 - Simulation results on the use of IC at the output of ΔT_O OLSO

ΔT_O, s	Attenuation parameter, ζ:					
	0,707	0,826	0,91	0,95	0,98	0,99
	Critical time constant, $\tau_{CR.OL}$,s					
30	358,93	142,5	66,7	51,43	41,86	41,18
60	668	240,7	102,5	75,5	61	59
90	975,7	340	132,5	96,4	76,5	74,3

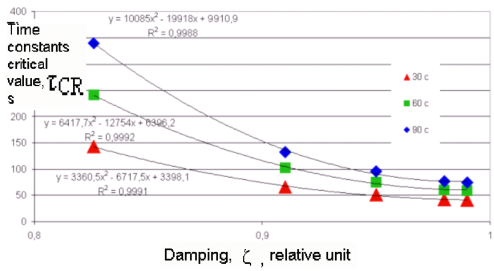

Figure 2 - Dependence of the critical time constants for the three durations of the monitoring interval

For Fig.2 simulation results for different durations of the observation interval are presented. The diagram shows the trend equations approximating the simulation results and the values of the approximation reliability.

The constructed polynomial trend lines (i =

0, 1, 2) allow us to find empirical dependence of $Y = f(\alpha_i, X^i)$ of the scalar variable Y on the factors X and estimates of the vector of parameters α. The factor X_1 is the relative damping coefficient ζ, and the factor X_2 is the duration of the ΔT_O observation interval.

The form of the approximating function $Y = AX^2 - BX + C$. Table.2 summarizes the coefficients A, B, C, and the results of operations transactions between them.

The largest information about the required empirical dependence is contained in the first row of the table.2 for $\Delta T_O = 30$ s. Analysis of this information allows you to write the desired expression in the form:

$$\tau_{CR.OL} = G(\Delta T_O)\,(1 - \zeta)^2 + D,$$

where D = (C-A) - a constant whose value is close to the value of $\tau_{CR.2O} = 38.7 \pm 1.0$ s at T1 = T2, D has a dimension of time;

$G = A_{MIN}$ - constant depending on the duration of the observation interval.

Table 2-Results of approximation of simulation data

ΔT_O, s	Estimates of the parameter vector α:					
	A	B	C	C-A	B/A	A/A_{MIN}
30	3360	6717	3398	37,6	1,99	1,0
60	6417	12754	6396	-21,5	1,99	1,91
90	10085	19918	9910	-174	1,98	3,00

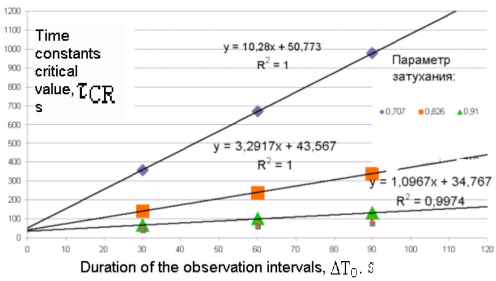

Figure 3 - Dependence of the critical time constants for various parameters of attenuation of the OLSO

Direct shown in Fig.3 shows the linear nature of the relationship between the values of the critical time constants and the duration of the observation intervals.

5. Conclusion

In this work, the ability of the interval criterion to determine the steady state in the transition process of MC, presented by the second order oscillation link model, was tested.

Numerical simulation of TP showed that the interval criterion correctly determines the moment of the steady-state value only up to the critical value of $\tau_{CR.OL}$. This value when the damping coefficient is less than 1.0 in OLSO polynomial dependence significantly increases tenfold compared to $\tau_{CR.2O}$ at K = 1.0.

Further work should be aimed at determining the constants of the empirical formula for the critical time constant and assessing the degree of performance of the function found, i.e. the suitability of the empirical dependence for practice.

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Information about the Authors:

Bekhtin Yuriy Stanislavovich. Ryazan radio engineering Institute (1983). Doctor of science (2009), Professor (2013). National research University "Moscow power engineering Institute" (MPEI), Institute of automation and computer engineering (AVTI). Research interests: digital signal processing.

Web address: *www.mpei.ru*

e-mail address: yuri.bekhtin@yandex.ru

Lupachev Alexey Alekseevich. Tula Polytechnic Institute-Automation and telemechanics (1974). Ph. D. (1985), S. S. (1992), National research University "Moscow power engineering Institute" (MPEI), Institute of automation and computer engineering (AVTI), associate Professor - Department of information and measuring technology (IIT). Research interests: development of intelligent measuring instruments.

Web address: *www.mpei.ru*

e-mail address: LupachevAA@yandex.ru

Serov Nikolai Andreevich. Moscow power engineering Institute (1971). Ph. D. (1985), associate Professor (1986), National research University "Moscow power engineering Institute" (MPEI), Institute of automation and computer engineering (AVTI), associate Professor - Department of information and measuring technology (IIT). Research interests: analog measuring devices.

Web address: *www.mpei.ru*

e-mail address: serna2004@list.ru

Makarychev Peter Konstantinovich. Moscow power engineering Institute (1976), National research University "Moscow power engineering Institute" (MPEI), Institute of automation and computer engineering (AVTI), Senior lecturer-Department of IIT. Research interests: digital signal processing.

Web address: *www.mpei.ru*

e-mail address: makpk@mail.ru

Khodyreva Valeria Stanislavovna. "NRU "MPEI", AVTI. Bachelor in computer Science and engineering. Research interests: digital signal processing.

Web address: *www.mpei.ru*

e-mail address: khodyrevavs@gmail.com

Petsinyarzh Arkadiy Romanovich. Student of Bauman Moscow State Technical. Research interests: experimental data processing.

Website: *http://bmstu.ru/*

e-mail address: arkasha.pe@yandex.ru