

## Methodological approach for identification the function of the object for automatic regulation system of the continuous technological processes

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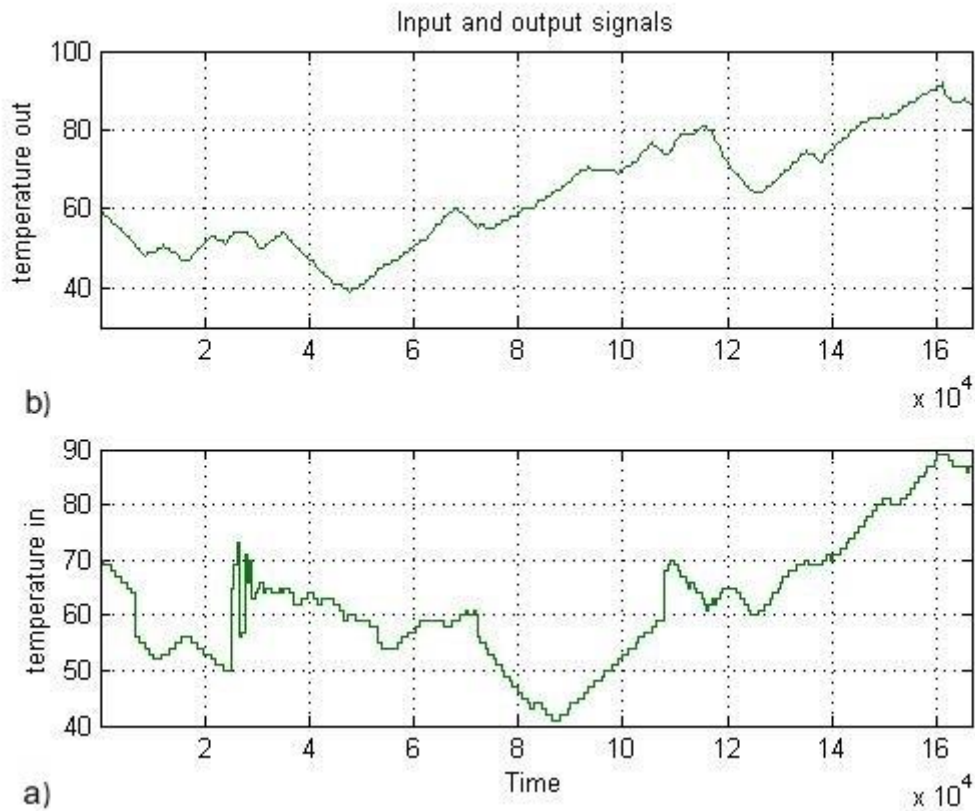
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**Abstract.** The article describes one of the approaches to the implementation of the functional approximation problem of nonlinear characteristics of the object of automatic regulation system based on the identification the function of the object, the analysis of input and output characteristics of the object, and numerical characteristics of random values.

In conditions of the continuous technological processes of the complex dynamic systems, modes which involve a constant change of adjustable parameters it is not possible to obtain the experimental static characteristic of the automatic regulation system volume.

Though the task to raise the regulation quality, to improve transient characteristics including the regulation decrease and totally the reduce of the excessive energy consumption for the own needs requires to build a dynamic model able to show quite fully the technological control object [1]. The presence of a priori information, in this case, the input and output of nonlinear characteristics of the object allows accelerating the process of object identifying, more precisely, obtaining its abstraction expressed with transfer function with a high degree of reliability. Turning to the application software, in particular, System Identification Toolbox Matlab package, we analyze the available a priori information for the object (Fig. 1) performing surface heat transfer function.





**Figure 1.** Nonlinear object characteristics a) input b) output

A priori information is presented as the input object characteristic - change of the thermal agent temperature of the supply circuit ( $C^0$ ) over time, and the output characteristic - change of the thermal agent temperature of the output circuit ( $C^0$ ) over time.

Time series analysis is based on the alternation of transfer functions with a variable number of poles and subsequent finding of the optimal conversion coefficient values  $K_p$  and the time constant  $T_{pi}$  by Gauss-Newton method, iterative numerical method of finding a solution to the problem of least squares, by means of System Identification Toolbox, in which the posteriori output characteristic will be brought most closer to a priori output characteristic by means of functional approximation method [2, 3].

Time series analysis of the full length at transfer of the alternation functions with a variable number of poles has shown that with number increase of transfer function poles the degree of reliability curves -  $F$  increases, though the achieved maximum is  $F = 38,05\%$  (Table 1.).

Table 1. Results of the analysis of time series of full length ( $N = 1$ )

Segment number, $n$	Quantity of Poles, $i$	Range of authenticity $F$ , %	View of Transfer Function	Conversion Factor ( $K_p$ ), Time Constant ( $T_{pi}$ )
1000	0	0,8598	$G(s) = K_p$	$K_p=0.86003$

	1	3,436	$G(s) = \frac{Kp}{1 + Tp_1 * s}$	Kp=9.7581e5 Tp1=3.8838e12
	2	-0,7378	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$	Kp=1.1301 Tp1=9.9231 Tp2=0.002
	3	37,05	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$	Kp=-1.7007e6 Tp1=5.176e11 Tp2=3.3712e5 Tp3=0.0072701

Initial knowledge about the object can judge that the surface heat transfer process is very inertial in nature; therefore, the transition process from one stable state to another, within the static characteristic, is also a long time [4]. Thus, the task of enhancing the credibility of curves is based on the allocation of the static characteristic from the time series of full length.

Not taking into account the structural features of the object, the outdoor temperature and the room temperature, we carry out site investigation of time series with a variable number of sampling points by separation and subsequent analysis of the original time series of full length. This approach will also allows to analyze the numerical characteristics of the obtained random variables, provided a sufficient number of time series sections [5].

The first step is to separate three sections ( $N = 3$ ) from the starting time series of full length. We introduce the concept of conditional probability of  $P_i$  - the weight of a particular structure of the transfer function in the task of curves approximation -  $N$  sections of time series, where  $i$  - the number of poles of the transfer function. The obtained results (Table 2), including the conditional probability  $P_1 = 0,68$  and  $P_3 = 0,32$ , do not allow to make an unambiguous conclusion about the functional relationship between parameters such as of  $N$ ,  $P_i$ , and  $F$ , and also of the character pattern between  $P_i$  and  $F$  at a variable  $N$ . We note that at  $N = 3$ , the transfer function of the lower weight ( $P_3$ ) corresponds to a high degree of curves reliability  $F = 64,35\%$ . For answers to these questions we continue the analysis of time series of full length sections at  $N = 10, 20, 40$ .

Table 2. Results of the time series analysis with separation of three sections ( $N = 3$ )

Segment number, n	Quantity of Poles, i	Range of authenticity F, %	View of Transfer Function	Conversion Factor (Kp), Time Constant (Tpi)
1	0	16,08	$G(s) = Kp$	Kp=1.0157
	1	54,05	$G(s) = \frac{Kp}{1 + Tp_1 * s}$	Kp=2.9334e9 Tp1=6.7235e14
	2	65,23	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$	Kp= 1.4082e7 Tp1= 2.3103e12 Tp2= 21035

	3	66,03	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$	Kp=1.7031 Tp1= 417.13 Tp2= 49031 Tp3= 49115
2	0	-16,5	$G(s) = Kp$	Kp= 0.86751
	1	0,2535	$G(s) = \frac{Kp}{1 + Tp_1 * s}$	Kp=3772.3 Tp1=3.3409e 10
	2	-15,85	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$	Kp=0.86755 Tp1=134.52 Tp2= 134.64
	3	-15,45	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$	Kp=0.86442 Tp1=0.001 Tp2=730.04 Tp3=0.001
3	0	12,05	$G(s) = Kp$	Kp= 0.79075
	1	40,08	$G(s) = \frac{Kp}{1 + Tp_1 * s}$	Kp= 0.76735 Tp1= 13701
	2	40,14	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$	Kp= 0.7757 Tp1= 0.001 Tp2= 8890.7
	3	30,03	$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$	Kp=0.72007 Tp1= 1595 Tp2=39384 Tp3= 39375

As the number of sections (N = 10, 20, 40) increases at separation of full length initial time series and their subsequent analysis the following results were obtained - Table 3, 4, 5, as well as numerical characteristic of F reliability degree as a discrete random variable.

Table 3. Results of the time series analysis with separation of 10 sections (N = 10), the number of sampling points - 100

Quantity of Poles, i	Conditional Probability, Pi	Range of authenticity F, % (average)	Mathematical Expectation $M_N(F)$ , %	View of Transfer Function
0	0,12	-5,891	38,75	$G(s) = Kp$
1	0	0		$G(s) = \frac{Kp}{1 + Tp_1 * s}$
2	0,18	30,01		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$
3	0,7	44,63		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$

Table 4. Results of the time series analysis with separation of 20 sections ( $N = 20$ ), the number of sampling points - 50

Quantity of Poles, $i$	Conditional Probability, $P_i$	Range of authenticity $F$ , % (average)	Mathematical Expectation $M_N(F)$ , %	View of Transfer Function
0	0	0	61,45	$G(s) = Kp$
1	0,13	69,37		$G(s) = \frac{Kp}{1 + Tp_1 * s}$
2	0,37	53,77		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$
3	0,5	65,1		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$

Table 5. Results of the time series analysis with separation of 40 sections ( $N = 40$ ), the number of sampling points - 25

Quantity of Poles, $i$	Conditional Probability, $P_i$	Range of authenticity $F$ , % (average)	Mathematical Expectation $M_N(F)$ , %	View of Transfer Function
0	0	0	75,76	$G(s) = Kp$
1	0,06	68,15		$G(s) = \frac{Kp}{1 + Tp_1 * s}$
2	0,22	77,97		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)}$
3	0,72	73,54		$G(s) = \frac{Kp}{(1 + Tp_1 * s)(1 + Tp_2 * s)(1 + Tp_3 * s)}$

These results allow observing the effect of the following pattern: in the problem of curves sections approximation prevails the weight of transfer function with a large number of poles and as the number of sections ( $N = 10, 20, 40$ ) increases the curves reliability rises. The character of this pattern in this study is not specified, though the obtained characteristics can be shown in the following functional relationship:

$$M_N(F) = \sum_{j=1}^i F_i \cdot P_i, \quad (1)$$

Expression (1) is mathematical expectation of  $F$  reliability degree in solving the problem of  $N$  sections approximation by means of transfer functions with different numbers of  $i$  poles and  $P_i$  conditional probabilities.

An interesting result of the time series analysis is the transfer function (2) with number of poles  $i = 3$ , reliability degree  $F = 94,65\%$  and mathematical expectation  $M_N(F) = 75,76\%$ :

$$G(s) = \frac{133,45}{(1 + 5045,3 \cdot s)(1 + 2789,3 \cdot s)(1 + 1.7955 \cdot e \cdot 7 \cdot s)} \quad (2)$$

The obtained expression (2) with a maximum degree of reliability determines the surface heat transfer function in one of  $N = 40$  sections ( $n = 32$ ) and does not allow to describe other 39 sections with the similar reliability, however, the conditional probability for this type of transfer function -  $P_3$  is 0.725 that says of the maximum weight of this type transfer function in the solution of the problem of  $N$  sections curves approximation.

Thus, it is possible to increase the curves reliability degree by following steps:

- The separation of time series sections with a variable number of sampling points;
- The analysis of time series sections, alternating the transfer functions with a variable number of  $i$  poles and subsequent finding of the optimal values of  $K_p$  transformation coefficients and  $T_{pi}$  time constant by Gauss-Newton;
- The acquisition and subsequent analysis of the numerical characteristics of  $F$  reliability degree.

It is acceptable to assume that the final result of this approach is the value of mathematical expectation of reliability degree -  $M_N(F)$ , which physical meaning, in this study, can be interpreted as a display indicator of the static characteristics from the full length time series, expressed in percentage, in solving the problem of curves approximation by alternating of four transfer functions with a variable  $N$ .

The results obtained in this study, namely methodological aspects of ASR object identification in conditions of continuous TP, may be applied as one of the approaches for assessing the reliability degree of the transfer function in solving the problem of curves approximation [6, 7].

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