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IDENTIFICATION ALGORITHM OF CONTROL OBJECTS

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АЛГОРИТМ ІДЕНТИФІКАЦІЇ ОБ'ЄКТІВ КЕРУВАННЯ

Лорія М.Г.

The analysis of the dependence of the efficiency of control objects identification algorithm on the methods of initial data selection: the uniform distribution of points on transient response curve and by characteristic points, is carried out. The dependence of the approximation error on the number of selected points on transient response curve is investigated.
Keywords: *approximation, nonlinear least squares method, uniform distribution of points, derivatives.*

Introduction

The growth of raw material cost on world markets leads to a rapid increase in the cost of Ukrainian production. Therefore, at present, the share of the cost of natural gas in chemical plants production reaches 75%. Thus, in order for domestic products to be competitive in the world market, there is an urgent need for more efficient use of raw materials, energy, etc. That is why, it is necessary to optimize production processes. On the majority of enterprises, the technology upgrade has been carried out, including control systems. However, as it turns out, this may not be enough if the major device in the automatic control system – a regulator that generates a control signal in order to obtain the required accuracy and quality of transient process, is not tuned properly. As the analysis of literary sources shows, the proportion of improperly tuned regulators used in the industry is about 30%. However, before finding the regulator settings, it is necessary to determine the transfer function of the control object, and for this purpose, it is necessary to identify the control object [1, 2, 3].

When identifying any transient process by transient response curve of an equivalent control object, using nonlinear least squares method, the developer faces the question, how, where and how many points on the transient response curve of the equivalent control object it is necessary to take in order to identify it with a sufficient degree of accuracy by second differential equation [4, 5, 6, 7].

The purpose of work is a comparative analysis of the methods of initial data selection for identification algorithm: by uniform distribution of points or by characteristic points.

Approximation of control objects

In [5] it is proposed to use a uniform distribution of points for the approximation of the transient characteristic of control object of the transient process of the second order link. The dependence of approximation accuracy on the number of points on the transient response curve, which are selected by uniform distribution of points, is investigated. The results of studies have shown that for approximation of transient function of an equivalent control object of any type with an error (the maximum deviation of the curve, which is approximated and the transient process of the second order link δ_{max}) of not more than 3%, it is enough to break the transient response curve by 15 equal parts along time axis between the start and end of the transient response curve (transient response curve reaching a constant value) and take 15 points on the transient response curve. However, such an approach does not take into account all the features of control object and, accordingly, is not able to provide maximum accuracy of approximation.

In [6], it is proposed to use the characteristic points, which are global extrema of derivatives of the output signal by time, to approximate the control object transient characteristic of the transient process of the second order link. The results of studies have shown that for the approximation of the transient function of an equivalent control object of any type, it is enough to take the characteristic points of the first two derivatives, which are selected based on the fact that each derivative will have at most two global extremes, that is, two characteristic points, as well as points: the start and the end of transient response curve. At this, the approximation error δ_{max} does not exceed 3%. The further increase in the number of characteristic points when using the third and fourth derivatives is practically not affected by the approximation error. The advantage of the proposed algorithm is that, firstly, the coordinates of the characteristic points are uniquely determined; and secondly, they can be determined both in the process of characterization and after it.

We will conduct a comparative analysis of the methods for selecting the initial data on examples of transient process of different types using characteristic points and uniform distribution of points.

Comparative analysis

Let us consider the approximation of the transient response curve of the control object aperiodic on the examples of transient response curve of the bleaching tower (Fig.1a) and gas reactor (Fig.1b) in nitric acid production , and the transient response curve of control object oscillating on the examples of transient response curve of gas turbine GTT-3-M (Fig.2a) and steam turbine (Fig.2b) in nitric acid production.

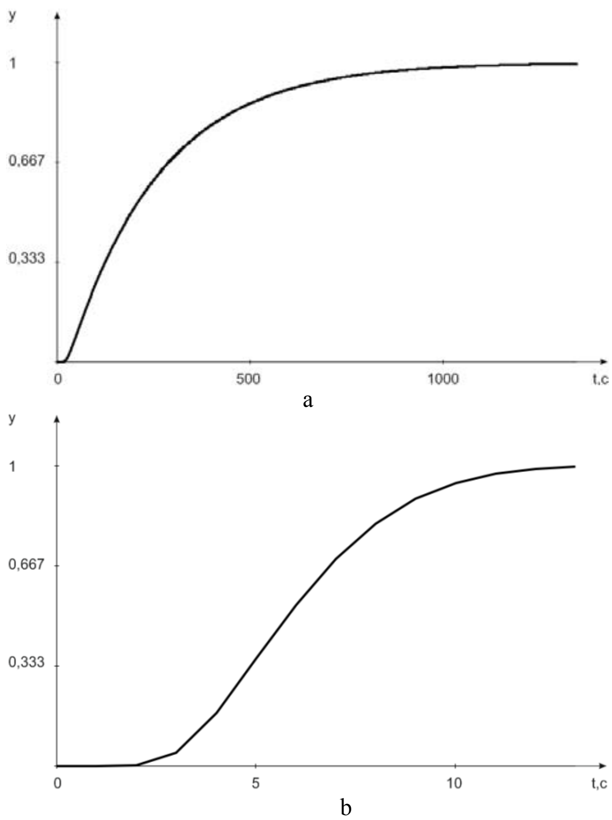

Fig. 1. Transient response curves:
a – bleaching tower; b – gas reactor

To approximate the transient response curve of an equivalent control object (Fig.1,2) by the corresponding transient process of the second order link with the time of delay, unknown parameters of the transitive function should be determined (K_p– transmission coefficient , determined by the transient response curve and for the transient response curve data is equal to 1, time constant T_1, T_2 and delay time τ). The values found for these parameters and the approximation errors (the maximum deviation between the curves δ_{max} and mean square deviation σ), depending on the number of points N , is given in tables 1-4: the transient process of the bleaching tower is given in Table 1, transient process of gas reactor – in Table 2 , transient process of turbine GTT-3-M – in Table 3, transient process of steam turbine– in Table 4.

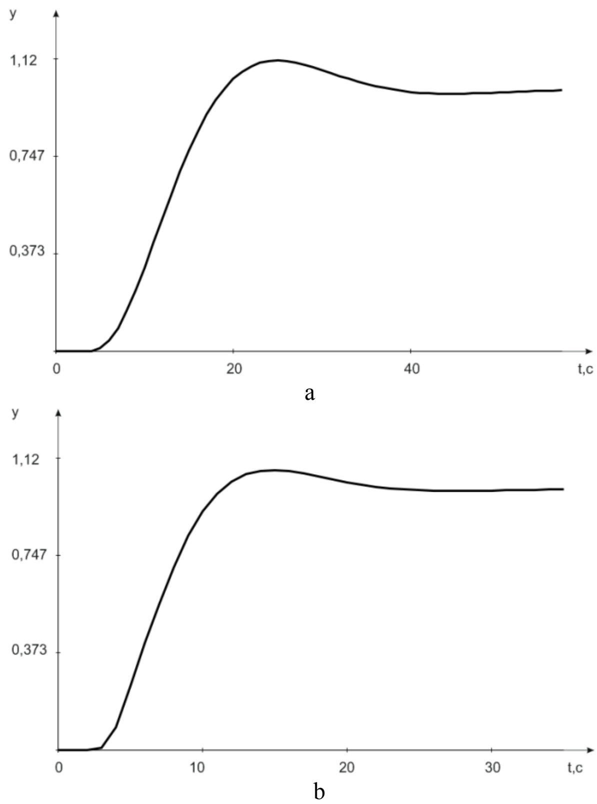

Fig. 2. Transient response curves:
a – turbine GTT-3-M; b – steam turbine

The research was conducted using the mathematical package «MathCAD» [7].

In Tables 1-4 for selecting the initial data using the uniform distribution of points was chosen as many points as for the methods for selecting the initial data using characteristic points, and also 1000 points were chosen to show that it makes no sense to take many points, since with number of points increase, the approximation error δ_{max} does not significantly change

From the results of the research (Tables1-4), the dependence δ_{max} and σ on the number of points, when approximating the control object according to the initial data selected by the uniform distribution of points and by characteristic points, it follows that for the approximation of an equivalent control object by the characteristic points by the second order link maximum 6 points are sufficient (two points – the beginning and the end of the transient process, and two points (global extrema) on the graphs of the first two derivatives, which are determined uniquely and maximally characterize the dynamic properties of control object. Whereas, in order to approximate the control object by uniform distribution of points, in many cases, 15 points are necessary, and sometimes even this is not enough to ensure that the approximation error δ_{max} does not exceed 3%..

Table 1

The value of the parameters and approximation errors, depending on the number of points for the transient process of the bleaching tower

Algorithm	Deri-vative	Numb. of points N	Parameters of transient function of the second order link			Approximation errors	
			T_1	T_2	τ, c	$\delta_{max,\%}$	σ
Character. points	1	4	11.305	237.424	61.248	0.034	$1.720*10^{-4}$
	1,2	6	11.498	237.475	61.072	0.010	$1.246*10^{-4}$
	1,2,3	8	11.537	237.444	61,041	$7.292*10^{-3}$	$6.080*10^{-5}$
	1,2,3,4	10	11.596	237.397	60.993	$3.795*10^{-3}$	$3.749*10^{-5}$
Uniform distribution of points	w/o deriv.	4	12.531	237.415	60.003	0.156	$6.341*10^{-4}$
		6	11.441	237.415	61.150	0.023	$8.754*10^{-5}$
		8	11.329	237.415	61.269	0.041	$1.600*10^{-4}$
		10	11.322	237.415	61.275	0.042	$1.640*10^{-4}$
		…	…	…	…	…	…
		1000	11.577	237.415	61.008	$4.379*10^{-3}$	$5.418*10^{-6}$

Table 2

The value of the parameters and approximation errors depending on the number of points for transient process of the gas reactor

Algorithm	Deriv.	Number of points N	Parameters of the transient function of the second order link			Approximation errors	
			T_1	T_2	τ, c	$\delta_{max,\%}$	σ
Characteristic Points	1	4	1.233	1.241	3.443	10.958	0.165
	1,2	6	1.818	1.818	2.615	2.957	0.059
	1,2,3	8	1.815	1.815	2.622	2.938	0.058
	1,2,3,4	10	1.815	1.815	2.622	2.938	0.058
Uniform Distribution of points	W/o Deriv.	4	1.149	1.156	4.093	21.699	0.234
		6	1.827	1.827	2.536	3.248	0.064
		8	1.700	1.700	2.811	4.153	0.055
		10	1.748	1.747	2.716	3.298	0.054
		…	…	…	…	…	…
		1000	1.734	1.734	2.751	3.616	0.054

Table 3

The value of the parameters and approximation errors depending on the number of points for the transient process of GTT-3-M turbine

Algorithm	Deriv.	Number of points N	Parameters of the transient function of the second order link			Approximation errors	
			T_1	T_2	τ, c	$\delta_{max,\%}$	σ
Characteristic points	1	4	5.829	5.180	4.961	2.291	0.023
	1,2	6	6.187	5.371	4.625	1.158	0.015
	1,2,3	8	6.195	5.376	4.614	1.130	0.015
	1,2,3,4	10	6.195	5.376	4.614	1.130	0.015
Uniform distribution of points	W/o Deriv.	4	5.750	5.155	5.401	4.969	0.052
		6	5.931	5.190	4.942	2.223	0.018
		8	6.107	5.327	4.671	1.273	0.013
		10	6.146	5.371	4.610	1.116	0.014
		…	…	…	…	…	…
		1000	6.078	5.317	4.727	1.452	0.013

Table 4

The value of parameters and approximation errors depending on the number of points for the transient process of steam turbine

Algorithm	Deriv.	Number of points N	Parameters of the transient function of the second order link			Approximation errors	
			T_1	T_2	τ, c	$\delta_{max,\%}$	σ
Character. points	1	4	3.910	3.049	2.417	2.118	0.016
	1,2	6	3.773	2.929	2.561	1.520	0.013
	1,2,3	8	3.774	2.920	2.575	1.510	0.014
	1,2,3,4	10	3.774	2.920	2.575	1.510	0.014
Uniform distribution of points	W/o Deriv.	4	3.925	3.062	2.285	3.577	0.025
		6	3.892	3.052	2.387	2.449	0.015
		8	3.906	3.906	2.336	2.992	0.019
		10	3.845	3.02	2.444	1.981	0.012
		…	…	…	…	…	…
		1000	3.815	2.985	2.495	1.578	0.012

Conclussion

In addition to the examples given in this work, a number of control objects with varying degrees of oscillation and inertia were investigated. According to the results of these studies it can be concluded that the identification of the control object by characteristic points is better than by the uniform distribution of points, since: firstly, the coordinates of the characteristic points are determined uniquely; and secondly, they can be determined both in the process of characterization and after it; thirdly, the number of points used, while providing the required accuracy , decreased by 1.5-3 times compared to the algorithm of uniform distribution of points [6,8].

Thus, in this work it is shown that when approximating an equivalent control object by the differential equation of the second order, it is reasonable to take the characteristic points of the transient process curve of an equivalent control object as the initial data. This allows to substantially facilitate the process of analysis and optimization of the dynamic characteristics of the automatic control system and significantly simplify the search for optimal regulator settings (ORS) by quadratic optimization function [9].

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Лорія М.Г. Алгоритм ідентифікації об’єктів керування

Проведено аналіз залежності ефективності алгоритму ідентифікації об’єктів керування від способів вибору початкових даних: рівномірним розподілом точок на кривій розгону та за характерними точками. Досліджено залежність похибки апроксимації від кількості обраних точок на кривій розгону.

Ключові слова: *апроксимація, нелінійний метод найменших квадратів, рівномірний розподіл точок, похідні.*

Лория М.Г. Алгоритм идентиикации объектов управления

Проведен анализ зависимости эффективности алгоритма идентификации объектов управления от способов выбора исходных данных: равномерным распределением точек на кривой разгона и по характерным точкам. Исследована зависимость погрешности аппроксимации от количества выбранных точек на кривой разгона.

Ключевые слова: *аппроксимация, нелинейный метод наименьших квадратов, равномерное распределение точек, производные.*

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