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MATHEMARICAL MODEL FOR TRANSITIONAL PROCESSES QUANTITY EVALUATION IN SYSTEMS OF ELECTRIC DRIVE CONTROLLING

The paper presents the fuzzy mathematical model for transitional processes quality evaluation in the systems of controlling over electromechanical objects. There had also been made the précised tuning using the genetic algorithms apparatus application.

Keywords: *model, electromechanical system, diagnostics, genetic algorithm.*

Urgency

The operation of the electromechanical systems stipulates for their operation, in particular, in the transitional modes, caused by both, the changes of operating factors of input controlling influences and various exciting operations which destroy the normal system functioning. Under such conditions the electromechanical system must provide for stable operation with the fixed quality factors which characterize its operating dynamics. The evaluation of quality factors enables to make a conclusion about the technical state of the object under diagnosing.

If electromechanical system is stable in the transitional modes but it doesn't provide for the needed transitional process, then such a system cannot be operated practically [1].

Some aspects of this question's solution are described in works [2-5].

Thus the work [3] presents the developed mathematical model of diagnosing the electric drive controlling systems, however, the suggested approach is mostly suitable for the analysis of the fixed operating modes. The works [4, 5] present the other way of solving the above problem by creation of diagnostic models in the form of the adapted neuron fuzzy nets.

Since the evaluation of quality factors allows the to make a conclusion about the technical state of the object under diagnosing, let's make up a corresponding mathematical model, based on usage of elements of fuzzy theory. To tune up the model operation with specific object under diagnosing, let us use the genetic algorithms apparatus, which is the most modern on the given stage without the problem of local extremum, which is not peculiar for it.

Problem solution

Regulation quality is usually evaluated by a number of indexes, the main of which are the following: the overcorrection value, regulation time, the number of oscillation of the regulated value during the time of transitional process [6].

The mentioned quantity indexes of transitional processes shall be used as the input variables of models, and quantity index of functioning – as the output variable. If necessary to improve the diagnosing quality, it is possible to introduce the other additional variables which characterize the electromechanical system operation.

Table 1

Factors of input variables

Indexes	Practical usage		
	Seldom	Often	Avoid
Overcorrection, %	0	10-30	50-70
Oscillation number	0	1, 2	3, 4

The values of the output variables for different systems differ, and for most of the systems are within certain limits (table. 1) [1,6].

For the description of the input x_1, x_2, x_3 and the output d variables we will use the linguistic evaluation according to terms, presented in table 2. For the description of separate non-fuzzy terms

T let us use the model of membership function (MF) type [7].

$$\mu^{T}(x) = \frac{1}{1+\left(\frac{x-b}{c}\right)^{2}}, \qquad (1)$$

where b – the coordinate of maximum MF; c –factor of stretch concentration MF

Table 2

Linguistic evaluation of variables

Parameters	Name	Value range	Terms
x_1	Overcorrection	0%...100%	small (S), average (Av), allowed (A), considerable (C)
x_2	Oscillation number	0…5	small (S), allowed (A), considerable (C)
x_3	Time of transitional process	0 c….10 c	small (S), average (A), allowed (A), considerable (C)
d	Quality	1…5	unsatisfactory (d_1), inadmissible (d_2), sufficient(d_3), high (d_4), very high(d_5)

Using the introduced terms of linguistic variables and logical deduction tree (Fig.1) we develop the expert knowledge base which is fuzzy information-carrying medium on cause-and-effect relation between the output variables (Table 3).

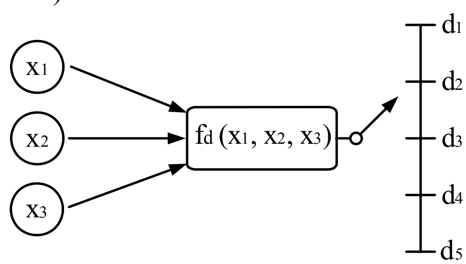


Fig. 1. Logical deduction tree

Table 3

Expert knowledge base

Input variables			Output	Input variables			output	Input variables			Output
x_1	x_2	x_3	d	x_1	x_2	x_3	d	x_1	x_2	x_3	d
S	S	S	d_5	Av	S	A	d_3	Av	A	C	d_2
S	S	Av		Av	A	A		Av	C	A	
Av	S	S		A	A	Av		Av	C	C	
Av	S	Av		A	A	A		A	A	C	
S	A	Av	d_4	C	A	A		C	A	C	
Av	A	Av		S	S	C	d_2	C	C	A	
S	S	A	d_3	S	S	C		C	C	C	d_1

Value of MF parameters for the terms of input variables are determined by the peculiarities of the specific system. On the stage of model preparation, the values of term parameters are arbitrarily set from the range of those possible. So, orienting on the systems which are widely used in practice, they may be presented as in table 4.

Table 4

Initial MF tuning parameters of fuzzy terms

Зм.	Terms	MF		Зм.	Terms	MF		Зм.	Terms	MF	
		b	c			b	c			b	c
x_1	(S) (Av) (A) (C)	0 10 20 30	2,88	x_2	(C) (A) (C)	0 1,5 3	0,46 0,29 0,46	x_3	(S) (Av) (A) (C)	0 0,75 1,5 2,25	0,23

To receive the simulation results, on the basis of expert knowledge base and MF terms, we create the base of fuzzy logical equations, using the operation ● (I-min) and ∨ (OR-max). The importance of separate logical rules equals unity, as the given stage stipulates for rough tuning of the model.

Fuzzy logic rules of quality evaluation of transitional processes of the system look like (2) – (6).

$$\begin{aligned}\mu^{d_5}(d) = {} & \left[\mu^{M}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{M}(x_3)\right]\vee \\ & \vee\left[\mu^{M}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{C}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{M}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{C}(x_3)\right],\end{aligned} \tag{2}$$

$$\begin{aligned}\mu^{d_4}(d) = {} & \left[\mu^{M}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{C}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{C}(x_3)\right],\end{aligned} \tag{3}$$

$$\begin{aligned}\mu^{d_3}(d) = {} & \left[\mu^{M}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{Д}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{Д}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{Д}(x_3)\right]\vee \\ & \vee\left[\mu^{Д}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{C}(x_3)\right]\vee \\ & \vee\left[\mu^{Д}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{Д}(x_3)\right]\vee \\ & \vee\left[\mu^{B}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{Д}(x)\right],\end{aligned} \tag{4}$$

$$\begin{aligned}\mu^{d_2}(d) = {} & \left[\mu^{M}(x_1)\cdot\mu^{M}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{M}(x_1)\cdot\mu^{B}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{B}(x_2)\cdot\mu^{Д}(x_3)\right]\vee \\ & \vee\left[\mu^{C}(x_1)\cdot\mu^{B}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{Д}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{B}(x_1)\cdot\mu^{Д}(x_2)\cdot\mu^{B}(x_3)\right]\vee \\ & \vee\left[\mu^{B}(x_1)\cdot\mu^{B}(x_2)\cdot\mu^{Д}(x_3)\right],\end{aligned} \tag{5}$$

$$\mu^{d_1}(d) = \left[\mu^{B}(x_1)\cdot\mu^{B}(x_2)\cdot\mu^{B}(x_3)\right]. \tag{6}$$

The tweaking of the developed fuzzy model for the specific system requires the correction of MF parameters of fuzzy terms of input variables. For that we use the apparatuses of genetic algorithms, which provides for simultaneous many-sided search in the set range and is based on the operations of crossing, mutation and selection.

Classical genetic algorithm consists of the following sequence of operations [8]:

1) generation of the initial population of chromosomes;
2) evaluation of the chromosomes adaptability in the population;
3) test of an algorithm break condition;
4) chromosomes selection;
5) usage of genetic operators;
6) creation of new population;
7) switching to step 2;
8) if the condition of break is fulfilled, then the selection of the "best" chromosome.

In the condition of the given task, the chromosome structure (fig. 2) is formed from the parameters MF $c_i^{m_i}$, $b_i^{m_i}$ terms a_{m_i} for each of variables x_i, which are being optimized , and balances of rules in the fuzzy knowledge base w_k (for each line).

c_1^1	b_1^1	...	$c_1^{m_1}$	$b_1^{m_1}$	...	c_n^1	b_n^1	...	$c_n^{m_n}$	$b_n^{m_n}$	w_1	...	w_N
1-ша змінна						n-та змінна					ваги правил		

Рис. 2. Chromosome structure

The initial population which consisted of ten chromosomes, was formatted casually in the set interval of the allowed values $[\underline{c}_i, \overline{c}_i]$, $[\underline{b}_i, \overline{b}_i]$, $[\underline{w}_i, \overline{w}_i]$.

The elements of chromosomes are set as follows [7]:

$$\begin{cases} c_i^0 = \text{Random}([\underline{c}_i, \overline{c}_i]), \\ b_i^0 = \text{Random}([\underline{b}_i, \overline{b}_i]), \\ w_i^0 = \text{Random}([\underline{w}_i, \overline{w}_i]), \end{cases} \qquad (7)$$

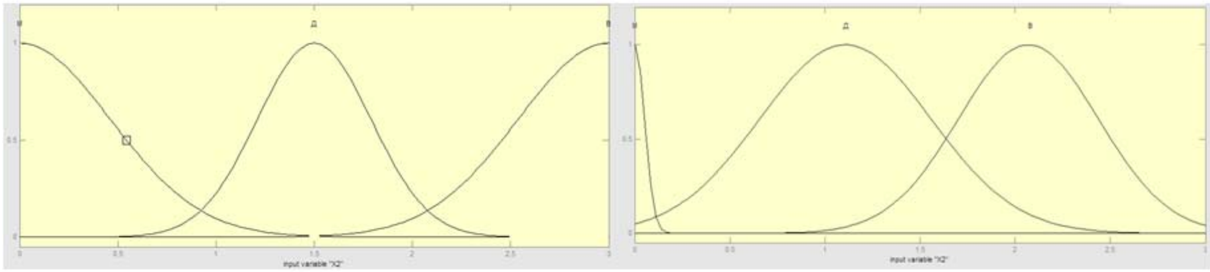
where $\text{Random}([\underline{\xi}_i, \overline{\xi}_i])$ – means the operation of finding the uniformly distributed on the interval $[\underline{\xi}_i, \overline{\xi}_i]$ random number; $\underline{\xi}_i$ – low interval bound; $\overline{\xi}_i$ – upper interval bound.

Procedure of formation of the new population was built on the mechanism of the elite selection, which stipulates for the selection of the best chromosomes among the volume of the wide population, which was created on the basis of the previous one after using genetic operators of crossing and mutation.

Criteria of learning was the sum of squared deviation of values, determined by the fuzzy model, as well as the data from the learning sampling, received in the process of the research of the real object.

The result of optimization of the suggested mathematical model, which was made with the help of the program written in Delphi, allowed to receive the new values of MF parameters and balances of the rules of fuzzy knowledge base.

So, membership functions of fuzzy terms of such factor as "number of oscillation" prior and after the usage of the optimization procedure, are given on fig. 3.



а) б)

Fig. 3. MF terms for parameters "number of oscillation" prior (a) and after (б) usage of the optimization procedure

The behavior of the optimized fussy model for the evaluation of the transitional processes, which take place in the operation of the electromechanical processes, had been researched in the environment of Matlab 6.5 [9]. And in one case of twenty one, the evaluation of the optimized system was somewhat different from the expert one, which testifies to the high reliability of its work.

Conclusions

1. There had been suggested the fuzzy mathematical model for the quality evaluation of transitional processes in systems of electric drive controlling.
2. There had been shown the possibility of tweaking of fuzzy model for operation with the specific object under diagnosing.
3. Technical realization of the suggested model can be realized by the soft or hardware way for monitoring of technical state of controlling systems for electromechanical objects.

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