An Induction Motor Control System Based on Artificial Intelligence

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***Abstract*— The paper shows a control system using artificial intelligence as an example of an induction motor with a frequency changer. Management is implemented using a fuzzy output controller. The optimal parameters of the fuzzy controller are determined. The calculations were carried out in the environment of dynamic modeling of technical systems SimInTech.**

Keywords*— *control system; fuzzy controller; artificial intelligence; induction motor

I. Introduction

Fuzzy control is applied if there is insufficient knowledge of the control object (its transfer function), in case if there is control experience. Based on this experience, the expert forms the basis of the rules of the fuzzy controller. An example is a water pump, the parameters of which (water consumption, moment of inertia of the entire system) vary over a wide range and cause great difficulties in the calculation. The expert is able to manage such an object well enough, using only the sensors readings and the accumulated experience.

The use of a fuzzy logic controller can also be justified by the nonlinearity of the control object. The use of linear proportional-integral-differentiating (PID) controllers in such systems most often leads to poor control quality: a large value of overshoot, a transient response time, and a steady error.

Many studies have examined various types of control system [1–4]. The comparison of fuzzy controllers with classic ones based on a review of literary sources is considered in detail in [3].

II. Control System

The control object is an induction motor controlled by a frequency changer. The detailed description of an induction motor with a frequency converter and its application are presented in article [4].

The engine model is presented as a second-order aperiodic element:

$$W_o(s) = \frac{1}{2s^2 + 3s + 1} \tag{1}$$

The control system consists of a control object and a PID controller, covered by feedback, a fuzzy adaptation block (FAB) of the parameters of the PID controller and the source of the reference signal. It's structural diagram (Fig. 1).

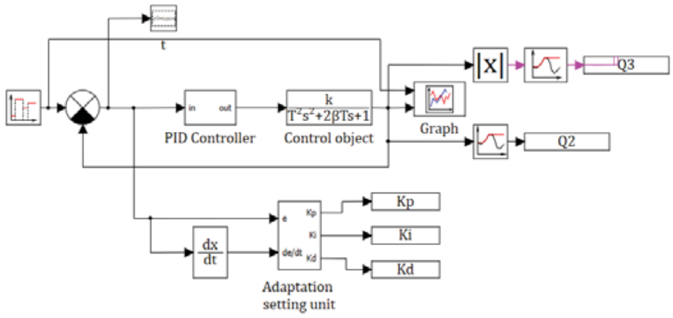

Fig. 1. Block diagram of the control system

Based on the work [1], which substantiates the feasibility of using a fuzzy controller, we selected the PID controller with the adaptation of its settings K_p, K_i, and K_d through FAB as the main regulatory element. Thus, the use of FAB improves the robustness of the system. The block diagram of the PID controller is given below (Fig. 2).

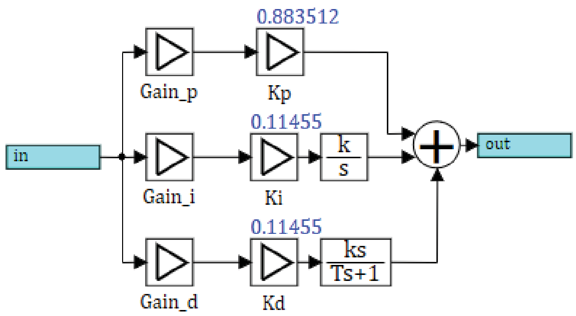

Fig. 2. Block diagram of the PID controller

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FAB receives the input control error *e* and the rate of change *ė* and outputs the values of the coefficients of the proportional, integral and differentiating components of the PID controller.

To apply the methods of fuzzy logic, it is necessary to convert clear variables into fuzzy, when the truth of the statement can be judged based on the value of its membership function. The range of values of the input variable is divided into subsets of Nl, NM, NS, Z, PS, PM, PL. Within each of them, the membership function is built. [2].

For the output variable in the conditions of our problem, the range is divided into 4 subsets of the values of Z, PS, PM, PL from zero to some positive value. This is due to the fact that the PID controller coefficients cannot be negative.

Control process consists of three basic steps [3]:

- Fuzzification of input variables, which is a procedure for finding the values of membership functions of fuzzy sets, based on clearly defined source data.
- Defining fuzzy output using a block of rules.
- Defuzzification of output variables in fuzzy output systems, which is a procedure or process of finding the usual (well-defined) value for each of the subsets. The purpose of defuzzification is to use the results of a logical conclusion to obtain the value of each of the output variables, which can be used by special devices external to the fuzzy inference system.

The setup process using the fuzzy logic unit should be begun with an approximate calculation of the initial values of the controller coefficients. After that the membership function is formulated. In this paper, the membership function for each subset has a triangular shape.

The ranges of the parameters of membership functions for the input signals is [-1.5 ... 1.5], for the output signals [0 ... 1].

III. Creating a Rule Base

To adjust the coefficients when compiling the control logic, it is necessary to be guided by the following considerations [2]:

- An increase in K_p leads to an acceleration of the transient response, a decrease in stability, and a decrease in static error. A decrease in K_p leads to a slowdown of the transient response, an increase in stability (decrease in oscillability) and an increase in static error.
- An increase in K_i leads to a decrease in the static error and to an increase in its oscillability. A decrease in K_i leads to an increase in static error, but reduces its oscillability.
- An increase in K_d leads to an increase in the stability of the process and its speed, but at the same time the controller becomes susceptible to high-frequency noise; a decrease in K_d leads to a decrease in the stability and speed of the process, but at the same time, high-frequency interference has a smaller effect on the control process.

Thus, we provide the following patterns for calculating the parameters [2]:

1. The greater the absolute value of the mismatch error and its derivative, the greater should be K_p and the less K_i and K_d.
2. The smaller the mismatch error and its derivative, the less K_p should be and the more K_i and K_d.

The rules for PID controller coefficients are given below (Table 1, Table 2).

TABLE I. RULES FOR K_P.

			e						
			+			0	-		
			LP	***MP***	***SP***	***Z***	***SN***	***MN***	***LN***
ė = de/dt	+	***LP***	LP	LP	MP	SP	MP	LP	LP
		MP	LP	MP	SP	SP	SP	MP	LP
		SP	MP	SP	SP	Z	SP	SP	MP
	0	***Z***	SP	SP	Z	Z	Z	SP	SP
	-	***SN***	MP	SP	SP	Z	SP	SP	MP
		MN	LP	MP	SP	SP	SP	MP	LP
		LN	LP	LP	MP	SP	MP	LP	LP

TABLE II. RULES FOR K_I AND K_D.

			e						
			+			0	-		
			LP	***MP***	***SP***	***Z***	***SN***	***MN***	***LN***
ė = de/dt	+	***LP***	Z	Z	SP	MP	SP	Z	Z
		MP	Z	SP	MP	MP	MP	SP	Z
		SP	SP	MP	MP	LP	MP	MP	SP
	0	***Z***	MP	MP	LP	LP	LP	MP	MP
	-	***SN***	SP	MP	MP	LP	MP	MP	SP
		MN	Z	SP	MP	MP	MP	SP	Z
		LN	Z	Z	SP	MP	SP	Z	Z

Based on the obtained rule base, a logical control function is compiled, a fragment of which is given below (Fig. 3):

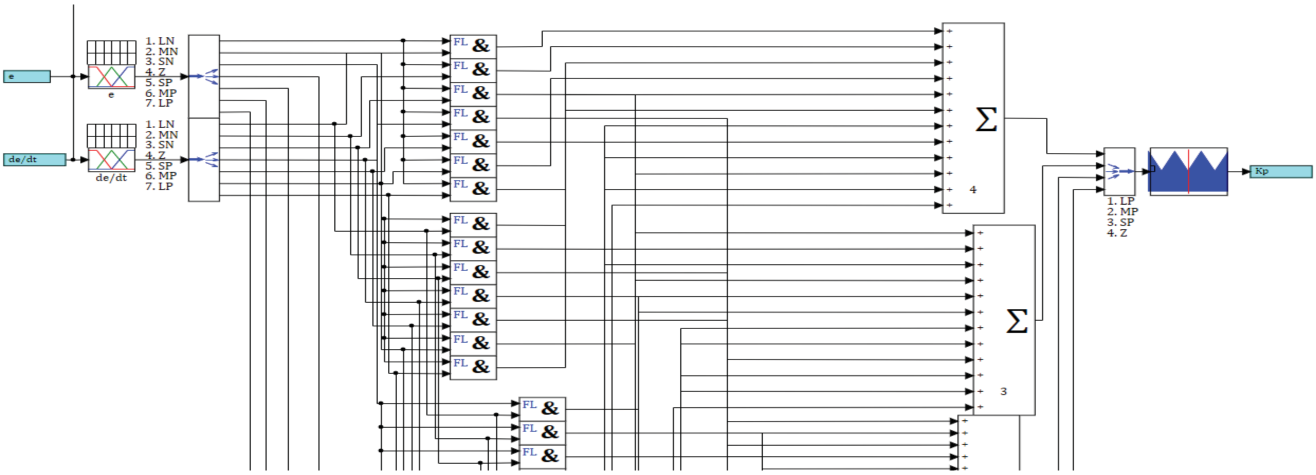

Fig. 3. A fragment of the internal structure of the FAB for calculating Kp

IV. Optimization of Coefficients

Using FAB as a source eliminates the need to set the parameters of the PID controller, but requires setting the parameters of the membership functions for input and output signals. This problem can be easily solved if relative parameters are used as parameters of membership functions, which are then multiplied by scaling factors Gain_p, Gain_i и Gain_d.

Scaling coefficients cannot be uniquely determined. Therefore, for a fuzzy PID controller, it is necessary to solve the optimization problem, namely, the problem of choosing values at which the criterion for the quality of the transient response reached an acceptable level.

The transient response time t <0.3c and overshoot of 10% were selected as criteria for the transient response. A step function is used as the setting function.

Optimization was carried out throughout the transition process. As a result of optimization, we have the following optimal values of the coefficients:

Gain_p = 51,62

Gain_i = 28,99

Gain_d = 49,29

These coefficients make it possible to reach the transient response time of t = 0.29 s and an overshoot of 10%.

It is important to note that optimization is performed once, and then the PID controller parameters are changed using FAB.

V. Modeling Results And Discussion

The calculations were carried out in a dynamic simulation environment SimInTech. The transient response obtained during the simulation is presented in Fig. 4. To simulate changes in the system parameters, the damping coefficient of the control object was varied from 1 to 2 for 5 s. It can be noticed that the output signal is stable with an overshoot of 10% and a decay time of 0.3 s. Static error in steady state is equal 2 %.

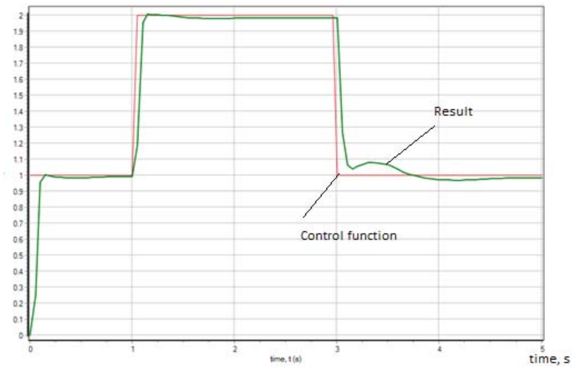

Fig. 4. Diagram of the transient response

As a justification for the appropriateness of the use of FAB, the following is a graph of the transition process without its use (Fig. 5). The PID controller coefficients have fixed values obtained by the FAB unit during the previous simulation.

$K_p = 0,866$

$K_i = 0,113$

$K_d = 0,113$

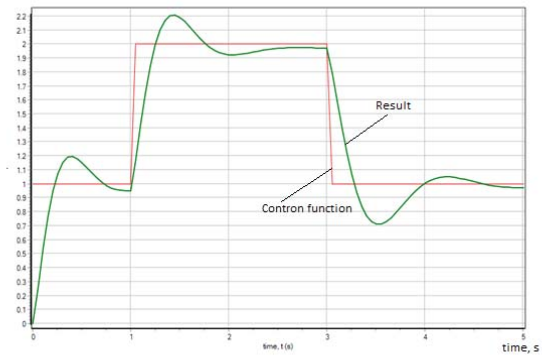

Fig. 5. Diagram of the transient response without FAB

From the graph obtained, it can be seen that such a system is characterized by lower speed and greater overshoot of 20 %.

VI. Conclusions

As a result of this work, we can draw the following conclusions:

- Using a PID controller with adaptation of its parameters through a FAB is much more efficient than using a separate PID controller or a separately fuzzy controller.
- Using FAB allows you to increase the robustness of the system.

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