

## Speed control of the asynchronous motor using LabVIEW



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### ABSTRACT

In this paper a comparative study on the methods of adjusting the speed of a three-phase asynchronous motor with a rotor in a short circuit was presented. For the same structure of the experimental stand used, two programs were created, implemented, and validated in LabVIEW. For the first method, the program in LabVIEW was made with the PI (proportional-integrative) controller and for the second method, the program in LabVIEW was made with the Fuzzy Logic controller. Following the analysis of the resulting graphs, it was found that the speed control system made with the fuzzy logic controller ensures an increase in its performance compared to the speed control system made with the conventional PI type controller. The indicial responses of the adjustment system of the three-phase asynchronous motor speed with PI controller or Fuzzy Logic controller have been determined in real-time by means of the experimental stand. The override of the speed adjustment system is decreased from the value of 26.9% corresponding to the PI controller to the value of 2.3% corresponding to the Fuzzy Logic controller and the duration of the transient time is decreased from the value of 2.2 s related to the PI controller to the value of 0.5 s, related to the Fuzzy Logic controller. By using the Fuzzy Logic controller, the amount of electrical energy required to supply the electric drive system made with a three-phase asynchronous motor will be reduced. This three-phase asynchronous motor speed adjustment algorithm can be implemented for other electric drive systems from different industrial applications.

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### 1. Introduction

The frequency static converters allow the modification of the electric energy parameters (voltage and frequency) by transforming the A.C. currents of constant voltage and frequency from the industrial mains supply into A.C. currents of variable voltage and frequency. The frequency static converters are used for the power supply of three-phase electric motors. Real-time ordering of the frequency static converters is realized with the microcontrollers from the Compact RIO control board structure. In works [Kumar and Patnaik \(2015\)](#), [Aggarwal et al. \(2015\)](#), and [Salim \(2015\)](#) was presented the speed adjustment algorithms with proportional-integrative (PI) controller or Fuzzy Logic controller that was implemented in LabVIEW for DC motors or servomotors. A comparison of the

results obtained through the Fuzzy Logic controller versus the conventional PI controller for controlling the speed of the D.C. motors or induction motors has been presented in the works of [Nagarajan et al. \(2019\)](#), [Acikgoz \(2018\)](#), [Shaija and Daniel \(2016\)](#), [Rajpoot et al. \(2018\)](#) and [Usha and Subramani \(2018\)](#). In the works of [Asija \(2010\)](#), [Faisal and Paliwal \(2018\)](#), [Kalhoodashti and Shahbazian \(2011\)](#), and [Manjunatha \(2017\)](#); the speed adjustment algorithms with PI controllers and Fuzzy Logic controllers have been presented that were simulated in MATLAB-SIMULINK for three-phase asynchronous motors. In the study of [Livinti and Pusca \(2012\)](#), a speed control algorithm with a PI controller implemented in LabVIEW for the three-phase asynchronous motor was presented. The purpose of this work is to present two methods for adjusting the speed of a three-phase asynchronous motor with short-circuit rotor in real-time, supplied from a static frequency converter. In the case of the first method, a conventional controller of proportional-integrative type (PI) is used, whilst in the case of the second method, a Fuzzy Logic controller is used. If the designing of the PI controller requires the determination of the transfer function

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of the fixed part in the speed adjustment loop, the designing of the Fuzzy Logic controller is based on rules and does not need the determination of the transfer function for the fixed part of the speed adjustment loop. For implementing the speed control algorithms through a PI or a Fuzzy Logic controller the author has designed and manufactured an experimental stand in the Laboratory of Electrical Machines and Drives of the Engineering Faculty in Bacau and issued two programs in the LabVIEW programming environment. The control algorithms in real-time of the three-phase asynchronous motor speed have been validated and implemented on the experimental stand without modifying its structure. Based on the experimental results an analysis of the performances obtained in real-time for the two types of controllers has been done: The duration of the transient time and override.

## 2. Research method

### 2.1. Description and the operation of the experimental stand

Fig. 1 illustrates the block diagram of the experimental stand. It is composed of the following elements: CSF-frequency static converter; MAT-three-phase asynchronous motor; Tg-tacho generator; Laptop; Compact RIO control board; G-D.C. generator with separate excitation;  $R_s$  -load resistor. Livinti and Pusca (2012) presented the characteristics of these components. The static frequency converter (CSF) supplies the three-phase asynchronous motor with a squirrel cage rotor (MAT). On the spindle of the three-phase asynchronous motor, a D.C. generator is coupled, for its loading. The tacho generator Tg is coupled to the spindle of the D.C. generator. The reference signal for the closed speed control loop for the 2 types of regulators is generated in the range (0-5) V. from a potentiometer. This potentiometer is fixed on the front panels of the programs made in LabVIEW for each type of regulator. The feedback signal for the closed speed control loop for the two types of regulators is obtained from the tacho generator Tg through a resistive divider and a filter down in the range (0-5) V. The input channel 2 of the module NI 9215 was used for analog/digital conversion of the reaction signal. The output channel 2 of the module NI 9263 was used for digital/analog conversion of the control signal from the closed-loop for adjusting the speed for the two types of regulators. The modules NI 9215 and NI 9363 are part of the Compact RIO control board structure. The analog voltage of the signal from the output channel is the control signal for the static frequency converter. The rotation speed of the MAT with the rotor in a short circuit is obtained after processing the error signal for each closed loop for speed control with PI controller or with Fuzzy Logic controller. For each closed loop for real-time speed control, programs have been created and implemented in LabVIEW.

### 2.2. The mathematical model of the fixed part in the structure of the speed adjustment system

The fixed part of the speed adjustment system is composed of the following elements: static frequency converter, three-phase asynchronous motor, D.C. tacho-generator, and low-pass filter. It is considered that the D.C. tacho-generator and the static frequency converter behave like elements free of inertia. The transfer function of the static frequency converter  $H_{CF}(s)$  will be equal to a constant  $k_d$ . The transfer function of the tacho generator  $H_{Tg}(s)$  will be equal to a constant,  $k_{Tg}$ . From Livinti and Pusca (2012); the transfer function of the three-phase asynchronous motor with short-circuit rotor  $H_{MA}(s)$  is determined through the relation.

$$H_{MA}(s) = \frac{1}{sT_m(1+sT_r)} \quad (1)$$

where;  $T_m$  -electromechanical constant of time of the driving system;  $T_r$  -electromagnetic constant of time of the asynchronous motor. The low-pass filter is connected to the output of the tacho-generator and has the role to decrease the influence of the voltage pulsations of the tacho-generator on the behavior of the speed adjustment loop. The transfer function of the low-pass filter is given by the relation:

$$H_f(s) = \frac{1}{sT_f+1}. \quad (2)$$

The transfer function of the fixed part of the speed adjustment structure is calculated through the relation (Livinti and Pusca, 2012):

$$H_F(s) = H_{CF}(s) \cdot H_{MA}(s) \cdot H_{Tg}(s) \cdot H_f(s). \quad (3)$$

From Livinti and Pusca (2012), after performing several calculations the following values will result for the constants that intervene in the transfer function of the fixed part:  $T_m = 0.036 \text{ s}$ ,  $T_r = 0.013 \text{ s}$ ,  $k_d = 40$ ,  $k_{Tg} = 0.004$ ,  $T_f = 0.09 \text{ s}$ . The expression of the transfer function of the fixed part of the speed adjustment system will become:

$$H_F(s) = 40 \cdot \frac{1}{0.036 s(1+0.013 s)} \cdot 0.004 \cdot \frac{1}{0.09 s+1} = \frac{0.16}{0.036 s(1+0.103+0.00065 s^2)}. \quad (4)$$

The term in  $s^2$  in the parentheses at the denominator is renounced for simplifying the calculations and it will result:

$$H_F(s) = \frac{0.16}{0.036 s(1+0.103 s)} = \frac{4.44}{0.103 s^2+s}. \quad (5)$$

### 2.3. Synthesis of the PI controller and the fuzzy logic controller

The synthesis of the PI regulator from the closed speed control loop was presented in the paper (Livinti and Pusca, 2012). The parameters of the PI regulator are: the amplification factor  $K_c=1.1$  and the integration of cash  $\tau_i = 0,007$  minutes. The

parameters of the controller will be used for elaborating the LabVIEW program for adjusting the rotational speed (rpm) of the three-phase asynchronous motor through the conventional PI

controller. These parameters will be inserted into the program through the front panel. The block diagram of the Fuzzy Logic controller was presented using Livinti et al. (2016).

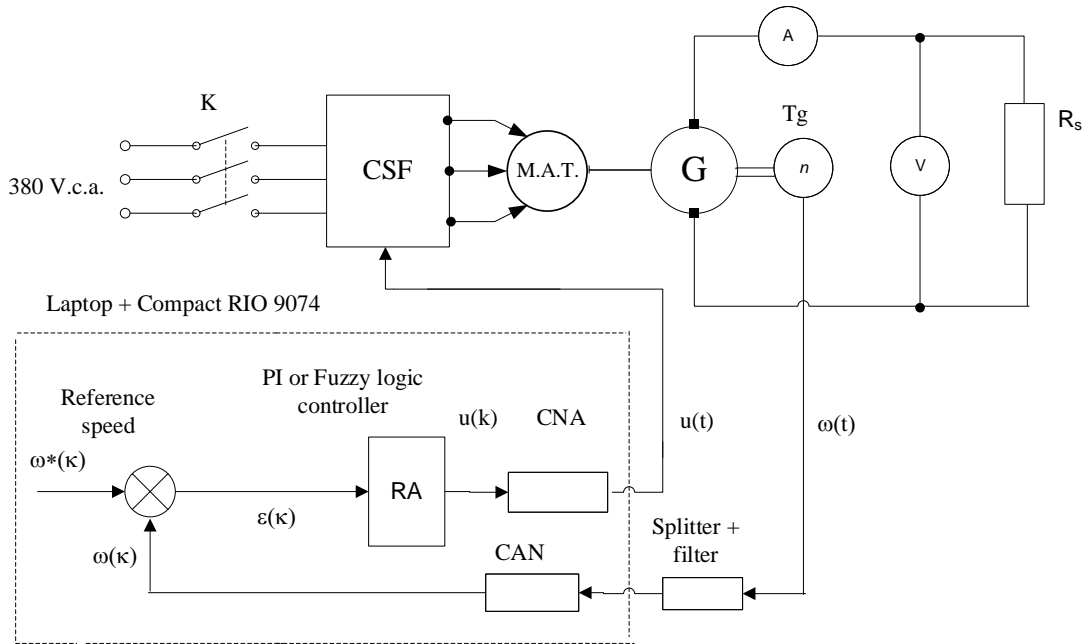


Fig. 1: The block diagram of the experimental stand

In this paper the same type of Fuzzy Logic controller was used, instead, two files were made for two different bases of fuzzy rules. The base of fuzzy rules is presented in Table 1. The  $\varepsilon(t)$  error and the  $\Delta\varepsilon(t)$  error derivative were used as input variables. The output variable used is  $u(t)$ . Each base of fuzzy rules is created in a file with the extension "fs" in the LabVIEW program using the Fuzzy Control Designer subprogram. Each file with the "fs" extension, corresponding to a base of rules, will be loaded in the "file path" block of the Fuzzy Logic controller in the block diagram of the program issued in LabVIEW as per Fig. 7, for adjusting the rpm of the three-phase asynchronous motor.

Table 1: The base of fuzzy rules

		e						
		NB	NM	NS	Z	PS	PM	PB
De	PB	Z	PS	PM	PB	PB	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	Z	NB	NM	NS	Z	PS	PM	PB
	NS	NB	NB	NM	NS	Z	PS	PM
	NM	NB	NB	NB	NM	NS	Z	PS
	NB	NB	NB	NB	NB	NM	NS	Z

For the first base of the fuzzy rules, the domains  $[-3 \div 3]$  were chosen for the input variables (Fig. 2 and Fig. 3) and for the output variable (Fig. 4). For the second base of fuzzy rules, the domain  $[-1 \div 1]$  was chosen for the input variables and for the output variable.

### 3. Results and discussions

A LabVIEW program is composed of 2 parts: A front panel and a block diagram. The block diagram

of the first method with PI controller is shown in Fig. 5 and the indicial response of the system of the speed control is shown in Fig. 6. The indicial response in Fig. 6 has been obtained in real-time by means of the first program issued in LabVIEW, for the parameters of the controller, inserted from its front panel. From the front panel Reference voltage for the frequency static converter has been manually modified, by means of a potentiometer.

The reference voltage for the static frequency converter is equivalent to the reference speed of the asynchronous motor and between these two rates, there is a relation of proportionality. This potentiometer is noted as "Dial" in the block diagram in Fig. 5.

The block diagram of the second method with a Fuzzy Logic controller is shown in Fig. 7 and the indicial response of the system of the speed control is shown in Fig. 8. The indicial response shown in Fig. 8 has been obtained in real-time by means of the second program issued in LabVIEW, for the first base of rules for which the domain of variation of the input variables and output variable has been  $[-3 \div 3]$ . From the front panel of the LabVIEW program, the reference voltage for the static frequency converter is manually modified through a potentiometer, in the same manner as for the first program. This potentiometer is noted as "Reference Control" in the block diagram at Fig. 7. The indicial response in Fig. 9 has been obtained in real-time by means of the second LabVIEW program, for the second base of rules for which the variation domain of the input variables and output variable has been  $[-1 \div 1]$  for various values of the reference voltage.

The admissible error for this type of controller must be included in the interval  $[-3, 3]$ . For the domain of the input values and the output value included in the interval  $[-1, 1]$ , by using the same base of rules the indicial response shown in Fig. 9 has been obtained. For an error higher than 1 the rpm adjustment system with Fuzzy Logic controller will lose its stability.

A comparative analysis of the performances obtained by means of a PI controller and of a Fuzzy Logic controller for adjusting the speed of a D.C. motor has been presented in the work (Nagarajan et al., 2019). The results presented in Table 2 have been obtained through simulation in MATLAB-Simulink.

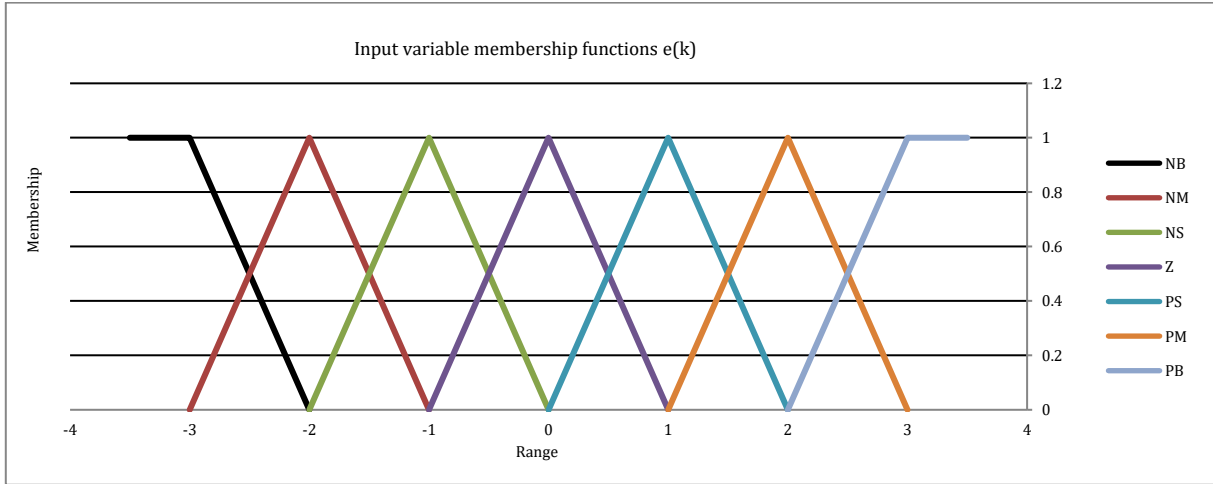


Fig. 2: The input variable e

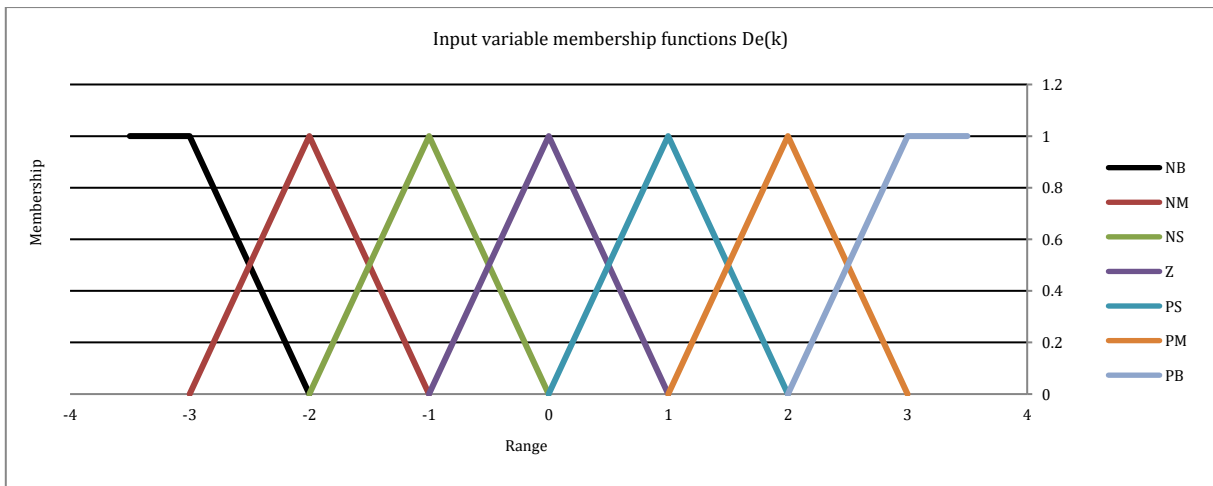


Fig. 3: The input variable De

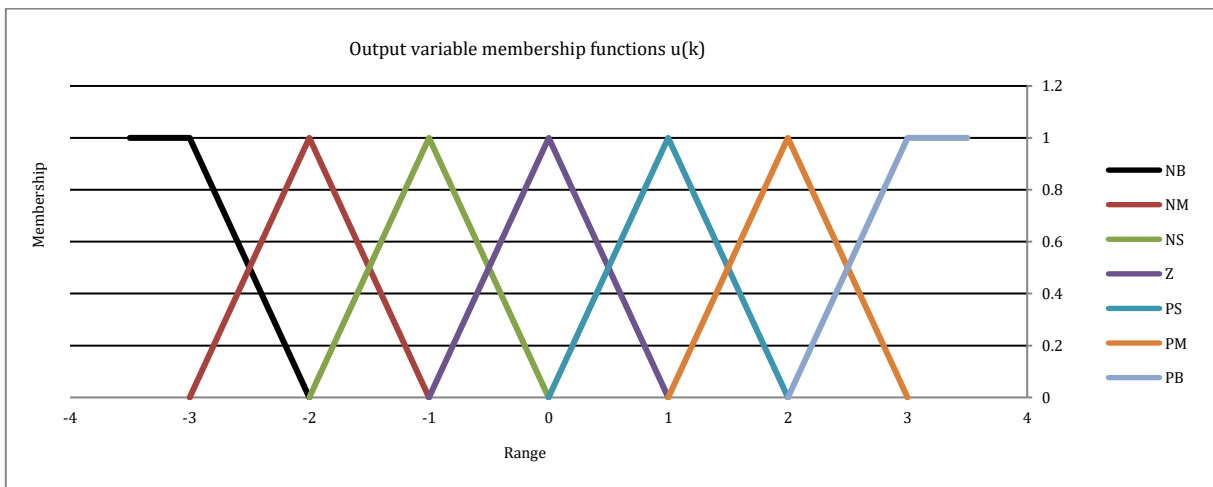


Fig. 4: The output variable

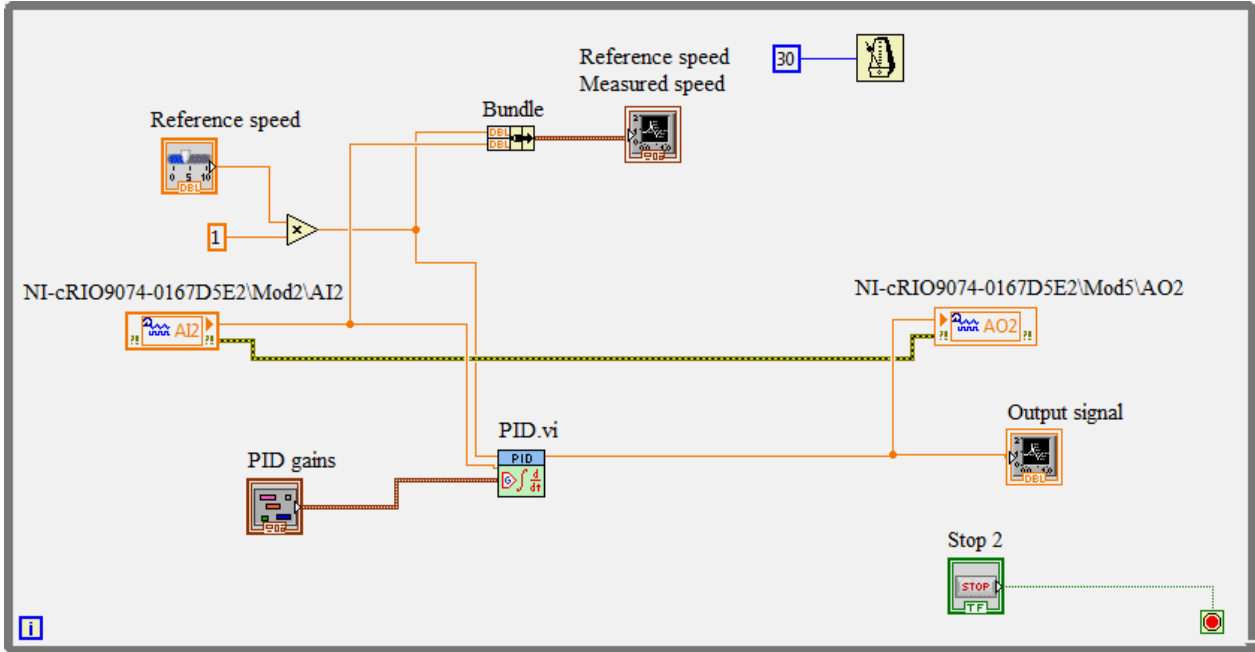


Fig. 5: The block diagram of the first method

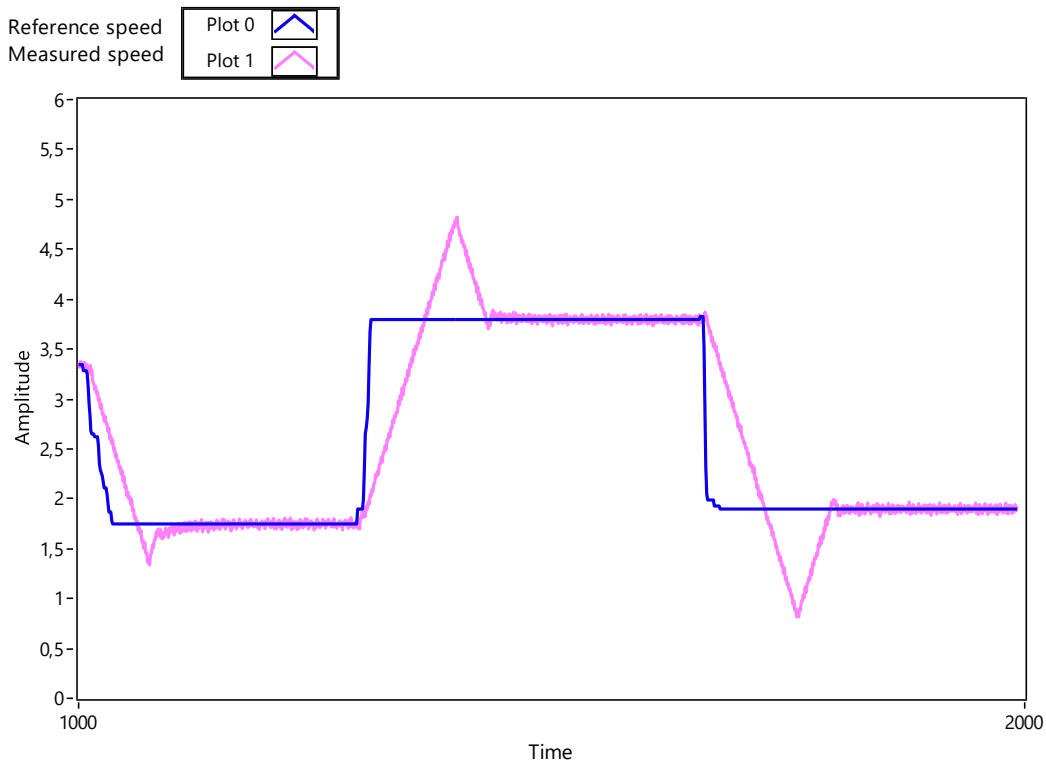


Fig. 6: Indicial response of the speed control for the first method

Table 2: Comparison between PID and FLC Controllers

SL. No	Parameters	PID	FLC
1	Settling time(sec)	1.3950	0.3405
2	% Overshoot	39.519	4.1997

Table 3: The results obtained for the proposed model

Response Parameters	PI	FLC
Rise Time (S)	0.06	0.03
Settling Time(S)	0.5	0.05

A comparative analysis of the performances obtained by means of a PI controller and of a Fuzzy Logic controller for adjusting the speed of a three-phase asynchronous motor has been presented in the work of Shaija and Daniel (2016). The results presented in Table 3 have been obtained through simulation in MATLAB-Simulink.

The comparative analysis of the performances obtained for the two types of regulators of the speed control system has been done based on the indicial responses shown in Fig. 6 and Fig. 8, respectively. These indicial responses have been obtained in real-time with the help of the experimental stand of the Laboratory of Electrical Machines and Drives, not through simulation.

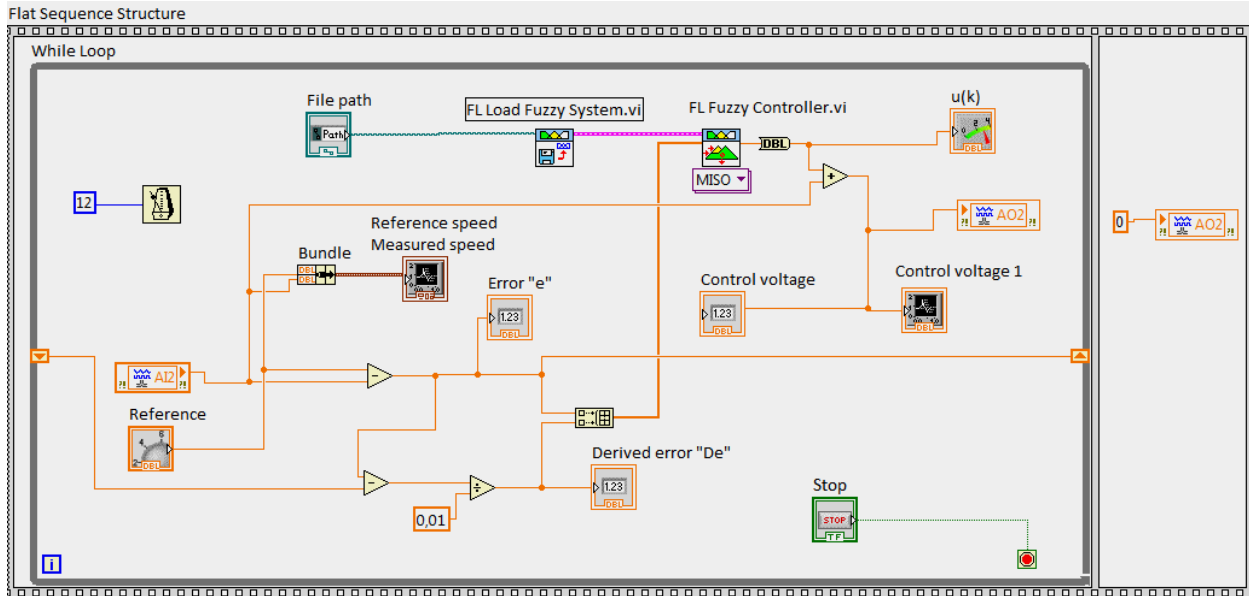


Fig. 7: The block diagram of the second method

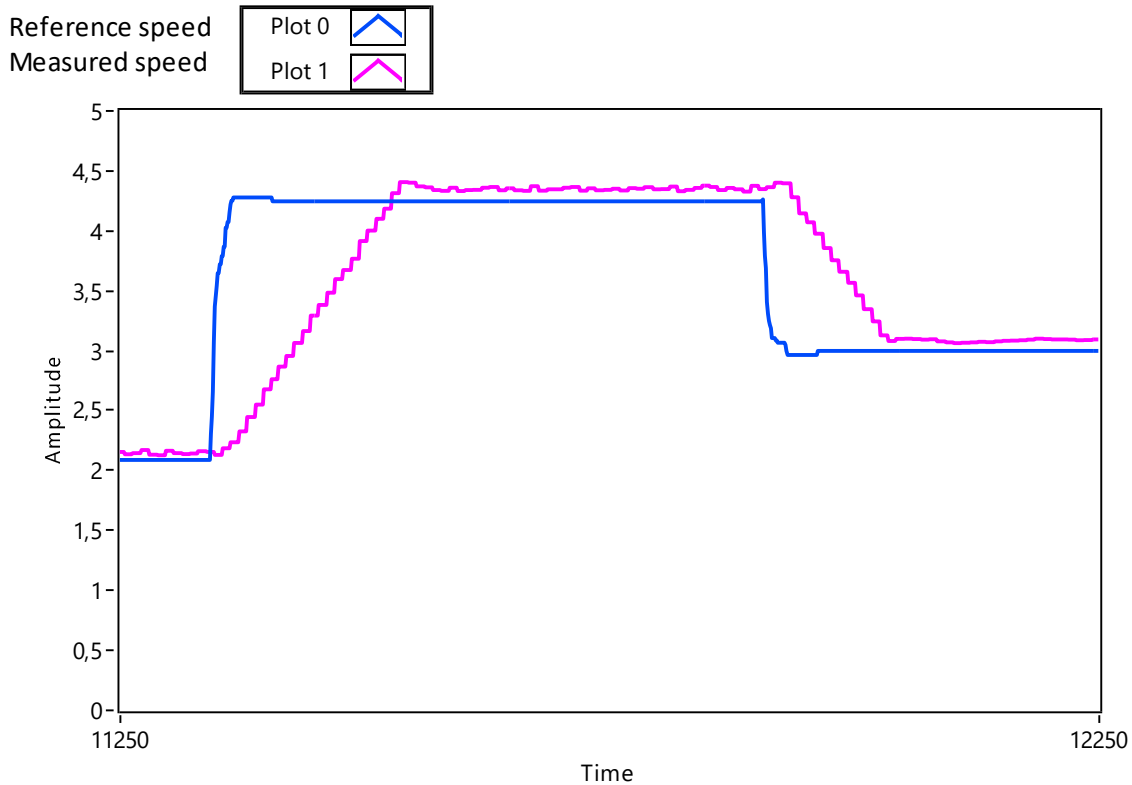


Fig. 8: Indicial response of the speed control for the second method for the domain [-3, 3]

The override  $\sigma$  of the adjustment system has been determined by means of the following relation:

$$\sigma = \frac{V_{max} - V_{ref}}{V_{ref}} \quad (6)$$

The override  $\sigma_1$  of the MAT speed control system made with a PI controller is determined from Fig. 6 on the basis of the indicial response for the value of the reference rpm corresponding to a voltage value of 3.9 V is:

$$\sigma_1 = \frac{V_{max} - V_{ref}}{V_{ref}} = \frac{4,95 - 3,9}{3,9} = 0,269 = 26,9 \% \quad (7)$$

The duration of the transient duty for the value of the reference rpm corresponding to a voltage of 3.9

V is equal to 2.2 s. The override  $\sigma_2$  of the speed control system made with a Fuzzy Logic controller is determined from Fig. 8 on the basis of the indicial response for the value of the reference rpm corresponding to a voltage value of 4.3 V, will be:

$$\sigma_2 = \frac{V_{max} - V_{ref}}{V_{ref}} = \frac{4,4 - 4,3}{4,3} = 0,023 = 2,3 \% \quad (8)$$

Better performances have been obtained for the speed control system made with the Fuzzy Logic controller. A picture of the experimental stand for the control speed of an asynchronous motor is shown in Fig. 10.



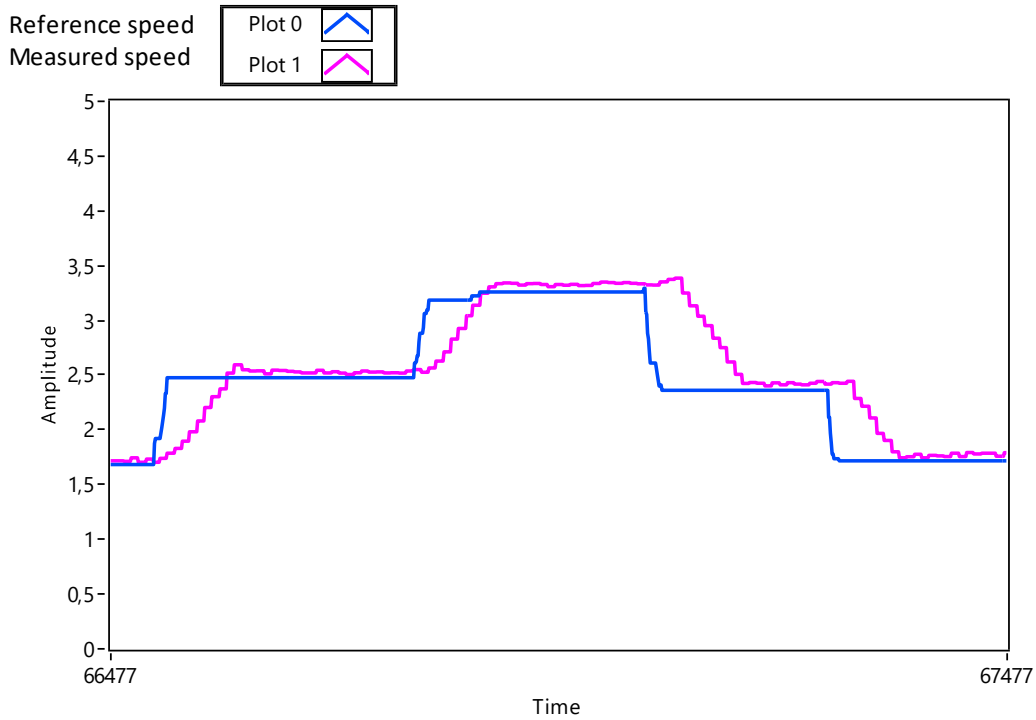


Fig. 9: Indicial response of the speed control for the second method for the domain [-1, 1]

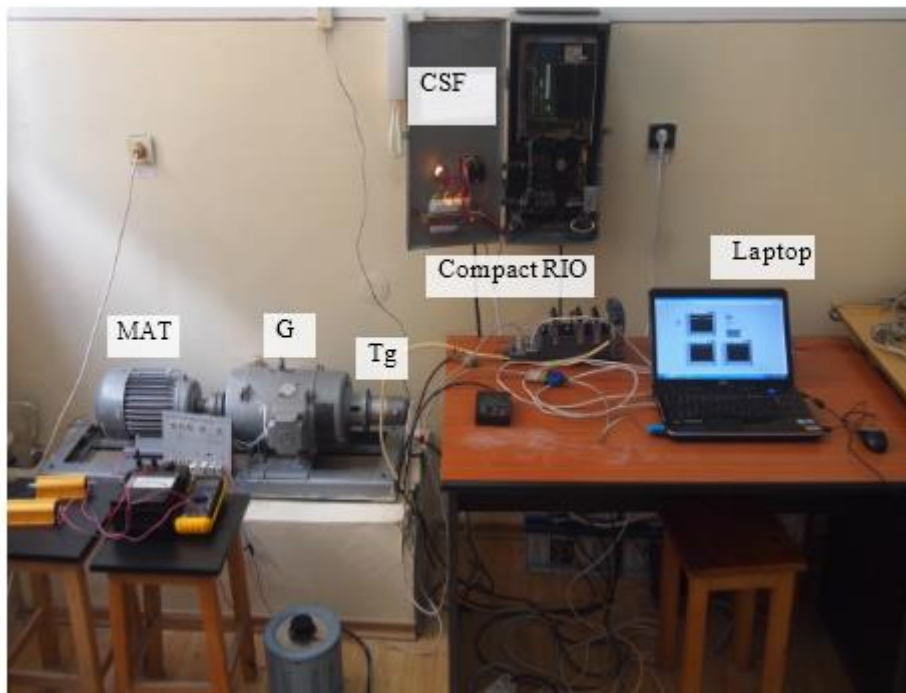


Fig. 10: The experimental stand for MAT speed control

The duration of the transient duty for the value of the reference rpm corresponding to a voltage of 4.3 V is equal to 0.5 s. The performances of the speed control systems are centralized in Table 4.

Table 4: The performances of the speed control systems

Performance indicator	PI controller	Fuzzy Logic controller
Override $\sigma\%$	26.9 %	2.3 %
Transient duty duration	2.2 s	0.5 s

#### 4. Conclusion

This paper presented a comparative study on the methods of adjusting the speed of a three-phase

asynchronous motor with the rotor in a short circuit. Two programs were created, implemented, and validated in the LabVIEW for the same structure of the experimental stand used. For the first method of speed control, the program in LabVIEW was made with the proportional-integrative (PI) controller and for the second method, the program in LabVIEW was made with the Fuzzy Logic controller. The experimental stand has allowed a comparative analysis of the performances obtained for the two types of regulators. Following the analysis of the resulting graphs, it was found that the speed control system made with the fuzzy logic controller ensures an increase in its performance compared to the

speed control system made with the conventional PI type controller. The override of the speed adjustment system decreases from the value of 26.9% to the value of 2.3% and the duration of the transient time decreases from the value of 2.2 s to the value of 0.5 s. The way how the domain of the membership functions affects the performance of the speed control system equipped with a Fuzzy Logic controller has been analyzed, as well. For the domain [-1, 1] of the membership functions and an error higher than 1, the speed control system made with the Fuzzy Logic controller will lose its stability. By using the Fuzzy Logic controller, the amount of electrical energy required to supply the electric drive system made with the three-phase asynchronous motor will be reduced. This three-phase asynchronous motor speed adjustment algorithm can be implemented for other electric drive systems from different industrial applications. The methods of adjusting the speed of an asynchronous motor with a short-circuit rotor will also be used for the practical activities of the students in the laboratory "Machines and electrical drives" of the Engineering Faculty in Bacau.

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### Compliance with ethical standards

### Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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