FUZZY SYSTEM FOR THE ADJUSTMENT OF THE CONTINOUS CURRENT MOTOR'S REVOLUTION

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Abstract: This paper presents the way a fuzzy regulator is made, regulator which is used for the adjustment of the revolution for a continuous current motor. Concrete going from a value of the revolution reference of 700 [rot/min] and from a value of the statorical current of the motor of 0,82 [A], (taking into account that the output of the system is 0 [rot/min]) all the stages of the fuzzy algorithm are covered and a firm value of the command which is given by the adjustor in this case. The extension of the applications field of the numerical systems for adjustments is, obviously, sustained also by the superior performances achieved by such systems, as is the case of the fuzzy system, comparing with the automation analogical conventional systems.

Keywords: fuzzy system, fuzzy algorithm, continuous current motor.

1. INTRODUCTION

Among the characteristics of the numerical systems which assure them high performances, we mention:

- high precision in transmitting and processing of the information;
- high speed for processing of the information;
- the possibility for memorizing information on long term without altering their content;
- the possibility to display some characteristic quantities from the process on systems. Display with various degrees of complexity and the possibility of an efficient communication man – computer through the computer's console.
- reducing the driving chambers number and removing the conventional panel of automation;

In the last years it has been noticed a significant increase of the number and variety of fuzzy applications.

Applications such this have extended on various domains and also the performing video equipment (video cameras), washing machines, microwaves equipment, and in the industrial control systems and of the medical instruments of high performance.

Driving the process through rules, known by the name of the driving through situations, is practically unfolded after the following description: to rely on the situation s(t) at the t moment is determined the class to which this situation belongs, class to which correspond such a command that transforms s(t) into s(t+1).

Mainly, the working of a fuzzy regulator takes place after the informational block scheme from fig. 1, and requires the following operations:

a) The firm information from the input (measured quantities, the prescribed quantity, the adjustment error) is 'converted' into a 'vague' representation; this operation is called fuzzyfication of the firm information.

b) The 'fuzzyficated' information is processed upon the base of a set of rules (rules base) after the formula:

IF (premise) THEN (conclusion),

which have to be 'well specified' in order to drive the process in subject; the principles (rules) to evaluate the set of rules are named interference scheme, and the result consists of the 'vague form' of the command u (the vague command).

c) The ‘vague’ command must be converted in a ‘firm’ expression, with the numerical value well specified and later on the physical nature well specified, directly usable at the level of the execution element; the operation is named defuzzyfication.

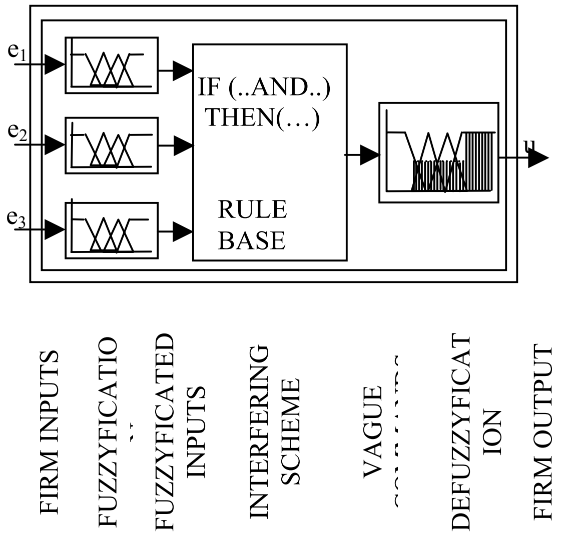

Fig. 1 The informational block scheme which describes the working of a fuzzy regulator

The making of these desideratum imposes to the specialists in the domain of the industrial processes driving to know the specific of the driven process and of the theory of automated systems, also to the process computers, of the working of the elements and above all how to program them to ensure the proposed purpose (supervising and driving in real time of the driven process).

2. THE SYNTHESIS OF THE FUZZY REGULATOR

2.1. The Fuzzyfication of the form information and creating the rules base

We’ll start to materialize a fuzzy regulator for a reversible adjusting of the revolution of a continuous electrical current engine. The nominal revolution of the engine is 1500 rot/min, and the domain for adjustment 1500 ÷ 1500 rot/min.
For the revolution adjustment of the engine we’ll define 3 linguistic variables, associated to the input quantities (the statorical current and the revolution error) and to the output quantity (the command).
After that, a vague representation on the revolution error for the revolution domain [-1500 ÷ 1500] rot/min and of the statorical current for the domain [0÷3,5]A through the medium of the belonging functions (in this case, the revolution error and the current are physical quantities to whom it is associated the linguistic variables revolution and current error) and a vague representation of the command for the domain [0 ÷ 5]V.
The linguistic variable revolution error can be vaguely characterized through the following linguistic terms:

Wm – low revolution error with the belonging function: μ_{Wm}= (–1500 –1500 –1000 0) (1)

Wp – moderated revolution error with the belonging function: μ_{WP} = (-1000 0 1000) (2)

WM – high revolution error with the belonging function: μ_{WM} = (0 1000 1500 1500) (3)

For the linguistic variables revolution and current error, the shape of the belonging function afferent to the linguistic terms is trapezoidal for the linguistic terms from the extremities and symmetric triangular for the linguistic term from the middle, as is seen in fig. 2:
The linguistic variable current may be characterized “vaguely” through the following linguistic terms:

Ym – low current – with the belonging function: μ_{Ym} = (0 0 0,58 1,7) (4)

YP – moderate current – with the belonging function: μ_{YP} = (0,58 1,7 2,86) (5)

YM – high current – with the belonging function: μ_{YM} = (1,7 2,86 3,5 3,5) (6)

For the command linguistic variable we’ll consider 3 linguistic terms:

Um – low command – with the belonging function: μ_{Um} = (0 0 2.5) (7)

Umd–moderate command– with the belonging function: μ_{Umd} = (0 2,5 5) (8)

UM – high command – with the belonging function: μ_{UM}=(2.5 5 5) (9)

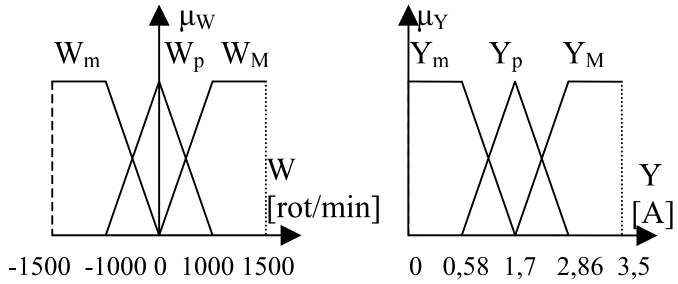

Fig.2 The shape of the belonging functions for the linguistic variable revolution and current error

The shape of the belonging function afferent to the linguistic terms is non symmetric triangular for the linguistic terms at the extremities and symmetric triangular for the linguistic term from the middle, as seen in fig. 3.

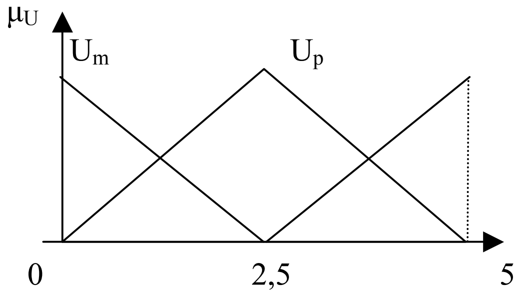

Fig. 3. The shape of the belonging function afferent to the command linguistic variable

In order to underline the way a fuzzy regulator “thinks” concerning fuzzyfication, we’ll determine the belonging degrees of a ferm value (Wo = ω_0–E_0 the revolution error) at the linguistic terms defined before.
Next will be exemplified the way in which the degrees of belonging are determined for a ferm value of the revolution ω_0 = 700 rot/min. The revolution error at the initial moment is therefore Wo=ω_0 – E_0 = 700, where E_0 is the output of the system in the initial moment (E_0 = 0)(10)
The afferent values of the belonging degrees of the firm value Wo = 700 at the defined linguistic terms are:

$$W_0 = \{\mu_{Wm}(W_0), \mu_{Wp}(W_0), \mu_{WM}(W_0)\} \tag{11}$$

We will calculate then the values of the belonging degrees.
According to the relation:

$$W_0 = \{\mu_{Wm}(W_0), \mu_{WP}(W_0), \mu_{WM}(W_0)\} \tag{12}$$

we have the 3-ouple:

$$W_0 = \{0 , 0.30 , 0.70 \} \tag{13}$$

For the fuzzy variable current, the values afferent to the degrees of belonging of the firm values Yo = 0,82 at the defined linguistic terms are:

$$Y_0 = \{\mu_{Ym}(Y_0), \mu_{Yp}(Y_0), \mu_{YM}(Y_0)\} \tag{14}$$

After we calculate the values of the belonging degrees we obtain the relation:

$$Y_0 = \{\mu_{Ym}(Y_0), \mu_{Yp}(Y_0), \mu_{YM}(Y_0)\} \tag{15}$$

we have the 3-ouple:

$$Y_0 = \{0.785 , 0.214 , 0\}$$

The rules base after which the fuzzy regulator works is:

R1: IF (e = Wm) AND (y = Ym) THEN (u = Um);
R2: IF (e = Wp) AND (y = Ym) THEN (u = Umd);
R3: IF (e = WM) AND (y = Ym) THEN (u = UM);
R4: IF (e = Wm) AND (y = Yp) THEN (u = Um);
R5: IF (e = Wp) AND (y = Yp) THEN (u = Umd;
R6: IF (e = WM) AND (y = Yp) THEN (u = Umd);
R7: IF (e = Wm) AND (y = YM) THEN (u = Um);
R8: IF (e = Wp) AND (y = YM) THEN (u = Umd);
R9: IF (e = WM) AND (y = YM) THEN (u = Umd),

2.2. The inference and composition of the rules

At any moment of time t*, the fuzzy algorithm activates the rules from BRF (as a parallel process). The output of each fuzzy rule is a fuzzy value (too), which results on the basis of the fundamental operations from fuzzy logic. So, each rule from BRF framework represents a logical expression built with the conjunction operator AND. Therefore, the intersection operation of the fuzzy multitude is applied, after which at the output is obtained a punctual minimum of the belonging functions from all the definition domain of the output variables.
And so, for a rule from BRF framework as:

R8: IF (e = Wp)AND(y = YM) THEN (u = Umd) (16)

we have:

$$\omega_{Umd} = \text{MIN}\ (0.30\ ,\ 0) = 0; \tag{17}$$

where: ω_{Umd} – is the scalar value for activating the fuzzy multitude Umd.
So this is a rule which won't be used because the scalar value of activation of the fuzzy multitude Um of the output variable is null.
As it follows, we retain only the useful rules (significant) for the given numerical case which are 4.

R2: IF (e = Wp)AND(y = Ym) THEN (u = Umd) (18)

$$\text{so } \omega_{Umd} = \text{MIN}\ (0.3\ ,\ 0.7) = 0.3; \tag{19}$$

R3:IF (e = WM)AND(y = Ym) THEN (u = UM) (20)

$$\text{so } \omega_{UM} = \text{MIN}\ (0.7\ ,\ 0.7) = 0.7; \tag{21}$$

R5: IF (e = Wp)AND(y = Yp) THEN (u = Umd);

$$\text{so } \omega_{Umd} = \text{MIN}\ (0.3\ ,\ 0.2) = 0.2; \tag{22}$$

R6: IF (e = WM)AND(y = Yp) THEN (u = Umd);

$$\text{so } \omega_{Umd} = \text{MIN}\ (0.7\ ,\ 0.2) = 0.2; \tag{23}$$

We observe that in the inference process the rules may have as result the same fuzzy multitude as output, generally activated with different ω_i coefficients. This is the case of rules R2, R5 and R6 from the example we analyze. So, the operation of inference is finalized at the level of the whole BRF through a technique of composition (combination) of the results of the elementary inferences (from witch i activated rule).
In our case, we adopt the method of composition known as MAX, after which the rules which have the same fuzzy multitude for output, it is activated (pondered) with the maximum value of the coefficient ω_i.
So, for the rules R2, R5 AND R6, the output fuzzy multitude Umd will be pondered with the coefficient ω Umd calculated as follows:

$$\omega\ \text{Umd} = \text{MAX}\ (\omega_2\ ,\ \omega_5\ ,\ \omega_6) = \text{MAX}\ (0.3\ ,\ 0.2\ ,\ 0.2) = 0.3 \tag{24}$$

The shape of each activated fuzzy multitude, from the whole universe of speech of the output variables depends on the used scheme of "codification". We will adopt the process of *codification with correlation through product*, according to which the fuzzy outputs of the system result through multiplication of the belonging functions of the output variable, with the scalar value of activation of the respective i rule.
In this way we applied the operation of inference with correlation through product as is shown in the graphics in fig. 4, and 5.

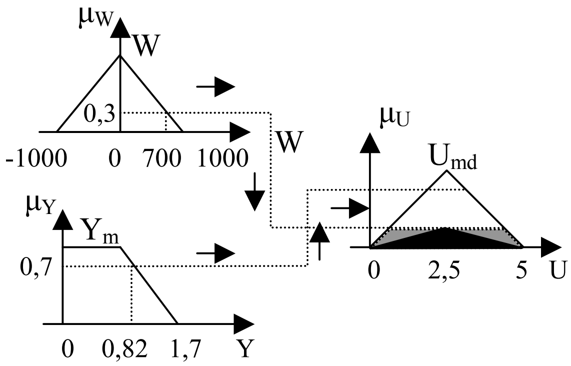

Fig. 4 Inference with correlation through product for R2

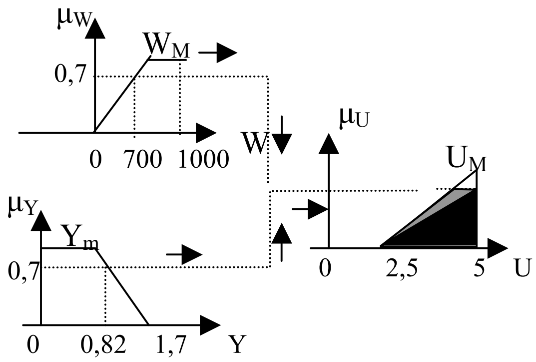

Fig. 5 Inference with correlation through product for R3

For the example considered fuzzy output of the system is:

$$O = MAX\,(\omega_2\,,\,\omega_5\,,\,\omega_6\,)m_{\,Umd}\;+\omega_3\cdot m_{UM} \tag{25}$$

which, geometrically speaking, sums up to the reunion of the surfaces limited by fuzzy multitudes as result of codification, as in fig. 6.

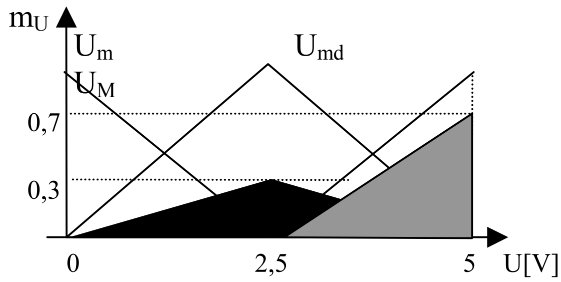

Fig. 6 The schematic representation of the multitude of the quantity for output obtained through reunion of the two surfaces (black and grey)

2.3. Defuzzyfication

In case of this application I chose the most used defuzzyfication method which offers the most substantial results, *the method of the gravity center (centroid)*. Adequate to it, if the fuzzy multitudes are determined through the method of inference with correlation through product, then it may be calculated the global gravity center on the basis of the local gravity centers of each i rule from BRF as follows:

$$u_k = \frac{\omega_{Umd} \cdot I_{Umd} \cdot c_{Umd} + \omega_{UM} \cdot I_{UM} \cdot c_{UM}}{\omega_{Umd} \cdot I_{Umd} + \omega_{UM} \cdot I_{UM}} =$$

$$= \frac{0,3 \cdot (0,3 \cdot 2,5) \cdot 2,5 + 0,7 \cdot \left(\frac{2,5 \cdot 0,7}{2}\right) \cdot 4,16}{0,3 \cdot (0,3 \cdot 2,5) + 0,7 \cdot \left(\frac{2,5 \cdot 0,7}{2}\right)} = \frac{0,562 + 2,54}{0,225 + 0,6125} = \frac{3,11}{0,837} = 3,88$$

The value so obtained represents the angle of ignition, α, which is applied to the command device on grill, this determining the corresponding opening of the tiristors of the totally commanded bridge and so the engine will be supplied with the correspondent voltage to the wanted revolution

3. EXPERIMENTAL RESULTS

The fuzzy regulator was software implemented, the communication with the process being made through a module made with the microcontroller PIC16F84.

The block scheme of such an adjustment system is presented in fig. 7, where the following notations were used:

M – continuous current mono-phased engine;
TG – revolution transducer (tahogenerator);
CAN – analogical – numerical converter;
CNA – numerical – analogical converter;
S – current shunt;
Conv. I–U – current **–** voltage converter;
PC – personal computer;
Conversion module RS232–RS485– block used for allowing the communication on great distances between the PC and the module PIC16F84.
DCG – command on grill device;
Signal conditioning – is a block for limitation at a certain value of the voltage given by the tahogenerator;

The answer of the system commanded with a fuzzy regulator comparing to the answer of the driven system with a conventional regulator when at input is applied a phase signal is presented in fig. 8.

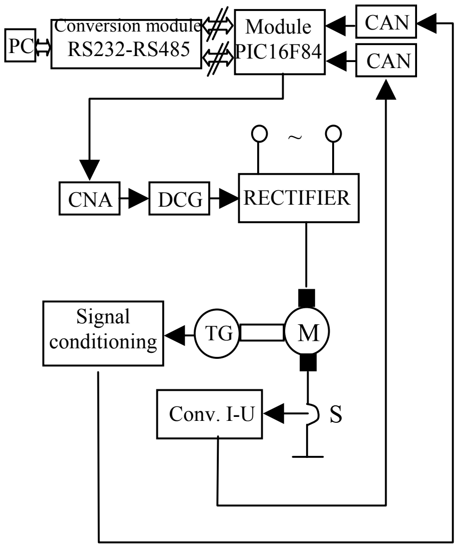

Fig. 7 The block scheme of the fuzzy system of adjustment with software implemented regulator

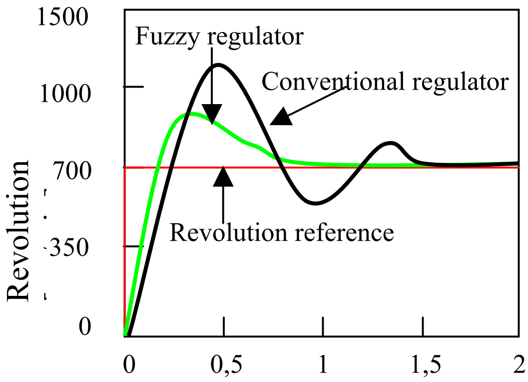

Fig.13 Experimental results

REFERENCES

1. Preitl Şt., Precup, E. (1995), *Introducere în conducerea fuzzy a proceselor*, Editura Tehnică, Bucureşti
2. Sofron E., Bizon N., Ioniţă S., Radian, R. (1998), *Sisteme de control fuzzy. Modelare AND proiectare asistată de calculator*, Editura ALL, Bucureşti.