FUZZY LOGIC CONTROL SYSTEM FOR THE AIR FLOW FROM THE TOXIC AND EXPLOSIVE AREAS

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Abstract : In this paper is proposed a method to increase the atmosphere quality from the toxic and explosive areas by the perfecting of the control system of the air flow which ensure the proper distribution of the air flow on the various paths. Because of the big number of the factors which intervenes and of the non-linearisation, is difficulty to establish a rigorous mathematical model, and on the ground of this is proposed the fuzzy logic control. After the synthesis of the control systems will be presented a simulation to having in view an evaluation of its behaviors.

Keywords: fuzzy logic control, air flow control , toxic and explosive areas, simulation.

1. INTRODUCTION

By the control of the air flow, the ventilation process have to ensure the maintenance in the standard admitted limits of the atmosphere parameters in the working areas (gas concentration, dust and temperature).

The achievement of this object supposes the control both of the fans flow and the elements which ensure the distribution of this flow in the working areas. Because of the big number of the factors which intervene and of the non-linearisation, is difficulty to establish a rigorous mathematical model, and on this ground of this is proposed the fuzzy logic control

For the emphasizes of the commands which are necessary to achieved the proper air flows, we took into consideration the simplified canonic scheme of the system (figure 1) which is composed of n branches in parallels, each branch with proper regulation installation – IR_i , i = 1,n (adjustable register), and the general air flow (Q_0) is ensured by the fan V. Each branch (i) is characterized by an aerodynamic resistance R_i and is equipped with a control installation through the equivalent resistance of the branch can be modified.

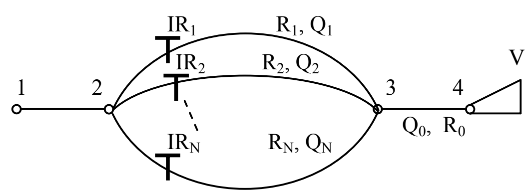


Fig. 1. The block diagram of the ventilation process.

The air flow Q_0 achieved by the fan is indicated by the static point of running-A (figure 2), placed on the intersection of the fan characteristic (H = f(Q) – curves 1, 2) and of the network (curves I, II).

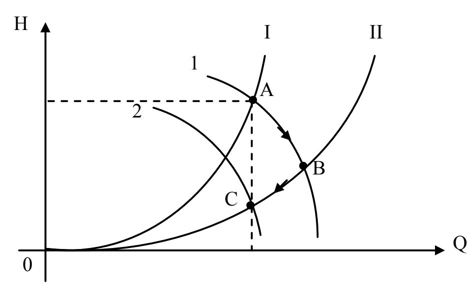


Fig. 2. The static point of running.

If in one of the branches (R_1) is necessary to change the air flow, this will be achieved through the adjustment of the afferent installation IR_1, with effects on the total resistance of that afferent branch. This will modify the air flow both in the considered branch (R_1) and in the other branches according to the next relations :

$$\begin{matrix} \frac{\partial Q_1}{\partial R_1} < 0 \\ \frac{\partial Q_i}{\partial R_i} > 0 \end{matrix} \qquad (i = 2,3,...,n) \qquad (1)$$

Therefore, to modify the air flow in one branch and maintain it in other is necessary to command the regulation installation of all branches. Consequently it will modify the network resistance and its characteristic (curve II) with effects on the static point (which goes in point B) and the fan air flow.

For the establish of the fan air flow (Q_0) is necessary its command for the translation of its running over a new characteristic (2), so that the static point of running translates form B to C.

It can said that the air flow regulation in a branch involves the command of the regulations installations in all branches, including the fan command.

The installations IR_i are represented by adjustable registers which has controlled the opening angle (registers with flaps and blind type) or the section by the linear moving of a flap.

The adjustment of the fans air flow is made using several methods : the modify of the angle of the lead flaps (in small domain), the modify of the angle of the rotor flaps, the modify of the angular speed.

If, for the fans characteristic (1), like the automatisation object, was established the determinist mathematical models, both for the static system and for the dynamic system, for the registers not exists such models because there are too much parameters which enters in the mathematical model.

Other aspect of this problem is that the entire volume of the workstation can varied in time in large limits for some industries like mining extraction, mining tunnels or others domains.

The establishing of a rigorous mathematical model for this system is very difficult to achieve because of the great number of factors which intervenes and the nonlinear characteristic.

On this ground in this paper is proposed the fuzzy logic command, possible to achieve because the process is a slow process.

2. THE SYNTHESIS OF THE FUZZY LOGIC CONTROL SYSTEM

For the synthesis of the fuzzy logic control system of the registers it was take into consideration the most complex case of a unit with toxic or explosive gas. The air flow in this units have to be ensured so that the gas concentration is maintained in the required limits.

The in-out mathematical model of the system, obtained through the linearisation at the small air flow variations, has the following form (2) :

$$\Delta C(s) = \frac{k_Q}{1 + T_l \cdot s} \cdot \Delta Q(s) \qquad (2)$$

, where ΔC(s) represents the variation of the gas concentration, ΔQ(s) represents the air flow variation and T_l is the time constant of the working area and depends on the unit volume and the initial air flow.

If are considered like state variables, the relative variations around the initial point (C_0, Q_0) of the concentration and the air flow, obtains the relations :

$$\begin{cases} x_1 = \frac{Q - Q_0}{Q_0} \\ x_2 = \frac{C - C_0}{C_0} \end{cases} \qquad (3)$$

If is considered like input variable, u – the variation of the air flow in time (state x_1), we will obtained, through proper processing, the in-state-out model :

$$\begin{cases} \dot{x}_1 = u \\ \dot{x}_2 = -\frac{1}{T_l} x_1 - \frac{1}{T_l} x_2 + \frac{k_Q - T_l}{T_l} u \\ y = x_1 + x_2 \end{cases} \qquad (4)$$

The coefficient k_Q depends on the coordinates of the static point :

$$k_Q = -\frac{C_0}{Q_0} \qquad (5)$$

The air flow variation in time is ensured by the control of the registers, changing (in function of its type) either the angle α (of the flaps) or the position l (of the register). Therefore it can said that the *c* variable depends on one of the two parameters according to relations (6) :

$$\begin{cases} c = f(\alpha) \\ c = f(l) \end{cases} \qquad (6)$$

The bloc diagram of the system for the registers control is presented in figure 3.

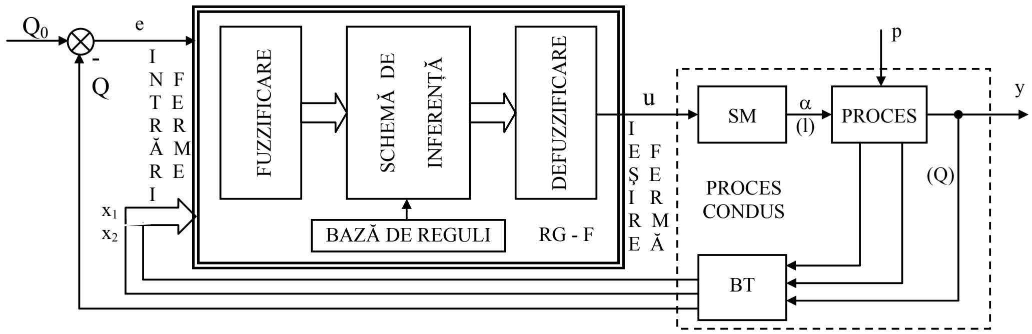


Fig. 3. The informational structure of the fuzzy system for the registers control.

The process includes the working area where it is sampled Δq and Δc and the register to control the air flow by commands α or l. The control of the angle or the moving is achieved using a servomechanism (SM) achieved by a stepper motor (MPP). The firm input is represented by the reference Q_0 and the relative variations of the air flow and concentration supplied through the bloc of the traducers BT.

The analog – digital conversion will be achieved by a ADC with 10 bits. Because the process is slow the sampling has a period $T_e = 60$ s.

The implementation of the control system can be achieved using a system with microprocessor or microcontroller. In this case, because the process is a slow process with big time constants (minutes), the fuzzy regulator can be implemented with programmable automatons witch contains 2 ÷ 4 analog inputs. The compact structure of this automatons, and the existence of some in and out digital interfaces permits the insertion of supplementary condition concerning to the process imposed restrictions.

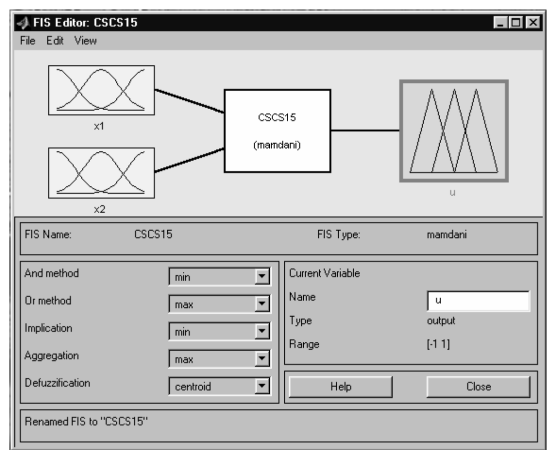
3. THE SIMULATION OF THE SYSTEM

On the ground of the bloc diagram of information structure of the control system was achieved the simulation of the system running.

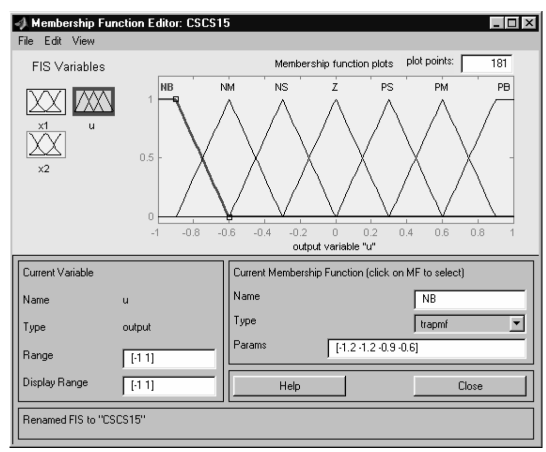
Was taken into consideration the inputs the output of the system (the air flow – Q → x1 and the debit – C → x2, and the command signal – u respectively). Also, was taken into consideration the system structure of the fuzzy logic controller and the auxiliary components.

The simulation was tested on the Matlab-Simulink platform, using the Fuzzy Logic Toolbox. First step in the FIS Editor was to create the input and output linguistic variables (x1 and x2, respectively u), according to the atmosphere parameters (C and Q) and the control variable respectively (figure 4.a).

The two input linguistic variables were chosen to have 3 linguistic values (N, Z, P) and the output linguistic variable was chosen to have 7 linguistic values (NB, NM, NS, Z, PS, PM, PB). For all linguistic values was chosen like membership function the triangle function (figure 4.b).



a)



b)

Fig. 4. The input and output linguistic variables (a). The membership functions (b).

For fuzzyfication and defuzzyfication was chosen the following methods : AND method is MIN, OR method is MAX, Implication method is MIN, Aggregation method is MAX and Defuzzyfication method is Centroid. These options were selected from the main FIS Editor window, but can be changed if the results are not proper.

The second step of the FIS Editor was to create the control rules table with the input and output linguistic values. In this way, was conceived a table with 9 rules described in figure 5. The rules are in the following form :

IF (x1 is …) AND (x2 is …) THEN (u is …)

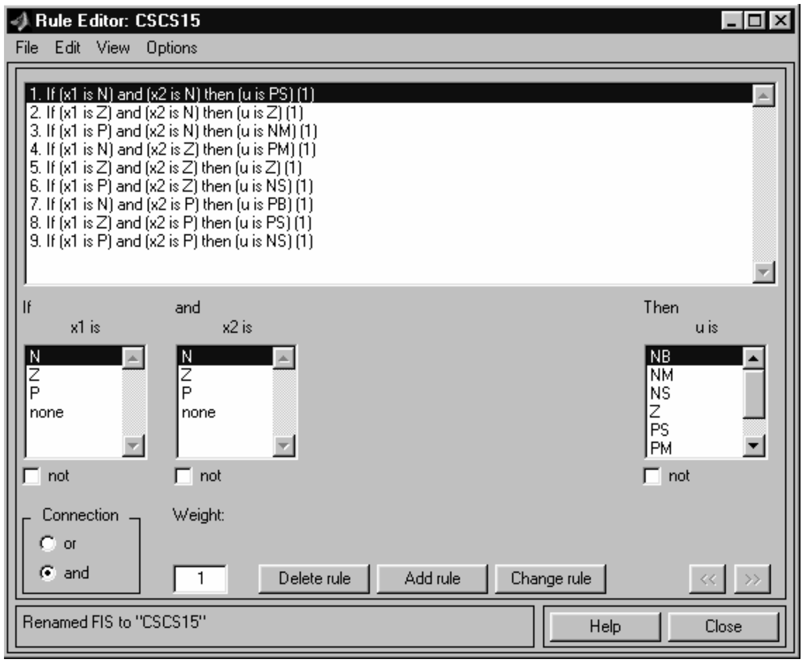


Fig. 5. The control rules table.

The nine rules were chosen by experience but can be modified to improving the results of the fuzzy controller and for a better running of the system.

With this rule table, the Fuzzy Logic Toolbox Editor can show the Rule Viewer (figure 6.a) and the Surface Viewer (figure 6.b).

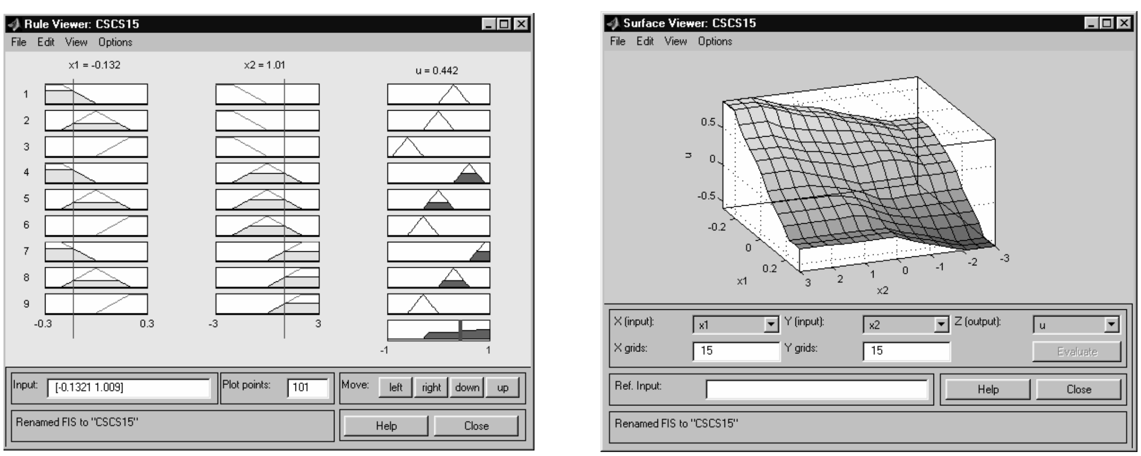


Fig. 6. The Rule Viewer (a). The Surface Viewer (b).

From the Rule Viewer (figure 6.a) we can see that the response (u) of the fuzzy logic controller, for all values of the inputs (x1 and x2), respects the fuzzy logic theory. Like example, for a real case, with x1=-0.132 and x2=1.01, the manual calculus of the output command signal gives a value u=0.439 and, using the MatLab Fuzzy Logic Controller, we have the value u=0.442, almost equal with the theoretical value. This fact shows that the rule table is correctly chosen.

After the conception of the virtual fuzzy controller, was created the simulation model (figure 7). In this model was introduced the fuzzy controller and was simulated some states of the real model using two Slider Gains ($C_0$1 and $Q_0$1). Also, in the simulation model was introduced the constants C_0 and Q_0 for changing the desired levels of the concentration and air flow respectively. After several simulations, with varied levels of desired concentration and air flow and for entire variation domains of the two inputs parameters which are sampled from the real system and simulated with the Slider Gains (C and Q), the reply of the fuzzy controller was very satisfactory.

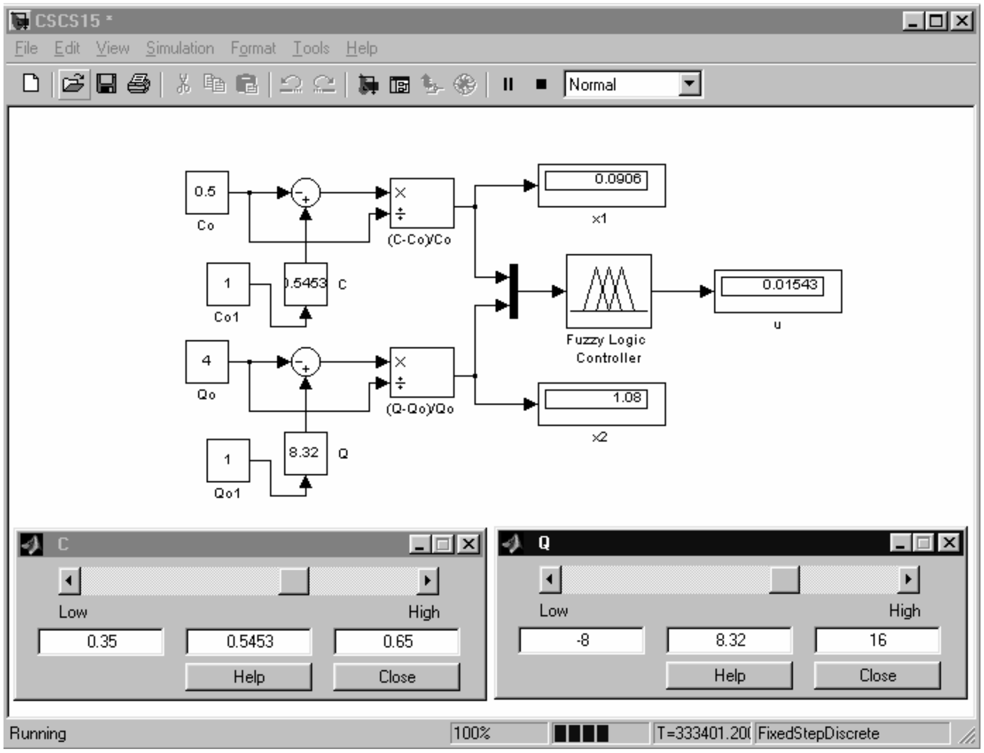


Fig. 7. The simulation model.

The final step of this work will be the testing of this model on the real system with real input parameters and real output control variables. For this purpose will be used an acquisition board (PCI 1710 or DSpace 2110) and External Mode of the Simulink platform.

4. ACKNOWLEDGEMENTS

Because this process is so complex and it is difficult to obtain a rigorous mathematical model, the fuzzy command represents a viable alternative.

The implementation of this system supposes a small cost than the using of a conventional regulator difficult to use in absence of a rigorous mathematical model.

The small dimensions, small costs and the compact structure of the programmable automatons permits the implementation of the system even in X environment conditions.

For the increase precision, after simulation and estimating performances, we will try to grow the number of linguistic terms for inputs linguistic variables from 3 to 5, and for outputs linguistic variables from 7 to 9. This will determined a increase of the number of rules from 9 to 25.

For the system performances evaluating was conceived a simulation system which work hardware-in-the-loop. The results are promising.

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