IOP Conference Series: Materials Science and Engineering

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To cite this article: Zhao Jing 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **563** 042072

IOP Conf. Series: Materials Science and Engineering **563** (2019) 042072 doi:10.1088/1757-899X/563/4/042072

Study and Application of Intelligent Control Technology in Local Fan of Coal Mine

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Absrtact. Local ventilator is an important equipment in the process of underground coal mine excavation, and its reliability and efficiency directly affect the safety of gas emission. Because of the characteristics of large lag, non-linearity and multi-disturbance of local fan control system, the traditional PID control method can not achieve the desired control effect, so an intelligent control technology, i.e. fuzzy control, is put forward and applied to the local fan control system, and the fuzzy control algorithm is improved. The improved fuzzy controller can pass through the local part according to the gas concentration in the heading face. The speed of fan is adjusted in real time to ensure the safety of underground working environment, and the fuzzy control of gas concentration and frequency conversion speed regulation of local fan is realized. The fuzzy control not only improves the ventilation control performance and automation level, but also has remarkable energy-saving effect and better control performance.

1. Introduction

Gas explosion accidents in underground coal mine mostly occur in mining face. For one thing, the tunneling face relies on local ventilators for air supply, too far away from the face or too much air leakage from the face will cause insufficient air supply, gas concentration can easily reach the explosion limit; for another thing, the tunneling face uses coal electric drill to drill holes, if the coal electric drill loses explosion-proof performance, it will often emit sparks. Therefore, a series of safety measures must be taken to ensure the safe and continuous operation of the local ventilator and not to stop the air at will when using the local ventilator for tunneling ventilation. In order to ensure the safety of underground work in coal mine, it is necessary to control the local ventilator in underground mine. With the advance of tunneling face, the air resistance and gas emission of roadway will change greatly. The constant speed control of local ventilator can not meet the requirements. Because the control system of gas concentration and local fan is a non-linear, large inertia and multi-coupling system, the traditional PID control can not achieve the desired effect.

With the development of intelligent control technology, fuzzy control is one of the important branches of intelligent control. Fuzzy control is a method of simulating human's fuzzy thinking so as to control some objects or processes intelligently, which can not be described by precise mathematical models. Intelligent gas drainage system takes fuzzy control as the control core and drives local ventilator by frequency conversion speed regulation. When gas is automatically discharged with maximum efficiency, the speed of local ventilator is automatically controlled according to the gas concentration and air volume at the mixed air flow of return air lane and the work of sensor detection, and the gas concentration at the return air flow is controlled by adjusting the output air volume in a safe range to achieve maximum efficiency.

2. Fuzzy Control

Fuzzy control is an important part of intelligent control. It can help people to use the knowledge of fuzzy set theory, fuzzy linguistic variables and fuzzy logic reasoning. It can elevate these fuzzy linguistic rules to numerical operations. Thus, computer can be used to complete the concrete realization of these rules, so as to achieve the goal of automatic control of certain objects or processes by machine instead of human. The block diagram of the fuzzy control system is shown in Figure 1.

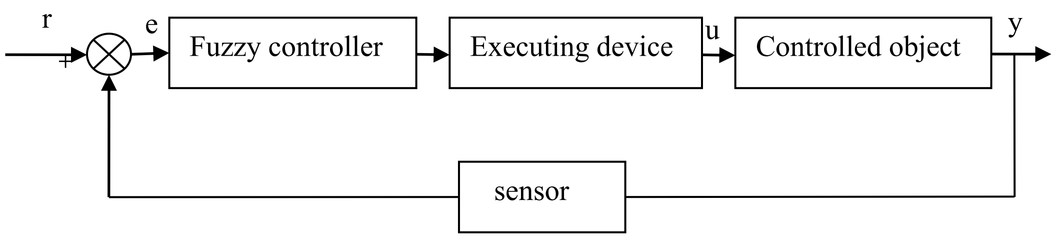

Figure 1. Block diagram of fuzzy control system

The fuzzy control system consists of a fuzzy controller, an input-output interface device, a controlled object, an actuator and a sensor. Among them, the fuzzy controller is the core of the fuzzy control system. The performance of a fuzzy control system depends mainly on the structure of the fuzzy controller. It is very important for the design of the fuzzy controller to adopt appropriate fuzzy rules, synthetic reasoning algorithm and fuzzy decision-making. The fuzzy controller is actually a computer. According to the need of the control system, both the system machine and the single chip computer can be used. The fuzzy controller realizes all kinds of fuzzy algorithms needed in the control process. Because the fuzzy control rules adopted are described by the fuzzy conditional statements in the fuzzy theory, the fuzzy controller is a kind of linguistic controller and an "intelligent" part of the control system. Fuzzy control system includes input fuzzification interface, database, rule base, fuzzy inference engine and output fuzzification interface.

The basic principle of the fuzzy control system is to convert the measured state of the controlled object into a fuzzy quantity described by human natural language through a fuzzy interface. Then, according to human language control rules, the fuzzy value of the output control quantity can be obtained by fuzzy reasoning. The fuzzy value of the output control quantity can be converted into the precise quantity that the actuator can receive through a clear interface.

3. Improvements of Fuzzy Controller

Because the speed of fan can track the change of gas concentration in real time and realize the real-time dynamic adjustment of ventilation volume, the fuzzy controller is improved. Its structure is shown in Figure 2. According to the deviation and deviation rate of gas concentration, the rule factor α of the two-dimensional fuzzy controller is adjusted automatically, the control rules are changed, the corresponding control quantity is generated, and the local fan is controlled.

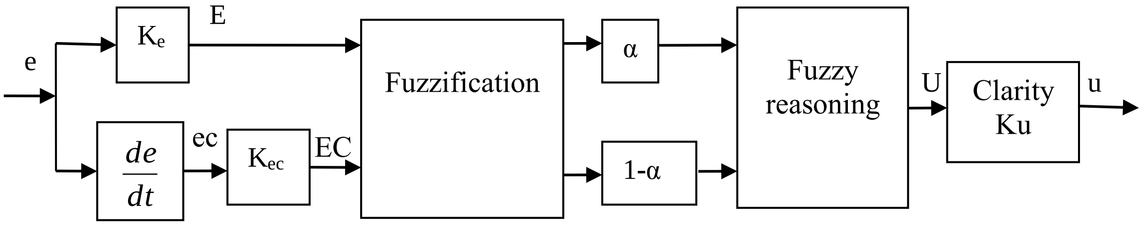

Figure 2. Improved Fuzzy Controller

E is the fuzzy variable of gas concentration deviation; e is the precise continuous quantity of gas concentration deviation; EC is the fuzzy variable of gas concentration deviation change rate; ec is the precise continuous quantity of gas concentration deviation change rate; u is the input voltage of control frequency converter; U is the fuzzy variable of control frequency converter input voltage; Ke and Kec are the quantification factors of E and EC respectively; Ku is the proportional factor of output; α is adjustment factor.

For two-dimensional fuzzy controllers, the control rules can be expressed by equation (1), when the domain levels of input variable deviation E, deviation rate EC and output control variable U are identical.

$$U = -\left[\alpha E + (1-\alpha)E\right] \qquad \alpha \in [0, 1] \qquad (1)$$

According to equation (1), by adjusting the value of α, the weighting degree of deviation E and deviation change rate EC to control output U can be changed, thus the control rules can be changed.

4. Design of Fuzzy Controller for Local Fan

In the coal mine air supply system, when the demand for on-site air is large or small, the stochastic strong execution process has a certain lag, the control accuracy is poor, and the law is difficult to grasp, so the mathematical model is difficult to determine. To solve these problems, an intelligent control system based on fuzzy control is designed. Fuzzy control process mainly completes the tasks of precision fuzzification, fuzzy reasoning and non-fuzzification. A two-dimensional fuzzy controller is designed by choosing deviation E of gas concentration and deviation rate EC as input and output speed U of fan as output.

4.1. Fuzzy Input and Output Variables

According to the "Coal Mine Safety Regulations", when the gas concentration reaches or exceeds 1.5%, it should enter the state of gas discharge. In order to achieve energy-saving effect, when the gas concentration is between 0% and 1.5%, the speed of local fan should be changed proportionally with the increase or decrease of gas concentration. The quantification domains of gas concentration deviation E, deviation rate EC and output speed U of local fan are {-6,-5,-4,-3,-2,-1,0,+1,+2,+3,+4,+5,+6}, and their fuzzy subsets are {NB, NM, NS, ZO, PS, PM, PB}. The linguistic variables are {negative big, negative medium, negative small, zero, positive medium, positive big} and the membership functions are symmetrical triangle function. The membership function diagram is shown in the Figure 3.

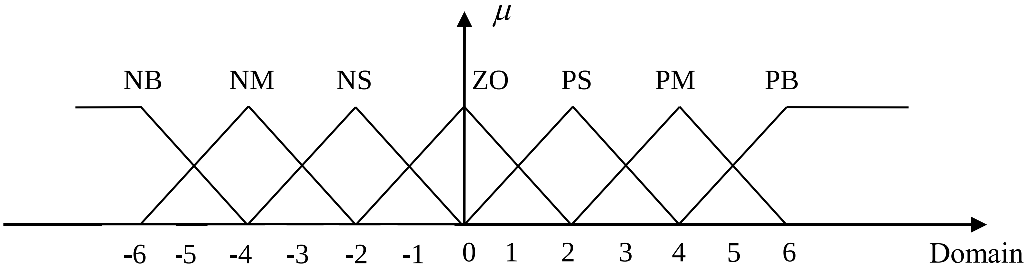

Figure 3. Membership function of gas concentration input E, EC and output U

4.2. Determine quantification factor and proportion factor

The basic domain of deviation E of gas concentration is set as [- 1,+1], and the quantification domain is {-6,-5,-4,-3,-2,-1, 0,+1,+2,+3,+4,+5,+6}, n=6. The quantification factor is Ke=6/1=6.

The basic domain of EC is set as [-0.5,+0.5], and the quantification domain is {-6,-5,-4,-3,-2,-1, 0,+1,+2,+3,+4,+5,+6},n=6. The quantification factor is Kec=6/0.5=12.

The basic domain of input voltage of local fan output is [0,10], and the quantization domain is {-6,-5,-4,-3,-2,-1, 0,+1,+2,+3,+4,+5,+6}, n=6, and the ratio factor is Ku=10/6=1.7.

4.3. Fuzzy control rules

According to the actual situation of the system, the adjustment factors α is adopted. Take α= 0.3. The fuzzy control rules of the system are shown in Table 1.

Table 1. Fuzzy Control Rules

U		**E**						
		NB	NM	NS	Z0	PS	PM	PB
EC	NB	PB	PB	PB	PS	NM	NM	Z0
	NM	PB	PB	PM	Z0	NM	NB	NB
	NS	PB	PB	PS	NS	NM	NB	NB
	Z0	PB	PM	PS	NM	NM	NB	NB
	PS	PB	PM	PS	NB	NB	NB	NB
	PM	PB	PS	PS	NB	NB	NB	NB
	PB	PB	PS	PS	NB	NB	NB	NB

5. Realization of MATLAB simulation

The simulation model of improved fuzzy control system is established by using the editor of fuzzy reasoning system of MATLAB graphical tool. The given signal is gas concentration. The parameters of asynchronous motor are rated power 1.5 kW, rated voltage 380 V, rated current 4.0 A, rated speed 950 r/m in. The simulated curve is compared with the experimental curve, and the results are shown in Figure 4.

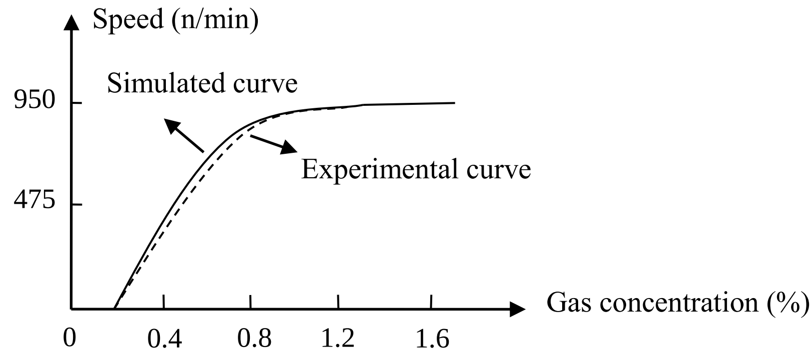

Figure 4. Simulated and experimental curves

It can be seen that the system can automatically adjust the fan speed according to the gas concentration, thus changing the ventilation condition of the heading face from Figure 4. When the gas concentration is low, the ventilator does not work or operates at a lower speed; when the gas concentration is high, the ventilator runs at a high speed to achieve the purpose of timely ventilation and drainage of gas.

6. Conclusion

The improved fuzzy controller is applied to the control system of local ventilator in coal mine. The simulation and experiment results show that the control system can continuously, dynamically and real-time adjust the frequency conversion speed of the ventilator according to the change of gas concentration in the heading face, that is, adjust the ventilation volume to change the gas concentration. The speed of ventilator can be adjusted adaptively with the gas concentration. It has the characteristics of high accuracy and good robustness. It not only improves the efficiency of ventilator, but also improves the ventilation condition of tunneling face, and the energy-saving effect is very significant.

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