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Application of Fuzzy-Control in Tunnel Ventilation

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Abstract: In the process of operation, the tunnel ventilation energy consumption is very big. And at the moment, the open mode of fans in their operation is unfixed. Based on the fuzzy control method to make the fans self-regulate and start, and make the system transform the number of open fans automatically under different conditions. Ensure that the ventilation system can not only gives full play to its performance but also saves energy.

Keywords: Fuzzy-Control; Tunnel ventilation; Energy saving

1. Introduction

At the moment, jet current ventilation is widely used in ventilation system, but in the operation there are no corresponding and constant opening ways. In general, site operators based on experience to choose open or shut down the number of different groups of fans. Actually, different tunnels have different air situation, it will change by the time and traffic, so the number of opening fans should be not the same in principle. This paper uses the fuzzy control method to realize the ventilation system adjustment online, and based on a fixed control rules to determine the number of open fan. In the current energy shortage situation of our country, this research has great significance to improve the economic benefit and the application level of high and new technology of highway tunnel (HE Chuan, 2005).

2. Based on CO Concentration Index to Design the Fuzzy Controller

CO concentration is an important index of the tunnel ventilation. Highway tunnel ventilation parameters are set in Highway Tunnel Ventilation Design Specification. During normal transportation, the design concentrations of CO of different tunnels can be valued according to Table.1(Highway Tunnel Ventilation Design Specification, JTG/T D70/2-01-2014).

Table 1. Design Concentrations of CO

Length of highway tunnel (m)	≤1000	≥3000
d_{co} (ppm)	150	100

Note: When the length of highway tunnel is1000 m ~ 3000 m, according to insertion method to fetch values.

For example, the tunnel with 1Km, CO concentration fuzzy controller is established with single input and single output. Input value of CO concentration fuzzy controller is the deviation value of CO concentration, and output value is the number of opening fans, then through the fuzzy rules to operate and adjust the number of opening or stopping fans. Ensure that the CO concentration of highway tunnel in the permitted range.

Find out the fuzzy relationship between output value and "e" which is deviation value. In operation, constantly testing values of "e" and taking their average every 3min. And take the average as the input value of the controller. According to the fuzzy control rules, controller can adjust the output value online, in order to satisfy different requirements of ventilation control in different pollution conditions.

3. Establishing the Fuzzy Controller

3.1. Set input and output parameters field and membership functions of fuzzy subsets

The CO design concentration of a expressway tunnel with 1Km is 150ppm(Highway Tunnel Ventilation Design Specification, JTG/T D70/2-01-2014). And the "e" which is the deviation of CO concentration is defined as:

$$e = s - C_{CO}$$

In the formula, s is the design concentration of CO and Cco is the measured value.

In the running process of fan, the actual concentration of CO range from 120ppm to 180ppm. For CO concentration change area is (-30, 30)ppm. In the ventilation system have four groups of fan, each group contains two fan, a total of 8 sets of jet fan. The real domain of discourse of CO concentration is [120, 180], Using the formula that "e=150- x, y=12(150-x)/60=(150-x)/5" change "x" which range from 120 to 180 to disperse domain of discourse {-6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6}. The fuzzy subset is {NB, NM, NS, Z, P}. Elements of the subset represent negative big, negative middle, negative small, zero, positive. NB shows pollutant concentrations much higher than the set value; NM shows pollutant concentrations a few higher than the set value; NS

shows pollutant concentrations a little higher than the set value; Z shows pollutant concentrations is basically the same than the set value; P shows pollutant concentrations a lower than the set value;

Fuzzy subsets of output variable M are set to{M4, M3, M2, M1, M0}. Quantifying parameters into discrete areas(0,1,2,3,4,5,6,7,8). The M4 shows that opening four groups of fans; The M3 shows that opening three groups of fans; The M2 shows that opening two groups of fans; The M1 shows that opening one group of fans; The M0 shows that do not open the fan.

The key to solve the problem of fuzzy control is setting membership functions correctly. The triangle is generally selected as the membership function curve. In this way mathematical expression and the operation is simple, less amount of calculation. And when the input value is changing, triangle function has a higher sensitivity than normal distribution function or the membership function with Bell-shaped gaussian distribution.

3.2. Setting fuzzy rules

In the designing of this system, input variable of fuzzy controller is level 5 fuzzy partition, contains five fuzzy rules. According to the control method and characteristics, fuzzy reasoning can be written as:

Rule1：if(e is NB)then (M is M4)

Rule2：if(e is NM)then (M is M3)

Rule3：if(e is NS)then (M is M2)

Rule4：if(e is Z)then (M is M1)

Rule5：if(e is P)then (M is M0)

3.3. Fuzzy inference

According to the different fuzzy quantity of input, and through the corresponding fuzzy control rules, the process completed in fuzzy controller called fuzzy reasoning(Dang jiangjie,2013). Fuzzy relation between the input and output shown by each fuzzy conditional statement uses the Mamdani reasoning method. Such as for Kp:

R1＝NB×M4;R2＝NM×M3;R3＝NS×M2;R4＝Z×M1;R5＝P×M0

"R" is fuzzy relation matrix, formula is $R=\bigcup_{i=1}^{5} R_i$, The fuzzy reasoning of output can be acquired with U＝e^{O}R.

3.4. Defuzzification

The precise transforming fuzzy quantity to accurate quantity is called "Defuzzification" (Zhong luo, Yuan jie, 2008). This controller uses the gravity method to defuzzy. Computation formula is as follows:

$$C(k)=\frac{\sum_i m_c(c_i)\ c_i}{\sum_i m_c(c_i)}$$

According to every fuzzy element X which is calculated, a precise value can be calculated which is corresponded in real field. Conversion formula is as follows:

$$M = X / 2$$

The value of M is the number of opening fans. Through the current value of parameter M, the goal of adaptive adjustment can be achieved.

3. Simulation: Establish the Fuzzy Controller in MATLAB

Into fuzzy editor with MATLAB, building a file named "The fuzzy controller of ventilation system". Building the membership function and the quantized interval of "e" that of input variable; fuzzy reasoning method "And" values "min", "Or" values "max", "Implication" values "min", "Aggregation" values "max", "Defuzzification" values "centroid". Structure model of fuzzy controller of ventilation system is shown in Figure 1. Membership function of input and output are shown in Figure 2, Figure 3.

The rule of fuzzy control is shown in Figure 4. When input e = 2.23 M values of 4.3.

Corresponding relations between output and input variables is shown in Figure 5.

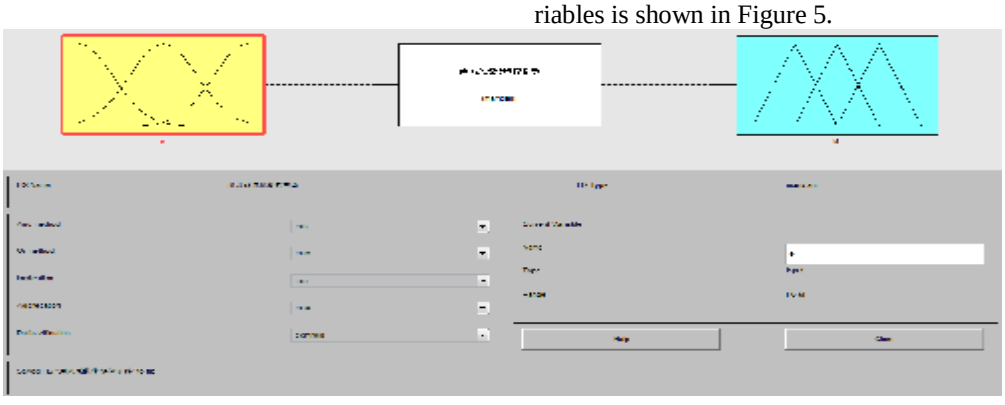

Figure 1. Ventilation system fuzzy controller

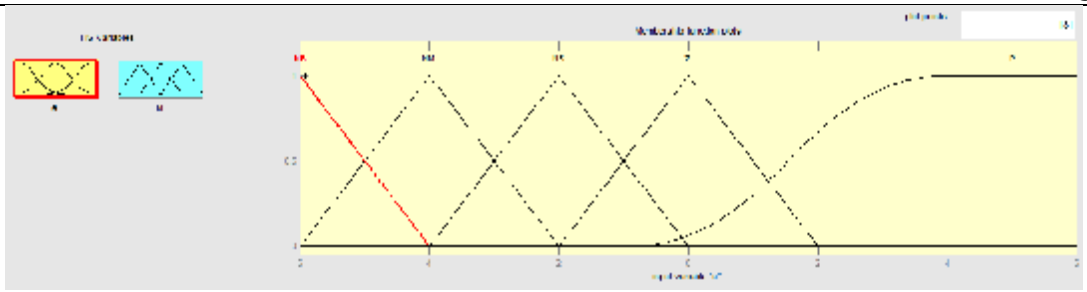

Figure 2. The membership functions of "e"

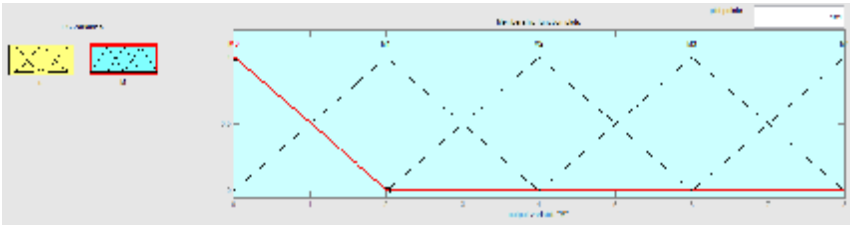

Figure 3. The membership functions of "M"

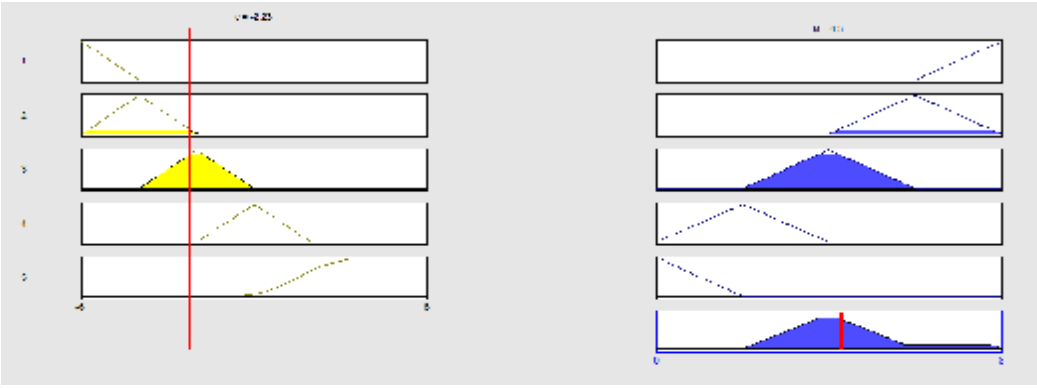

Figure 4. View the fuzzy control rules

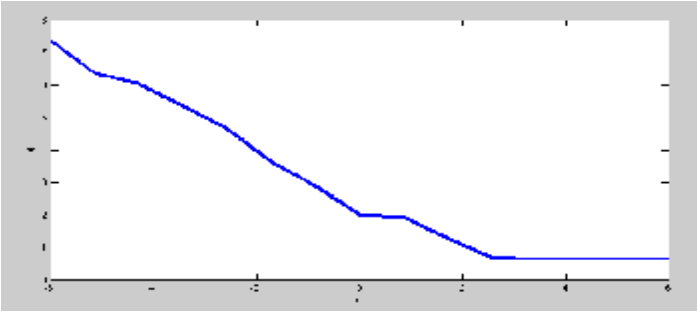

Figure 5. The corresponding relations between M and input variables

4. Conclusion

Through fuzzy control, apply fuzzy control to tunnel ventilation control. Realize the online fuzzy control of ventilation system, and make full play of the ventilation system performance and save energy. Compared with the traditional step of tunnel ventilation control, the fuzzy control of tunnel ventilation can effectively improve the tunnel air environment by starting a small amount of fan. Not only save a lot of energy, improve the operational safety of tunnel, lower the operating costs for the highway tunnel, but also reduce the start-stop frequency of fan and reduce the wear and tear of equipment.

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