



The Research and Practice in Long Tunnel Fan Remote Control Technology

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Abstract: This paper represents a new long tunnel fan remote control system which is designed for the current shortcoming in tunnel construction by using manual control of the fan. This system has advantages of centralized control, automatic intelligent, strong compatibility, easy maintenance, long distance communications, and low environmental requirements. It has been successfully deployed in Chengdu Railway Yuelongmen tunnel and was compatible with tunnel hydrogen sulfide gas monitoring system docking, automatically adjusting the fan speed according to the hole concentration of hydrogen sulfide gas, achieving good economic effect and ensuring construction safety. The system represented in this paper is a solution to the Long Tunnel Ventilation centralized management of automated intelligence.

Keywords: Tunnel Project, Aeration Control, Remote Intelligence, Fuzzy Control

1. Introduction

With the faster development of our national transportation construction, tunnel engineering plays a great role in rapid transit [1]. The length of tunnel in transportation projects becomes longer, especially in railway projects, the length of the single-seater tunnel increasing and the long tunnel being designed and built continuously [2]. With the limitations in construction, much longer auxiliary are required to achieve long tunnel bunt and rapid construction during the process of construction, and the length of the single head is longer and longer [3].

In order to solve ventilation problems in the long tunnel construction, forced ventilation is usually applied [4]. Relay ventilators at all levels need to be arranged away from the hole outside the duty room of the hole. However, because of the long distance between fans, controlling fans manually is not only a waste of time and human resource, but it's also difficult to achieve the hole outside the hole fan of the scientific linkage, causing damage to the fan and time wasted. How to carry on the centralized control and the system management of the long-distance ventilator has already become a key problem of ventilation construction of a special long tunnel [5].

Wu Y and Bakar M Z A succeeded in controlling smoke flow in tunnel fires by using longitudinal ventilation systems

based on computational fluid dynamics (CFD) technologies [6]. Ingason H and Li Y Z proposed longitudinal ventilation for fire tests [7]. Bartzanas T discussed the effect of vent arrangement on windward ventilation of a tunnel greenhouse [8]. And in this paper, with the construction ventilation scheme, the centralized control and management technology of the remote ventilator is combined with the prevention and control requirements of hydrogen sulfide and gas in this area to realize the automatic warning of over-standard early warning in the horizontal tunnel area of Yuelongmen tunnel in Chenglan railway. And the ventilation system is adjusted to achieve the purpose of saving cost and improve work efficiency.

2. Engineering Background

Narikawa ChengLan railway section (chengdu to lanzhou to chengdu sichuan main temple) Yuelongmen tunnel whose sketch is shown in Figure 1 for mixed passenger travelling electrification railway tunnel at a speed of 200 km/h, located in the longmenshan fault zone, across the central fault zone, is a double hole repairing tunnel, the total length of the left line is 19981 m, and the total length of the right line is 20042 m, in order to speed up the construction progress and to solve the issues of construction site, abandon dross, drainage, ventilation, disaster relief and so on, auxiliary tunnel set "1 flat

guide + 2 inclined well + 3 transverse gallery", combined with the topography and geology condition, adopted trackless transport organization construction. The distance between inclined well No. 3 and transverse gallery No. 3 is 9750m without auxiliary holes. Transverse gallery No. 3 has a length of 2405m and the length of the blind heading is nearly 8000 m, there are 5 or 6 working faces behind the hole, after entering the hole, we found that the segment of the work area was full

of hydrogen sulfide gas, the ventilation will be difficult.

According to the engineering characteristics and ventilation needs of the transverse gallery No. 3, we use the vice hole of transverse gallery No. 3 as a dedicated intake airway, which is shown in Figure 2 and set ventilation station in the intersection of the auxiliary hole and the normal hole. Ventilators at the ventilation station which are 2500m away from the duty room separately provide blowing ventilation to each working face.

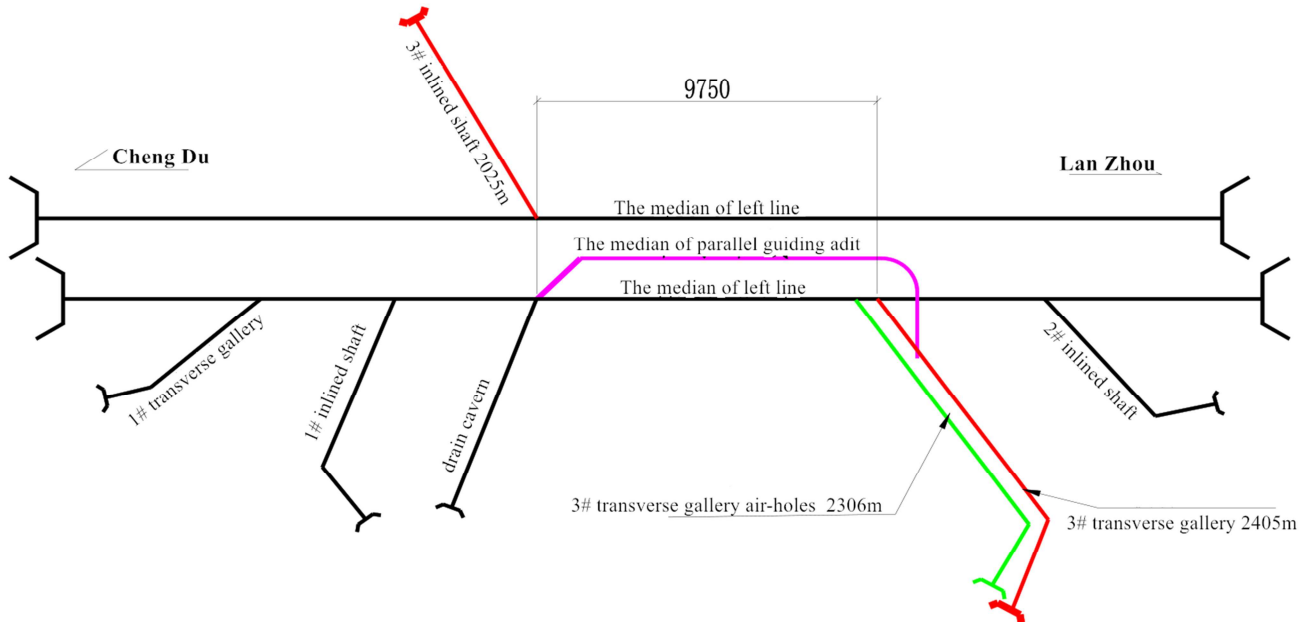


Figure 1. A sketch of Yuelongmen tunnel.

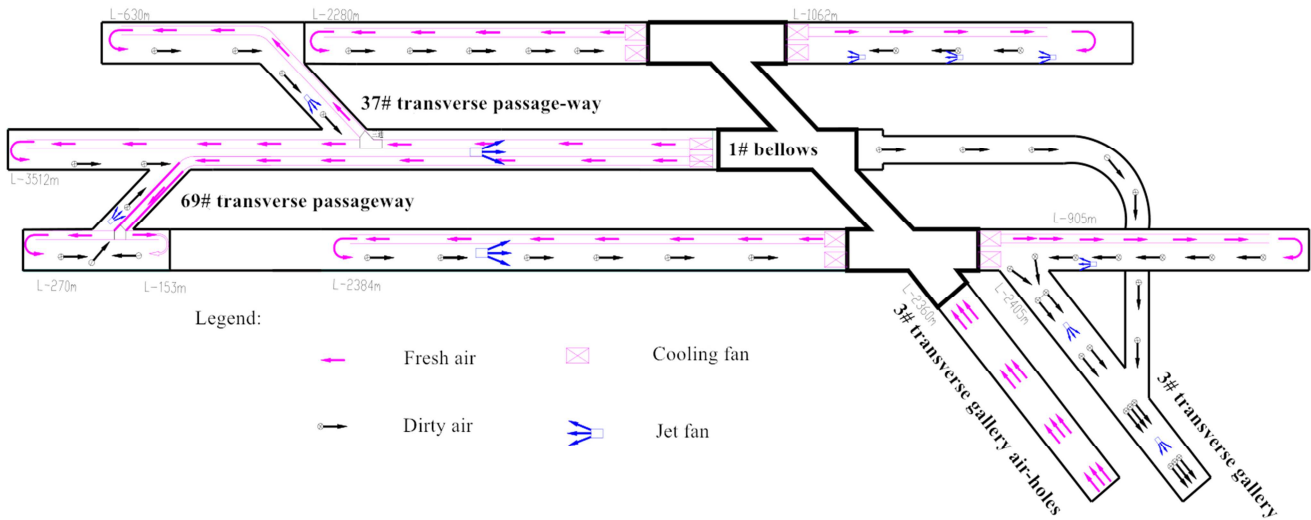


Figure 2. Yuelongmen 3# transverse gallery ventilation layout plan.

3. The Research of Ventilator Remote Control Technology

3.1. Purpose of Research

(1) Centralized control: Because of the long length of the inclined hole in the transverse gallery, the efficiency of manual management is low, and the multi-level relay

fans are not synchronized, which will lead to damage easily. Use the fan remote control technology to realize the management of ventilators through the duty room, centralize the start and stop control, ensure the safety of multi-level relay fan, and save energy [9].

(2) Remote control: With the optical fiber and the components connected to the ventilator, the fan remote control technology can control the start/stop and speed of all fans directly in the mouth of the cave, realized the

remote control and improved the working efficiency.

- (3) Intelligent automatic control: Ventilation is an effective measure to reduce the toxic and harmful gases, fan remote control system is compatible with hydrogen sulfide gas monitoring system, fan remote control system can induce the hydrogen sulfide gas concentration intelligently, once the concentration of hydrogen sulfide gas exceeds the critical value, the fan start or accelerate automatically to increase the ventilation, and reduce the concentration of hydrogen sulfide gas effectively to the safe value, ensure the safety of tunnel construction .

3.2. Designing Principle

Install software in the computer in the duty room of Yuelongmen tunnel transverse gallery No. 3, connect the computer and the fan in the tunnel, to achieve the remote centralized management of all fans and ordered starting according to the ventilation program through the duty room, at the same time through the compatible docking to the hydrogen sulfide gas monitoring system, the remote central control system induces and analyzes hydrogen sulfide gas concentration in the cave, automatically analyzes the requirement of ventilation in the working face according to the concentration, and then sends instructions to the ventilation fan to achieve the intelligent control.

3.3. Designing Scheme

- (1) This system is mainly composed of hardware part and software part. Hardware control part includes: Programmable Logic Controller (PLC), intermediate relay, fiber optic transceivers and air switch, and use the explosion-proof box to protect the hardware. The hardware composition and connection are shown in figure 3. Software part includes: the codes that control the fan, Browser/Server (B/S) controlling interface .
- (2) The system control process: The Industrial Personal Computer (IPC) send the signal, the optical transceiver switch the signal to the PLC, PLC send output to the intermediate relay according to the written procedures,

and the relay connect and control the Power Distribution Box of the fan. Tunnel fan remote central control system can manually use the B/S system on IPC end, it also can realize the compatible docking to the hydrogen sulfide gas monitoring system, automatically induce the concentration of hydrogen sulfide gas, and start or accelerate according to the concentration of automatic, specific data are shown in table 1 and table 2.

- (3) Optical fiber communication and signal transmission

This system using optical fiber as a data transmission channel, optical fiber can not only provide effective signal transmission between long distance, and it also has the advantages of strong anti-jamming capability, low loss of signal, high fidelity and low cost. Considering the tunnel environment is relatively poor, the system uses the rubber-covered optical cable, to prevent fiber damage due to collision [10].

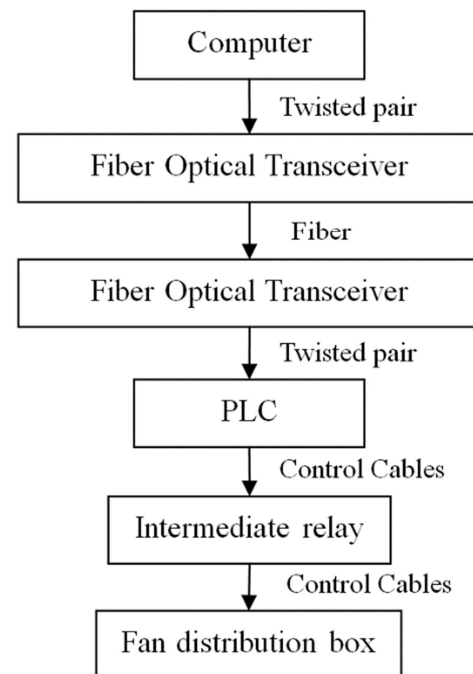


Figure 3. The structure of ventilation control system.

Table 1. Comparison between CH₄'s Concentration and fan status.

CH ₄ 's Concentration or Tunnel Status	Fan status	Measures
$Concentration \leq 0.3\%$	Low speed	Strengthen the surveillance
$0.3\% < Concentration \leq 0.5\%$	Middle speed	Strengthen the surveillance
$0.5\% < Concentration \leq 1\%$	High speed	Strengthen the surveillance and ventilation, trouble-shooting
$1\% < Concentration \leq 1.5\%$	High speed	Lockout, strengthen the ventilation, trouble-shooting
Blast in tunnel	High speed	Strengthen the ventilation when blasting

Photoelectric signal conversion: Optical fiber transmit light signal, IPC send and receive signals through twisted-pair, using optical transceiver converts the electrical signals in twisted-pair cable to the optical signals in the optical fiber transmission. Click the fan control button on the B/S software interface or trigger the signal for changing the status of fans, the optical signal can be transmitted through the rubber-covered optical cable at the speed of light, to the

optical transceiver in the control box, optical transceiver can swap the short-distance twisted-pair electric signals and the long-distance optical signals, As the core of the system is using PLC to control fans, and the input signal comes from the optical transceiver, we need to use optical transceiver to swap signal in the last stage of the signal transmission, and to input the signal into PLC through the twisted pair.

Table 2. Comparison between H_2S 's Concentration and fan status.

H_2S 's Concentration or Tunnel Status	Fan status	Measures
$Concentration \leq 10ppm$	Low speed	Strengthen the surveillance
$10ppm \leq Concentration \leq 20ppm$	Middle speed	Strengthen the surveillance
$Concentration > 20ppm$	High speed	Strengthen the surveillance and ventilation, trouble-shooting
Blast in tunnel	High speed	Lockout, strengthen the ventilation, trouble-shooting

PLC is a kind of electronic device which is specially designed for application in industrial environment, it uses a programmable memory, to perform the logic operation, sequence operation, timing, counting and arithmetic operations such as operating instructions in its internal storage, and can control various types of machinery or production process through digital or analog input and output, mainly includes the Central Processing Unit (CPU), Input/output (I/O) module, memory, function module, communication module and power module. When the optical transceiver signal is input into PLC through twisted-pair cable, PLC can carry on the corresponding output through the control cable according to the written program, for intermediate relay, PLC output logic level signal. Due to different type of fan, the control mode is different, The fan control applied in Yuelongmen tunnel in ChengLan railway can be divided into four kinds of state, including low speed, medium speed, high

speed, stop. PLC provides different output according to the different signal, and applying them to the corresponding intermediate relay, and intermediate relay sends the signals to the state control circuit in the fan control box via control cable, complete the change of the fan control process.

The fuzzy control block diagram of hydrogen sulfide gas monitoring system integrating tunnel ventilation remote control system is shown below. This system adopts the traditional control mode, namely by partitioning control level to get the control of the tunnel ventilation. The system uses fuzzy control of tunnel ventilation, selecting the concentration of hydrogen sulfide and gas which are collected by the hydrogen sulfide gas monitoring system in the real-time as the input of the fuzzy controller, obtaining the control results through fuzzy reasoning, and controlling the speed of the fan. The structure of fuzzy control is shown in Figure 4.

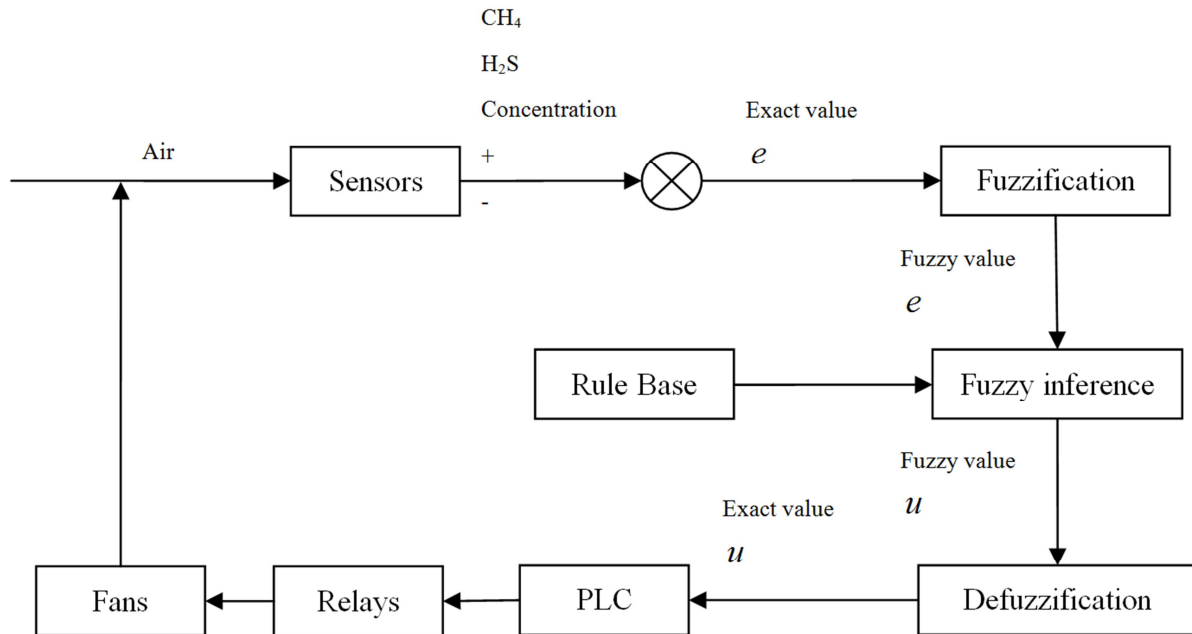


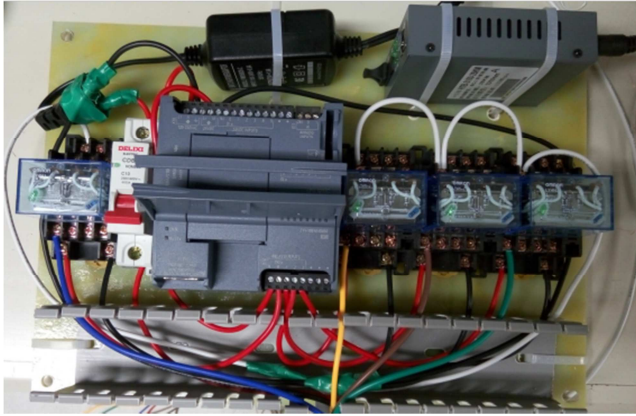
Figure 4. The structure of fuzzy control.

According to the contrast of gas concentration and the state of the fan control in table 1 and table 2, we defined the concentration of methane and hydrogen sulfide in fuzzy language as (negative big, negative medium, negative small, zero), expressed as (NB, NM, NS, Z), in which NB said the concentration of harmful gas was the largest, Z said the concentration of pollution was the smallest. When blasting is required, we need to manually close the fan, the operation is not the result of the automatic control system, so the fuzzy control ignored the process. Similarly, the state of the fan will

also be defined as variables (NB, NM, NS, Z) in fuzzy language, which mean high speed, medium speed, low speed and stop. However, even though the harmful gas concentration in the tunnel is as low as zero, considering the tunnel length, ventilation and other factors, such as carbon dioxide is accumulating, fan should not be shut down, so the actual fan stop state only exists in manual control mode, and does not exist in the system automatic control mode. Ventilation fuzzy control rules are as follows.

Table 3. Tunnel ventilation fuzzy control rules.

H ₂ SCH ₄ Fan	NB	NM	NS	Z
NB	NB	NB	NB	NB
NM	NB	NM	NM	NM
NS	NB	NM	NS	NS
Z	NB	NM	NS	NS

**Figure 5.** Specific installation.

Specific installation effect is shown in figure 5. The four relay in addition to the most on the left side of the relay on behalf of the stop, need to often open the connection, the other on behalf of the low speed, medium speed and high speed of intermediate relay all need normally closed the connection.

4. On-Site Installation and Debugging

- (1) First of all, test the hardware system in the line connection and the PLC. Connect the equipment in the above figure to the power supply, use twisted-pair cable, optical fiber and a new fiber optic transceiver to connect the fiber-optic transceiver in the IPC and control box, complete the signal conversion from electrical signal to optical signal, and use twisted pair connect the fiber optic transceivers in the control box and the PLC, open the B/S system control interface, respectively click the control button which is on behalf of the different state, observe the feedback of the corresponding relay in the control box, if the click of a different button changes the state of a different relay, then the system connection is normal, you can seal and install it.
- (2) Because the signal transfer between control room and the fan control box uses skin line cable, you need to set up the skin line cable to support the signal transmission. When setting the skin line cable, considering the tunnel conditions, line needs to be hanging above the cave, and tied together with the original lines, preventing the damage caused by engineering machinery vehicles.
- (3) During installation, the control box needs to be installed near the distribution box. The control box that near the entrance not only needs to control the fan, but it also

needs to be the information hub, connecting the other fan control box in the cave. And the four intermediate relay in the control box respectively control stop, low speed, medium speed and high speed of the fan, as shown in figure 4, the blue, yellow, brown, green line on the relay, respectively on behave of the stop, low speed, medium speed and high speed controlling. And the power of the control box need to be 220 v to 240 v ac supply, to make it work properly.

- (4) After the installation, when clicking different button on the B/S interface in the control room, signal will be transmitted to the PLC, making the different intermediate relay generates signal and then sends the signals to the distribution box of the fan, and changing the state of the fan.

5. Software Reliability Analysis and Improvement

5.1. Software Reliability Analysis

- (1) Tunnel ventilation and remote control system considered the harsh environment in the tunnel, the existence of flammable gas, the hardware is all integrated in a explosion protection box, the communication with the outside world rely on skin line cable, four control cable output control signal, high integration and internal invisibility, preventing artificial damage and danger in the flammable gas environment.
- (2) In order to make the controllers of the fan operate at a distance, and considering the tunnel engineering vehicles, the skin line cable is used as a means of remote signal transmission, leather line cable has low cost, signal decreases, and the wire in the cable can protect optical fiber from easily broken. Using cold connection is simple and convenient, and as we can increase the length of the fiber easily, it is easy to move the fans.
- (3) The programmable logic controller of the system. Programmable controller is specialized in industrial control computer area, its main characteristic is easy to use, simple programming, strong function, cost-effective, high reliability, strong anti-jamming capability, and it has self diagnosis and display function, which can easily find out the error.

5.2. Improvement

- (1) Fiber optic models are optimized for more robust fiber optics, and a dual-core fiber optic cable can be selected for use, as when one of the cores is broken, we can use another core for emergency communications. In addition, if conditions permit, try to use heat welding, further reduce the attenuation of light.
- (2) Add power on and off state display button in the B/S control system interface, for understanding the current state of the fan during the operation of the fan.

6. Conclusions

Through the use of the remote fan control system in long-distance tunnel, fan managerial staff can remote control the fan outside the tunnel, achieving the systematic management of all fans, saving time and effort. At the same time, the system can be compatible with the hydrogen sulfide gas monitoring system, and then automatically adjust the fan speed according to real-time monitoring of hydrogen sulfide and gas content. In addition, the control system uses PLC as the controller, which greatly improved the system reliability and anti-jamming capability. This system uses fiber optic cable as the signal transmission channel, effectively reducing the light attenuation in the long-distance transmission, and ensuring the smooth flow of the signal transmission channel in the harsh environment of the tunnel. Considering the existence of flammable gases, the hardware of the system is all integrated in a explosion protection box, isolated from the outside world, ensuring the safety of the system. Generally speaking, the remote fan control system in long-distance tunnel not only realizes the remote control and automatic control of the fan, but also takes the corresponding measures according to the special situation of the tunnel to ensure the safe operation of the system, effectively reduces the probability of damage and raises the work efficiency, ensures the safety of construction in the hydrogen sulfide gas tunnel.

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Biography



Luo Ningning (1971, Hunan lianyuan), Master of engineering, senior engineer. Mainly engaged in railway engineering construction technology management work. He is currently a railway project chief engineer and deputy chief engineer of his company. His research interests are Tunnels, Subways and water conservancy engineering construction technology. He authored 1 books, 5 publications in scientific papers.