Study on Digitalized Interlocking System Based on Intelligent Trackside Equipment

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Abstract: A digitalized interlocking system based on the intelligent trackside equipment is proposed on the basis of the existing full electronic computer interlocking system. The paper describes in detail the system functional structures as well as their regional control, digitalized trackside equipment design and remote intelligent operation and maintenance systems. The application of the system can greatly reduce the complexity of indoor equipment and improve the flexibility of system configuration and the system is the new generation of all-round digitalized interlocking system which is applicable to the unattended stations with more flexible configuration.

Key words: computer interlocking; regional control; intelligent trackside equipment; remote intelligent operation and maintenance system; digitalization

Introduction

Computer interlocking system is the important technical equipment to secure train operation safety in the station and improve the railway transportation efficiency. With the increasingly matured power and electronic control technologies, cyber communication technology and computer control technology, the full electronic computer interlocking system has come into being. It has been over ten years in China to carry out researches on the full electronic computer interlocking with its application beginning to take shape in scale. At present, most of the full electronic interlocking system that have been applied in China still adopt

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the mode of Full Centralized control, which puts together the interlocking equipment including all the implementing units in the control building and connects different kinds of cables with the trackside equipment. Therefore, there exist the weaknesses such as large quantities of cables and equipment in the control building, high complexity of system engineering construction and difficulties in upgrading and renovation.

The implementing units for the digitalized interlocking system based on intelligent trackside equipment are placed at the trackside outdoors. The implementing units combine with the trackside signal equipment to form the digitalized intelligent trackside equipment, making connections with the indoor interlocking system through cables or wireless technology in a way of safety communication. Such a way can reduce and even eliminate the hidden trouble in safety to the maximum due to the mixed wires of cables and improve remarkably the lightening-proof performance. Meanwhile, the system can improve the functions of railway signal basic equipment as well as the control and maintenance levels, reduce the energy consumption, make accurate control and real-time feedback so as to realize the railway station interlocking and even the digitalization of the entire signal system.

1 Structures of Digitalized Interlocking System Based on Intelligent Trackside Equipment

The digitalized interlocking system based on intelligent trackside equipment mainly includes the distributive control from the interlocking main control layer to the implementing layer, the evolution of digitalized intelligence as well as the building of remote intelligent operation and maintenance system.

The system keeps the structures of man-machine interactive layer and interlocking main control layer in the current full electronic computer interlocking system unchanged, moves the object controller and electronic implementing unit to outdoors to form the regional object controller by making the object controller combine with the safety communication unit and form the digitalized intelligent trackside equipment by making the electronic implementing unit combine with the trackside signal equipment. The structures of digitalized interlocking system based on intelligent trackside equipment are shown in Fig.1.

(1) The object controller connects with the indoor interlocking equipment by way of optical or wireless communication to receive orders of interlocking.

(2) The object controller adopts the way of regional control over the intelligent trackside equipment and issues the concrete orders of interlocking to different intelligent trackside equipment through CAN bus line and the corresponding trackside control units will act according to the orders of interlocking to control the signal equipment following the reception and in the meantime send the information of the working conditions for signal equipment to the object controller, thus completing the functions of control and condition collection for the signal equipment in the station.

(3) Meanwhile, the information of the working conditions for the trackside signal equipment will also be linked to the cloud server management unit of public network through the safe cyber interface. The staff of signaling and communication can use the mobile phone or computer to obtain the real-time information of the working conditions for the equipment in the station which will be convenient to conduct remote maintenance for the unattended stations and carry out the work of data analyses and failure prediction by the staff of research and development.

2 Key Equipment and Technologies of System

2.1 Indoor interlocking main control equipment

The indoor main control equip-

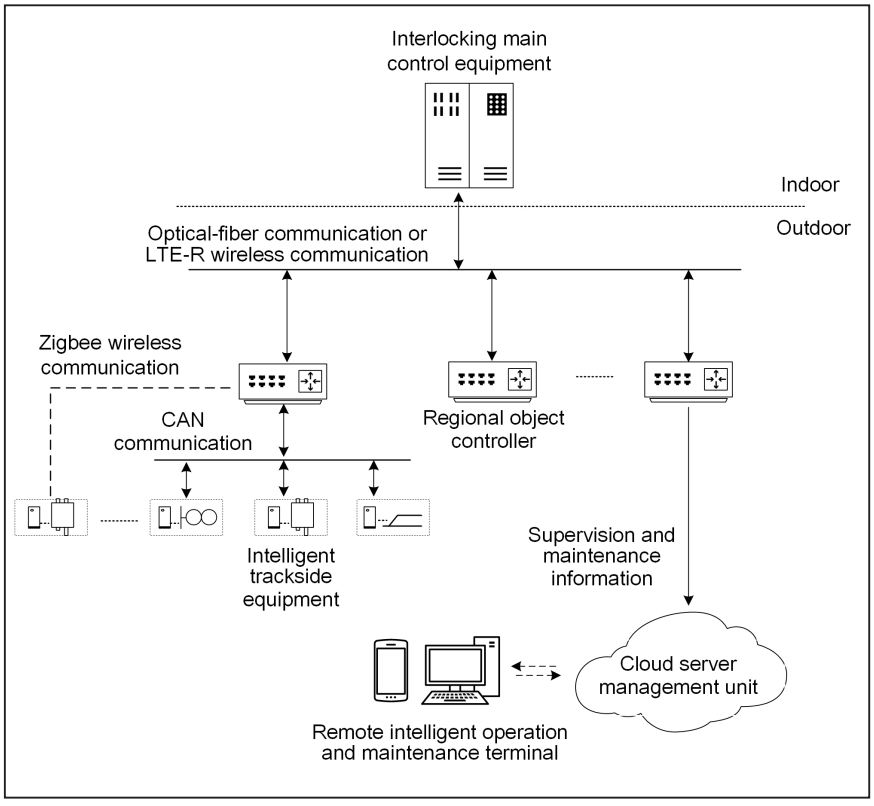

Fig.1 Structures of digitalized interlocking system based on intelligent trackside equipment

ment for interlocking mainly include the man-machine interface layer, interlocking main control layer and safe communication unit, for which the structures are shown in Fig.2. The roles of man-machine interface layer and interlocking main control layer are the same as those in the traditional computer interlocking system. The man-machine interface layer provides the monitoring interface of equipment operation and the analysis and maintenance interface for the staff of the station. The interlocking main control layer is the core part of the computer interlocking system which possesses the highest-level requirements of safety integrity and mainly fulfils the control and function logics of the entire system. The one linking with the interlocking logic unit is the safety communication unit which includes the optical communication units or LTE-R wireless communication units with the main functions of sending the interlocking orders generated from the interlocking logic units to the corresponding outdoor object controller by way of optical fiber or wireless communication.

2.2 Regional control of digitalized intelligent trackside equipment

As far as the means of regional control adopted by the digitalized intelligent trackside equipment is concerned, one each of the regional object controller including the object controller and the safety communication unit will be generally provided at the places where trackside equipment are concentrated at up throat and down throat. The distributions of digitalized intelligent trackside equipment in the station are shown in Fig.3.

The object controller makes the format conversion through the safety communication unit upon receiving the orders of interlocking, and then

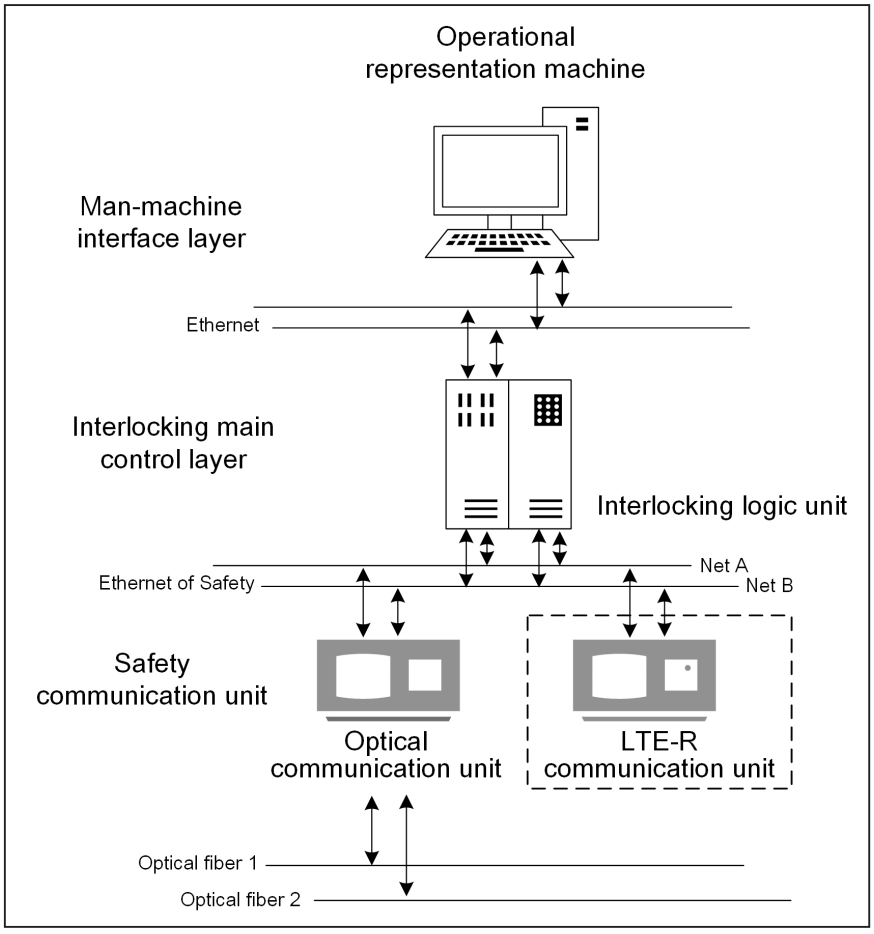

Fig.2 Indoor interlocking equipment structures

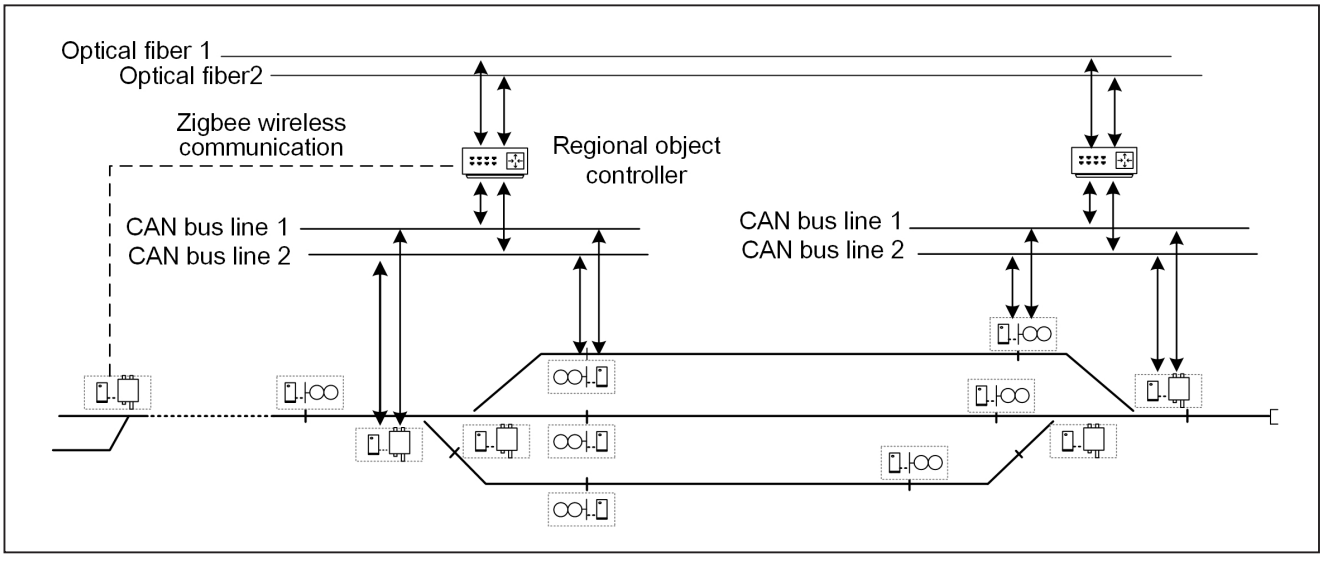

Fig.3 Distributions of digitalized intelligent trackside equipment in the station

sends the orders of interlocking to the corresponding intelligent trackside equipment through the CAN bus line. The digitalized trackside equipment are composed of one signal or one switch machine with one electronic implementing unit being allocated respectively which are distributed in the stations and yards in the way of allocation for the conventional signal equipment. Upon receiving the orders of interlocking sent by the object controller, conversion of turnouts and opening and closing of signal will be controlled and meanwhile the key information for the status of stations and yards will be sent to the regional object controller unit, enabling the real-time reception by the indoor interlocking equipment and monitoring system.

For the intelligent trackside equipment which are individually scattered between two stations and not easy to be differentiated to certain region, the CAN bus line cannot be able to support the communication of too far distance, for which one each of the Zigbee communication module can thus be added in the communication units of that trackside equipment and the object controller so as to realize the long-distance wireless control.

2.3 Digitalized intelligent trackside equipment

2.3.1 Secure and reliable control way

The digitalized intelligent trackside equipment need to be placed with a set of small two times two take two control units in the trackside equipment such as the turnout switch machine and the signal. Among them, two MCUs will be adopted for the safety control logic portion for separate computing of logic for interactive calling and dependent data through serial communication. The way of series-connection control with electronic switch and mechanical switch is adopted for output control portion to realize two-out-of-two control and avoid the board card failure of the device caused due to common cause failure (refer to Fig.4).

Double-set redundancy board cards are adopted for design of hot standby switching with the switching channel being allocated to secure that the standby module can be rapidly switched on seamlessly following the failure of one set of equipment.

2.3.2 Trackside equipment nearby control solution

The way of control for the outdoor equipment of the intelligent trackside equipment is turned from the indoor cable concentration to the direct trackside nearby control to further make indoor connection by way of communication. So one of the important research content for the intelligent trackside equipment is how the advantage of nearby control for the outdoor equipment can be brought into play.

(1) For the signal intelligent control unit, D.C. power source output to the signal can be directly achieved as there would be no longer electrical losses from long-distance transmission. Comparing with the current way of control by using the supporting lighting unit of 220V A.C. power, the utilization ratio of resources will be greatly improved while control cables are reduced.

(2) The signal intelligent control unit can be favorably applied to the functions of LED signal control and electric current collection, thus solving the problems of failing to collect the small electric current of LED signal from the current electric circuit and controlling the too many dot-matrix cables for LED signal.

(3) For the intelligent control unit of switch machine, more information for the internal key status of switch machine can be collected and uploaded which will be taken as the judgment bases for failure diagnosis and prediction and in the meantime making it possible to simplify the internal structures of the current switch machine and optimize the switching process of turnouts in future.

2.3.3 Power supply solution

Two ways of power supply including full centralized power supply and regional centralized power supply can be adopted. In the condition of scattered distribution of the outdoor intelligent equipment, the solution of regional solar batteries will be adopted for power supply, for which one set of the redundancy solar batteries will be allocated to the nearby equipment for power supply with respect to the relatively near region in terms of distance. The batteries can be directly charged through the power supply cables in addition to the charging through solar energy, thus avoiding the influence to the use of equipment in case of insufficiency in solar energy. For the stations with more centralized distribution of outdoor equipment, the way of full centralized power supply can be adopted.

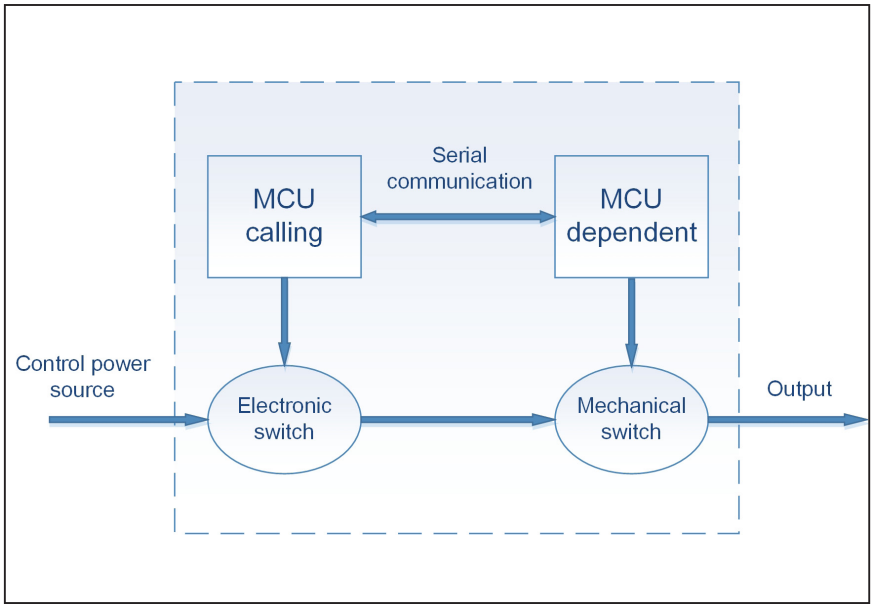

Fig.4 Schematic diagram of two-out-of two control for intelligent trackside equipment

2.3.4 Designs for electro-magnetic compatibility, lightning prevention, grounding and environmental protection

The product designs should meet the standards of outdoor equipment for railway signal including the conditions for air pressure, temperature, humidity, dust and sand, and biology and chemistry and the selection of chips needs to use the industrial grades, for which following parameters should be satisfied:

(1) Working temperature: -40 ~ 70 ℃

(2) Relative humidity: 10% ~ 100%（room temperature 25 ℃)

(3) Atmospheric pressure: 70 ~ 106 kPa（equivalent to altitude of being not over 3 000 m）

(4) Vibration requirement: It should meet the stipulations for category 2 equipment in TB/T 2846—2015 *Vibration Testing Method for Railway Ground Products*.

(5) IP protection grade: IP 55

(6) The electro-magnetic compatibility performance should meet the requirements in GB/T 24338.5—2009 *Rail Transit: Electro-magnetic Compatibility: Part 4: Emission and Disturbance Resistance of Signal and communication Equipment*.

(7) Lightning prevention performance should meet the requirements in TB/T 3074—2017 *Technical Conditions for Lightning Electro-magnetic Pulse Protection* and TB/T 3498—2018 *Lightning Testing Method for Railway Signaling and Communication Equipment*.

2.4 Remote intelligent operation and maintenance system

The remote intelligent operation and maintenance system is added to realize the real-time monitoring for the operational conditions of interlocking system, for which the results are shown in Fig.5.

The remote intelligent operation and maintenance system acquires the key status information of the signal equipment in stations and yards through the regional object controller. It can also acquire the information of working conditions and alarm for the object control unit and the intelligent

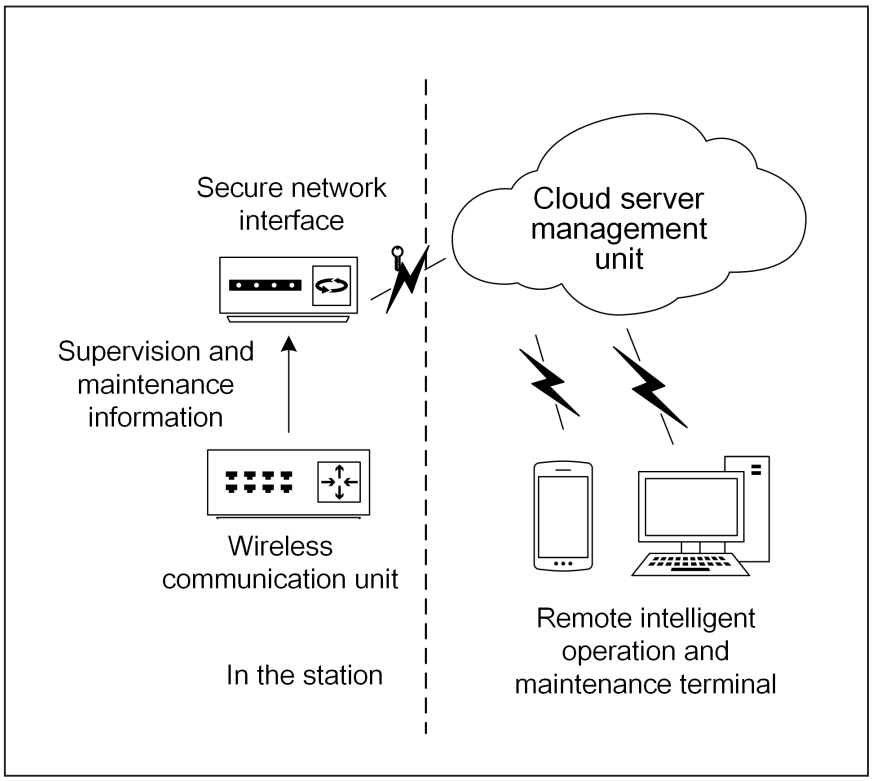

Fig.5 Structures of remote intelligent operation and maintenance systems

trackside equipment in addition to the necessary information of the electric current value for signal light and of the electric current for turnouts action. One-way communication channel linking the cloud server management unit of the public network will be formed through the secure network interface, with which the staff for signaling and communication maintenance or development can use the terminals of mobile phone or computer to call on the cloud server management unit so as to realize the real-time monitoring of different stations and yards and carry out analyses on failures in time. The terminals can open limits of authority for different data based on different business demands, whereas the users can make enquiries for the equipment in stations and yards according to the needs and limits of authority and receive the active report of alarm as well when the on-site equipment is abnormal.

The overall architecture of the system is built in reference to the basic system architecture of Internet of Things, for which only the expected receiving side can decrypt the received data so as to guarantee the completeness of the interactive data. Meanwhile, the system failure and the remote enquiry order will not be made to cause interference to the normal use of the on-site signal equipment through delimiting the system boundary.

The narrow-band Internet of Things possesses the advantages broader area of coverage, stronger penetration as well as low costs and power which applies to communication for remote areas or in the machine room of poor signal and can be used in the remote intelligent operation and maintenance system. The remote intelligent operation and maintenance system also applies to the multiple control situations such as the current computer interlocking system and the full electronic computer interlocking system and is the more intelligent and IT-based maintenance and repair system.

3 Conclusion

The digitalized interlocking system based on intelligent trackside equip-

ment simplifies the indoor equipment. In the prerequisite of guaranteeing the reliability, it reduces the outdoor control and communication wires and cables, possessing remarkable advantages in terms of construction complexity and costs as compared with the current system, being able to shorten greatly the construction period and reducing the time of on-site system commissioning and maintenance. Meanwhile, the system can provide the more intelligent and rational operation and maintenance solution for the equipment by adopting the multi-module optical fiber and the wireless communication trackside control mode. In particular, the remote operation and maintenance function of the system can enable the current planned inspection and repair of some stations to undergo fundamental changes so as to realize the true all-weather real-time monitoring.

The system not only applies to the conventional stations, but also possesses the remarkable advantages for the overseas projects, the remote areas of poor environmental conditions or the unattended stations. During the construction, it can simplify the contents of construction, reduce the construction period and in the meantime reduce the material costs and the high costs of human resources. During the use of equipment, it will reduce greatly the maintenance and repair workload of the professional personnel. The system logic processing unit and the trackside control unit adopt the hot-standby double-set redundancy which possesses the functions of supporting the remote monitoring for the equipment and failure information in the station and can better apply to the remote areas or the unattended stations.

(Translated by Zheng Mingda)

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