The Past, Present and Future of Railway Interlocking System

Conference Paper · September 2020

DOI: 10.1109/ICITE50838.2020.9231438

1 author:

Lujiang Huang
CASCO Signal Ltd
4 PUBLICATIONS **23** CITATIONS

SEE PROFILE

The Past, Present and Future of Railway Interlocking System

Lujiang Huang
CASCO Signal Ltd.
Shanghai, China
e-mail: huanglujiang@126.com

***Abstract*— Railway Interlocking system is the most fundamental and important part of railway signaling system. It ensures the safety of train movement. With the development of railway signaling system, it has experienced three stages: mechanical interlocking system, relay interlocking system and computer-based interlocking system. On the basis of reviewing the history of railway signal development, this paper introduces the development of interlocking system and discusses the future development direction of railway interlocking system.**

Keywords- railway signaling system; interlocking system; computer-based interlocking system; all-digital computer-based interlocking system; history

I. INTRODUCTION

The 200 years history of world railway development is a great revolution in transportation. The industrial revolution has promoted the development of railways. At the same time, the development of railways has greatly promoted the wheels of the industrial revolution. It has created railway giants and industrial power such as Britain and the United States in the 19th and 20th centuries. The rapid development of Chinese railways has laid a solid foundation for the rise of China in the 21st century.

With the development of the railway, the railway signaling system has gone from the stage of guiding trains by people riding horses to the stage of advanced methods based on network technology, computer technology and electronic technology. At the same time, the railway interlocking system (RIS) has also gone through several stages of mechanical interlocking; relay interlocking and computer-based interlocking.

This article reviews the history of important equipment in railway signaling system and focuses on the development of interlocking systems.

II. INTERLOCKING SYSTEM

A. Definition

Narrowly speaking, interlocking refers to the restriction relationship between the signals, switches and routes. General speaking, the restriction relationship between various devices in railway signaling system is interlocking. The interlock system is a part of the railway signaling system, which guarantees the movement of equipment according to the specified time sequence, to ensure the safe operation of the train.

B. Category

The interlocking system has experienced several major developments. According to the device form of realizing the logical relationship of interlocking, this paper divides the developments into the following three stages:

- Mechanical interlocking. The interlocking relationship is achieved by mechanical components. It has gone through two stages of all-mechanical interlocking system and mechanical plus electrical interlocking system.
- Relay interlocking. The interlocking relationship is achieved by relays and circuits based on wiring logic.
- Computer-based interlocking. The realization of interlocking relationship through software programs in computer or processor. It has gone through three stages: relay-based computer interlocking system, all-electronic computer interlocking system and all-digital computer interlocking system.

C. Composition

At every stages of the development, the interlocking system is composed of four parts: control panel, interlocking devices, actuators and outdoor devices. The development of each part constitutes the development of interlocking system. Such as, the control panel developed from control lever of mechanical interlocking age to control button of relay interlocking age. And now the control panel is realized by modern industrial control computer. Furthermore, the actuators passed through the following parts: mechanical lever control, the electrical relay circuit control, electronic hardware board control and all-digital control in the future. The basic structure of interlocking system is shown below:

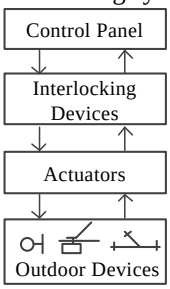

Figure 1. Basic structure of interlocking system

III. THE BEGINNINGS OF INTERLOCKING SYSTEM - MECHANICAL INTERLOCKING SYSTEM

A. *All-mechanical Interlocking System*

In 1843, the signal control based on lever which installed in Bricklayers Arms Junction of London was designed and developed by Charles Hutton Gregory. This control mode realized the centralized control of switches and signals. In the past years, centralized control has become the basic principle of interlocking system. Another key element of the interlocking system is that actions sequence of equipment will be pre-set in order to prevent the arrangement of conflicting route.

John Saxby was a signalman of Brighton and South Coast Railway Company in London. He is credited with being the first person to combine the mechanical operation of signals with interlocking safety devices.

In 1856, the first mechanical interlocking system was developed by John Saxby and also installed at Bricklayers Arms Junction. This system can not only control 8 semaphore signals and 6 switches by mechanical action bar in the signal room, but also prevent wrong operation. The schematic diagram is as follow [1]:

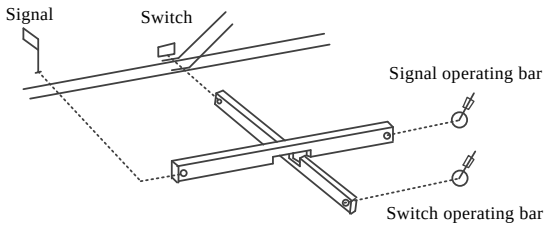

Figure 2. Schematic diagram of mechanical interlocking

Two parts of the mechanical interlocking system are introduced based on the Greenford east station in London [2].

The operating bar in the signal room is shown in the following figure (Fig. 3). The operating bar in different colours has different meanings: the black bar represents switch, the blue bar represents switch lock, the red and yellow bar represents different types of signals, and the white bar represents spare (unused).

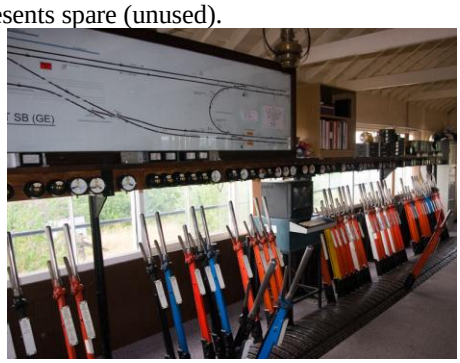

Figure 3. Operating bar in the signal room

The interlocking relationship in mechanical interlocking system is realized through the mechanical interlocking bed (Fig. 4). When the operating bar moves, the vertical tappet on the back will move up or down. The horizontal bar has a metal slot, which can be inserted into the groove on the side of the vertical tappet. The action of the lever can drive one or more horizontal rods to move left or right. If any operating bar is not in the correct position and the horizontal lever cannot be moved, the operating bar which needs to be operated will not be operated. As shown in Fig. 5, operating bar 40 should be operated after operating bar 41, 42, and 43.

Figure 4. Interlocking bed

Figure 5. operation sequence of operating bar

B. *Mechanical Plus Electrical Interlocking System*

The original mechanical plus electrical interlocking system controlled switch by mechanical device and controlled signal by electrical equipment. With the advantage of electrical control: longer control distance, without mechanical drive lever, switch and signal started to use electrical control gradually. Although the interlocking logic was still realized through the mechanical interlocking device, the interlocking system has started to move to the next stage.

IV. RELAY INTERLOCKING SYSTEM

When the Mechanical operating bar is replaced by a small one or button, the mechanical interlocking system was replaced by relay interlocking system which based on circuit wiring logic and relays.

In February of 1929, the first relay interlocking system was put in service by General Railway Signal (GRS) Company on the Chicago, Burlington and Quincy at Lincoln, Nebraska.

In February of 1937, the first installation of an all-relay interlocking with pushbutton automatic selection of routes and positioning of switches and signals, named NX

(Entrance-Exit) system designed by GRS, was put in service at Brunswick, England. The first application of NX system in the United States was installed at Girard Junction, Ohio, on the New York Central in 1937 [3].

A. *Control Panel of NX System*

Every the routes in the station-yard have entrance and exit. The operator can set the route by push the entrance knob and exit knob. When the switch needs to be maintained or be operated individual, operator can use the test key on control panel which as shown in the Fig. 6 [4].

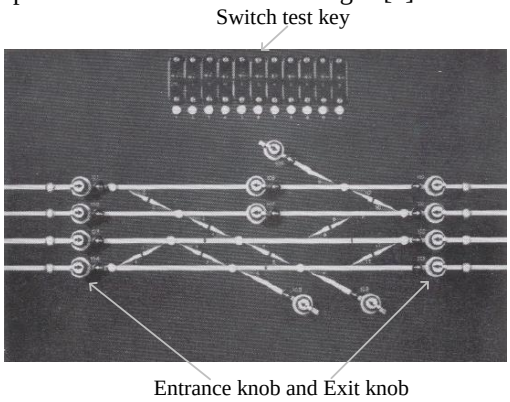

Figure 6. NX system control panel

B. *6502 Electrical Centralized Control*

In 1964, AX type safety signal relays was developed in China. In 1966, the box-type electrical centralized circuit was used in Zhenru station of Shanghai-Nanjing line. Experienced the problems of the 6501 electrical centralized control, the circuits were improved several times based on the box-type electrical centralized circuit. Finally, the modified circuits were named 6502 electrical centralized control. The 6502 electrical centralized control is widely used in China in the stage of relay interlocking system.

The control panel of 6502 system as follow (Fig. 7):

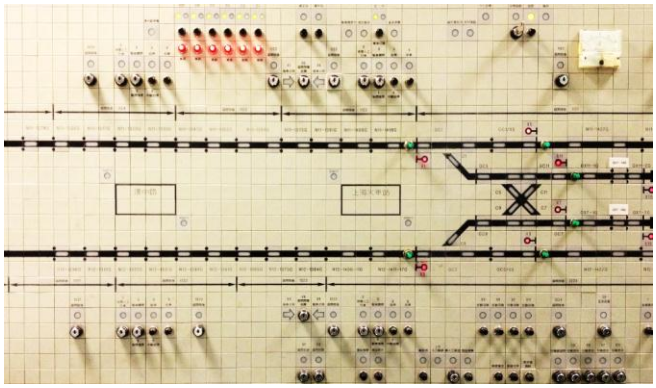

Figure 7. 6502 system control panel

A part of signal check circuit of 6502 system as follow (Fig. 8) [5]. This circuit can check the indication of point, the clearing state of track circuit and the conflicting route.

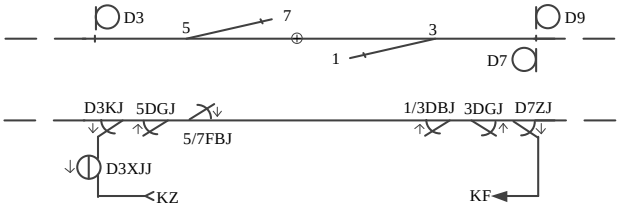

Figure 8. 6502 signal check circuit

V. TODAY'S INTERLOCKING SYSTEM - COMPUTER-BASED INTERLOCKING SYSTEM

With the development of computer technology, electronic technology and network technology, the heavy relay and complicated relay circuit is gradually replaced by electronic devices. Computer interlocking which based on the software and hardware went into historical stage.

Compared with the disadvantages of relay interlocking system: large in size, high investment, high failure rate, difficult in fault diagnosis and low automation efficiency, computer-based interlocking system has the following advantages: high safety, high reliability, high integration, high efficiency, simple maintenance and so on.

In 1978, the first computer-based interlocking system was put in service at Gothenburg station in Sweden by ABB Company [6].

In 1984, the first computer-based interlocking system of China was put in service at Meishan iron mine in Nanjing. It fills in the blank of China and opens a new chapter of research and application of computer-based interlocking.

On November 19 of 1991, Vital Processor Interlocking (VPI) which redeveloped by CASCO Company based on GRS's VPI product was put in service at Honghai station of Guangzhou-Shenzhen line. This is the first computer-based interlocking system on the main railway line in China.

In 2015, all-electronic computer interlocking system named iLOCK-E which independently developed by CASCO Company was put in service at Thanaleng station in LAOS. It is the first all-electronic computer interlocking system exported from China.

The control panel of computer-based interlocking system is realized by industrial control computer and display. Operator used the mouse to set route in stand of push the button in relay interlocking stage. The software programs achieved the operation of interlocking logic relationship. In different stages of computer-based interlocking, the way of control outdoor devices is also different.

A. *Relay-based Computer Interlocking System*

The relay-based computer interlocking system which retains part of the circuit of relay interlocking system is the most widely used type at present. After the operation of interlocking logic, interlocking process device drive the relay and the relay circuit drive the outdoor devices. It is the transition stage from relay interlocking stage to all-electronic interlocking stage. Under the background of relevant technology was not mature, developed from relay interlocking to all-electronic computer interlocking was not

conducive to the popularization and application of computer-based interlocking. The relay-based computer interlocking system has laid a solid foundation for the development of computer interlocking.

The system structure is shown below (Fig. 9):

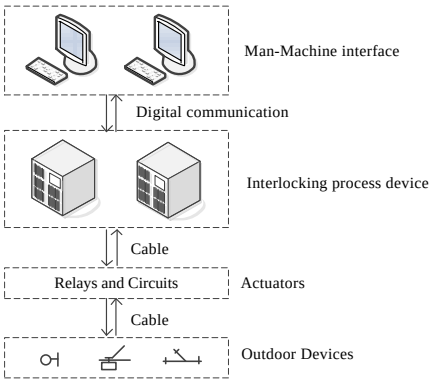

Figure 9. System structure of relay-based computer interlocking system

B. *All-electronic Computer Interlocking System*

The differences between all-electronic computer interlocking and relay-based computer interlocking are as follows:

(1) The actuator of the al-electronic computer interlocking system is the electronic unit or board which replaces the relay circuit built by the relay and cable in relay-based computer interlocking system. It uses cable directly controls outdoor equipment without any relay.

(2) Indoor device and outdoor device are separated by relays in relay-based computer interlocking system. The controlled plant is relay and system only needs to care about the on-off status of relay. But the controlled plants of all-electronic computer interlocking system are switch, signal, track circuit and so on. The system directly controls or collects the status of outdoor device and needs to care about more information of outdoor device.

The system structure is shown below (Fig. 10):

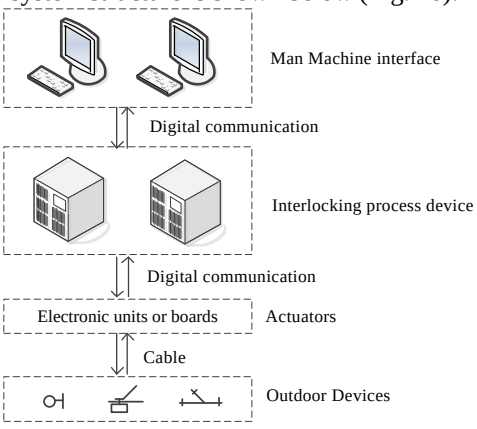

Figure 10. System structure of all-electronic computer interlocking system

The actuators of all-electronic computer interlocking system can be placed in different places: at the same place with interlocking process device, wayside or on another station.

All-electronic computer interlocking system has become the latest development direction because of high maintenance, less equipment occupation area, shorter construction period, lower project cost, and intelligent fault diagnosis and treatment, etc.

C. *All-digital Computer Interlocking System*

Both interlocking systems described above adopt cables to connect indoor and outdoor device and transfer the strong current from the indoor power supply panel to outdoor equipment by controlling the weak current. All-digital computer interlocking will be the next development stage and a revolution of computer interlocking. It is a new computer interlocking which based on wireless communication, intelligent outdoor equipment and without any cable connection with indoor and outdoor equipment. Outdoor equipment only needs the power supplied by the distributed power terminal and communicates with the interlocking process device by secure communication protocol. At the same time, interlocking process device will be more miniaturization and intellectualization.

The control process of the station based on all-digital computer interlocking system can be described as follows: After the operation by operator on intelligent man machine interface device, the information will be sent to intelligent interlocking process device by wireless communication. Then the operation result of intelligent interlocking process device will be sent to intelligent outdoor equipment which also can transmit the information to interlocking process device.

The system structure is shown below (Fig. 11):

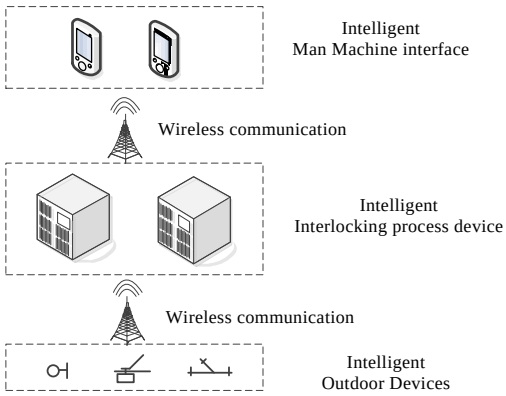

Figure 11. System structure of all-digital computer interlocking system

Now, the digital communication between interlocking system and axle counter system has been realized. Germany railway and Siemens are already started working on All-digital computer interlocking system [7].

VI. The Future of Interlocking System

A. From Centralized Control to Distributed Control

In the age of mechanical interlocking, centralized control of equipment was a choice to save manpower and material resources.

The actuators in the all-electronic computer interlocking system can be dispersed to different stations or wayside. All-digital interlocking system doesn't have actuators. In other words, the intelligent devices located in wayside are the actuators. The distribution of actuators is the first step. The second step is the distribution of interlocking process device and the man machine interface device.

B. Digitization and Intellectualization of Outdoor Device

With the development of technology, outdoor equipment will experience digitization and intellectualization. It is not only a collection of cables and mechanical components, but also intelligent equipment based on microprocessor, wireless communication module, data processing module and so on.

C. Integration of System or Function

From the independent interlocking systems to system integration, such as the integration of interlocking systems and train control systems [8]. Interlocking system will integrate some functions of other systems, such as all electronic interlocking already includes some functions of the computer monitoring system. Some functions of the interlocking system are integrated by other systems, such as operation terminals merged with CTC/TDCS system, no longer set up a separate operation terminal.

D. Intelligent Interlocking System

Artificial intelligence technology has begun to enter the railway industry in recent years, but its application in interlocking systems is still very small. The fundamental reason is that the interlocking system has high requirements for safety and reliability, and each operation result requires 100% certainty. The related algorithms of machine learning or deep learning in artificial intelligence are algorithms based on probability statistics and cannot achieve 100% accuracy. But this does not mean that the interlocking system is completely out of touch with artificial intelligence. Some functions that do not require high safety, such as interlocking system fault diagnosis, can apply data mining related algorithms. In recent years, the application of artificial intelligence technology has been brought to railway industry [9] and it also gradually applied to interlocking system [10]. The application is not only in fault diagnosis, but also in some aspects of interlocking systems.

Whatever the future of interlocking systems, the security requirements will be more stringent with the development of interlocking system.

VII. Conclusions

The history of interlocking system is also the history of railway signaling. After 200 years of development, the railway interlocking system has developed to the stage of computer-based interlocking. Based on the development of the interlocking system, this article looks forward to the future development of the interlocking system. Intelligentization, digitalization, networking and integration will be the future development direction of interlocking systems. At the same time, the development of interlocking systems will also drive the development of other systems and outdoor equipment.

Compared with other fields, the development of railway interlocking system is slightly slower, and even some technologies are still behind. However, the interlocking system will surely move towards one milestone after another with the development of science and technology.

Acknowledgment

Thanks to the providers of precious photos.

References

[1] Yoshinori Kon. The Current Status of Signal Control Systems,and Research and Development. JR EAST Technical Review-No.3

[2] Signals at Greenford. http://www.roscalen.com/signals/Greenford/index.htm. 2010.8.

[3] Alstom Signaling Incorporated. A Centennial: History of Alstom Signaling Inc. West Henrietta, New York: Alstom. 2011.12.

[4] General Railway Signal Company. The NX System of Electric Interlocking. Rochester, New York. OCLC 184909207

[5] He WenQing.6502 electrical centralized circuit [M] . Beijing:China Railway Press, 2007.

[6] Zhao Zhixi.Computer interlocking system technology [M].Beijing:China Railway Press, 1999

[7] TieXin. German railway digital interlocking technology and its development[J]. Modern Urban Transit, 2018(10):76-77.

[8] Lishixiang,Lupeiling,Tangshijun. Research on System Design of Train control systen and interlocking system integration[J]. Railway signlling & communication, 2016(3):1-3.

[9] Yanlianbao,Liping,Xue rui,etc. Intelligent Classification of Faults of Railway Signal Equipment Based on Imbalanced Text Data Mining [J].Journal of the China railway Society, 2018(2):59-66.

[10] Huang Lujiang. The Application of Data Mining in Fault Location of Computer Interlocking System in Railway Signling[C]. *2020 IEEE 5th International Conference on Cloud Computing and Big Data Analytics (ICCCBDA)*, Chengdu, China, 2020, pp. 331-335.