An interlocking system against human errors with a scalable, low cost, space saving architecture

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Abstract

Safety has the highest priority in railway track maintenance work. A new electronic interlocking system has been developed to strengthen maintenance work safety. It prevents human errors in interlocking logic definitions and the safety check sequence at the work place. Furthermore, the amount of the hardware of the developed system can be flexibly fit to any scale of stations with a low life-cycle cost and small installation space. A distributed architecture with one CPU device, several interface unit devices, and fibre-optic LAN provides the flexible scaling of the system. A new control data definition dodge eliminates the aged field interlocking structure of wired logic circuits of electromagnetic relays to lower cost and space requirements.

1 Backgrounds

East Japan Railway Company is promoting the development of next generation electronic interlocking devices. This section describes the motives behind the development.

There are two motives: prevention of human errors regarding the interlocking system; and the reduction of the cost for safety-related electronic equipment.

1.1 Human error in the wayside maintenance work

With conventional safety confirmation procedures for wayside maintenance
work, it is difficult to escape from human errors because all checks on the working plan table, approaching trains, and stop signals depend on human actions. Such procedures should be automated. But, also made absolutely fail-safe. During usual train service, an interlocking device detects the train and indicates a stop signal. The next generation electronic interlocking should be fail-safe devices to automate safety confirmation procedures for wayside maintenance work.

1.2 Human error in the interlocking logic setup

In existing electronic interlocking devices, the description of the control algorithm uses electromagnetic relay logic. Therefore, it is difficult to avoid the following types of human errors. One type is the design errors of interlocking data because description of the interlocking data is complex. A second type is wiring errors of the wired logic at the railway station field. Therefore, for the next generation electronic interlocking devices, visual interlocking data descriptions based on each case of track control should be applicable, and wired logic of the field should be eliminated.

1.3 Reduction of the life-cycle cost

Considering today's competitive situation in the mass transportation business, life cycle cost is a critical subject for all signaling systems. The most important factors for this are initial product cost and the maintenance cost. But another relevant factor is a stable supply of parts. The supply of hardware parts should be stable through the long life cycle of the electronic interlocking devices. So, it is desirable to apply general-purpose digital electronic parts for them.

2 Devices already released

2.1 Type 1 device

Safety has the highest priority in track maintenance work. So, just after the automatic safety check sequence for the work was established, the type 1 electronic interlocking device was released for practical use. Figure 1 shows an interlocking system architecture utilizing the type 1 electronic interlocking device. The type 1 device is installed between a PRC (programmable route controller) and an existing electronic interlocking device so as to keep alterations of the present field signal apparatus to a minimum. Cooperative interlocking control is done with the same type of interlocking device at an adjoining station to protect track maintenance work from incursion of a train into the work zone. Figure 2 shows the safety identification procedure used to begin track maintenance work using the system in figure 1.

A new definition dodge for control data that is easy to understand even for a non-experienced personnel is applicable to the type 1 device. (This article does not treat the definition dodge.)
Station route controller with interlocking logic

Type 1 interlocking device

CPU unit (Triplex system)

Existing interlocking device

Interlocking device

Wired logic of relays

Field signal apparatus

Safety check for maintenance work

Relay logic equivalent process

Figure 1: Interlocking system with type 1 device.

Reference and registration

Track maintenance work plan database

Application and permission

Cooperative interlocking action

Station route controller

Adjacent station route controller

Portable wireless terminal

Track maintenance worker in the field

Figure 2: Safety check sequence of the track maintenance work.
Furthermore, a general industrial process control computer and a real-time operating system are packaged as a CPU to execute the interlocking algorithm. Application of the latest computer technology to signal devices is made by this. The safety of the type 1 device is secured by the loosely coupled triplex system architecture and fail-safe 2-out-of-3 majority logic circuit.

The type 1 device does not satisfy all the concepts given in section 1, but it is suitable for expanding the automated maintenance working support system on lines which have a conventional interlocking system. This device has been used from 1993 on main commuter lines in the Tokyo metropolitan area, and it has contributed greatly to safety. Space to add a new device to the existing interlocking stations is necessary to apply the type 1 device. But, there are some stations on these main commuter lines which do not have enough space.

2.2 Type 2 device

The type 2 device was developed for small stations. Figure 3 shows the architecture of an interlocking system using the type 2 electronic interlocking device. This device is installed in place of a conventional interlocking device. The peripheral input-output interface is used to control the signal apparatus of the field directly, and cooperative interlocking control with a type 1 or type 2 interlocking device is done at an adjoining station.

Types 1 and 2 devices have the following features in common: a safety related function for track maintenance work; a new definition dodge for control data; use of a general industrial process control computers; a loosely coupled triplex system architecture; and fail-safe 2-out-of-3 majority logic circuit. But, because the number of controlled objects is small, throughput as a computer system for the type 2 device is smaller than the type 1 device.

This device has been used since 1998 on main commuter lines in the Tokyo metropolitan area.

Figure 3: Interlocking system with type 2 device.
3 Subjects

The maintenance work support system can be expanded rapidly by using electronic interlocking devices of the two developed types. But, the following subjects still remain.

(1) Wired logic circuit in the field
For both types 1 and 2 devices, human errors due to continued use of wiring are still possible.

(2) Irregularity of the equipment update cycle
Equipment updates tend to become irregular because conventional interlocking devices are contained in the interlocking system that type 1 device is used for. So, there is a possibility that equipment maintenance cost could increase. One way around this is to develop a new device that has drastically higher throughput than that of the type 2 device. But, the architecture of the type 2 device has one more problem.

(3) Lack of scalability
The type 2 electronic interlocking device unifies a peripheral input-output interface unit with the CPU unit to adapt it to a narrow signal house. Therefore, for station larger than middle scale where the number of field signal apparatus is more than several, the architecture of the type 2 can not be applied in a suitable size device rack.

Figure 4: Developed system with type 3 device.
4 Development of type 3 device

The authors developed the type 3 interlocking device to deal with the above subjects.

4.1 Hardware architecture

Figure 4 shows the architecture of the new interlocking system using type 3 device. A peripheral input-output interface is assigned to a suitable number of interface unit devices corresponding to the scale of a railway station. The interface unit devices are distributed along the wayside, and the CPU device and interface unit devices are connected together with a fibre-optic LAN (local area network). Freedom of the installation of the interlocking system is increased dramatically by this architecture. Any scale of interlocking system can be built with the same hardware and software.

The problems of irregularity of the equipment update cycle and the lack of scalability pointed out in section 3 were solved by this. It can be expected that the costs for design, production, installation and maintenance will be decreased. Furthermore, the control response becomes more rapid compared with the type 1 device system because the interlocking logic processing stage is halved.

4.2 Structure of the devices

4.2.1 CPU device

Like for type 1, the CPU device is composed of a general-purpose process control computer in the loosely coupled triplex system, and safety is secured with the fail-safe 2-out-of-3 majority logic circuit.

4.2.2 Interface unit device

The interface unit device is newly developed. As mentioned later, this device controls each control line of the signal apparatus directly and individually. So, a fault of this device brings about a dangerous condition. Therefore, this device has a hardware structure for fail-safe outputs, i.e. the interface unit device has two electronic circuit boards, the CPU board and the output board.

The CPU board collates each arithmetic result of two CPU chips by a fail-safe collation circuit to detect an arithmetic error of a CPU chip. So to prevent the same arithmetic errors being caused on both CPU chips at just the same timing by electromagnetic noise, an actuation timing difference is given to the CPU chips. As long as the normal arithmetic results of both CPU chips are the same, the output signal of the fail-safe collation circuit keeps an alternative wave form. The CPU board gives the said signal and the time-sequential arithmetic result signals of the two CPU chips to the output board. On the output board, an "alternative AND" circuit keeps alternating its output as long as all the said signals from the CPU board are alternating decisions for fail-safe on or off of the control signals for the signal apparatus.
4.3 Effect of the new data definition dodge

A clear definition dodge of the control data for interlocking logic was developed for type 1 stage which was a visual definition dodge for the control logic of the field signal apparatus. (This article does not refer to the dodge.) But the field signal apparatus control logic became free from the field wired logic that was one typical human error factors of interlocking systems.

With this definition dodge, the size of the interface unit device becomes a minimum because there is no need for the wired logic circuits using electromagnetic relays. The software cost of the interface unit device can be expected to low because it is unnecessary for the unit to judge the contents of the field signal apparatus control logic, so the installed software on every interface unit devices becomes uniform. Thus, the developed interface unit device has space saving and low cost equipment as well.

5 Conclusions

The developed type 3 device has following features.
(1) Scalability by distributed architecture
(2) Lower human error possibility, lower life-cycle cost, and space saving size due to use of a new control data definition dodge

The type 3 device was put into operation in July 2001. It is now being produced for the Chuo Line which is one of the highest frequency commuter lines of East Japan Railway Company.

References