Development and Commercialization of IP-based Railway Interlocking in Korea

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SUMMARY

The project "Development and Commercialization of IP-based Railway Interlocking in Korea" is part of RSRA(Railway Signal Research Association)'s research into the application of IP-based railway interlocking system engineering for railway in Korean signalling system.

In cooperation with Korea Rail Network Authority as infrastructure manager, RSRA is participating in the IP-based railway interlocking in Korea project to develop technical interface standards for signalling equipment. Nowadays, rail infrastructure is faced with more and more diversity when interfacing subsystems, caused by an increasing number of different suppliers in replacement and renewal projects. Especially modifying electronic systems from different suppliers usually coincides with the costs. Standardization is now coming closer by using modern internet-based technology. This makes it possible to use the same solutions for improved monitoring and diagnosis. These innovations can help to achieve the ever increasing safety and efficiency requirements of our busy railway network.

A research and development of ERTMS/ETCS Level 3 in Korea, which is the government-led project followed by KTCS-2(ETCS-2), has now been in its 1st stage since April 2018 and will be continued until December 2020 under the responsibility of Korea Rail Network Authority. IP-based railway interlocking will be used for the standardization of the interface between ETCS-1, 2, 3 and interlocking with slight modification of data packet.

1 INTRODUCTION

Technologies of railway signaling system have been concentrated in high speed and high density train service on the basis of the development of network technology (computer & communication) and signalling control technology. The interlocking system aims to electrically interlock the signalling devices such as light signal, point and track circuit for safe and rapid train operation and shunting in a station. Also build database using computer software, handling a train route by mutually interlocking the logic to prevent false or illegal operations in handling signal equipment. And more basically, it should fulfill a safe operation of trains to avoid derailment or collision of trains.

In this study, the interlocking system that controls a route in diverse train operation environments in Korea has been developed into a distributed IP (Internet Protocol)-based network system from a conventional relay-based centralized interlocking system. Also, safety and reliability have been verified through an on-track test on the integrated railway test track and standardization of the signaling system interface based on the IP-based railway interlocking has been carried forward. After the specification of the IP-based railway interlocking including the interface standard specification is standardized based on KRS (Korean Railway Standards), it will be applied for conventional, high speed and urban railways including KTCS-1, 2 and 3 (ETCS-1, 2 and 3) approximately from 2022 for commercialization.

2 IP-BASED RAILWAY INTERLOCKING

2.1 Overview

Usually, the interlocking system in Korea performs its original function of controlling a train route in a station but also assumes a safe train operation in connection with various and complex external train control system. In case of conventional railway, for example, it interfaces with various kinds of equipment such as CTC (Central Traffic Control), RBC (Radio Block Center), LEU (Line side Electric Unit), TLDS (Track circuit Level Detection System) and etc. However, in case of urban railway, the interlocking system is operated in association with ATS

(Automatic Train Supervision), ATO, CBTC and so on, which are different systems from conventional railway. In addition, the signalling system of high speed railway that largely consists of interlocking (IXL) and automatic train control system (ATC) heavily relies on foreign technologies and the technology transfer has not been made so far.

In this circumstance where interface with complex and multiple external systems has been performed and standards & rules for interface are not consistent among suppliers, the electronic interlocking has been more focusing on interface with external systems than on a safe route control, which is its original function. Accordingly, this study aims to improve safety of a train operation by constructing electronic interlocking system in a distributed way and standardize the interface specification based on the IP-based railway interlocking system and develop a flexible form of system.

2.1.1 Applied Standards

- KRS(Korean Railway Standards) SG 0015-17(R) Electronic Interlocking
- EULYNX Baseline 3

2.1.2 Current Status and Analysis

In Europe, railroad operators have been working on the project for development of IP-based electronic interlocking and standardization and commercialization of interface on the basis of Euro Interlocking (1999 to 2008), INESS (Integrated European Signalling System (2008 to March 2012) and up to EULYNX Project (since 2014). Baseline 3 specifications have been issued in December 2018 and more documents will be released in 2019.

The capacity of an existing interlocking system in Korea is dependent upon the configuration of a station. The capacity for maximum operation can be configured with 128 signals, 128 points and 256 track circuits and it is constructed in a centralized way to electrically separate the relay used for the interface between electronic interlocking devices and local devices in order to directly control each local devices. In case of the existing system, it performs local interface using the relay for a train control in a way to interface one relay for one information and display and control local operations by receiving each information with an input card to monitor operations and local facilities. To exchange information between electronic interlocking and local devices, multiple signalling cables are connected as individual parallel information between interlocking rack and relay rack. And then in the relay rack, operating information of each local device is connected via a physical circuit and transmitted to a local device as electrical signals (AC, DC) to run the local device. For electronic interlocking, an input/output card and a relay rack for control are connected internally using a cable less than 20 m and each local device is controlled by placing a control cable less than 2 km to connect and control the internal control relay and local devices.

2.2 IP-based Railway Interlocking

The IP-based railway interlocking has been implemented in a distributed way that uses a local control device (IP control unit) for interface with a trackside signalling devices, instead of a relay. The local IP control unit controls local devices such as light signal, point by directly connecting with the network using a redundant optical communication. It is also designed to control multiple stations at a distant interval by extending the interlocking control distance up to 40 km. All the systems are configured in a redundancy to increase availability and each system control is comprised of CPU certified with SIL 4. Besides, the Network Management System (NMS) is introduced so that an operator can monitor and control the system operation from a remote place using a distant network and a distributed system, which in turn makes it possible to monitor and handle obstacles or abnormal operation during the operation.

2.2.1 System Configuration

Figure 1 shows the configuration diagram of the IP-based railway interlocking system.

- The redundant network, consisting of external ring and internal ring around the electronic interlocking
- Open Network : To interface with CTC, RBC, adjacent interlocking, level crossing devices, etc.
- Closed Network : To interface with I/O module, light signal module, point module, train detection module, etc.

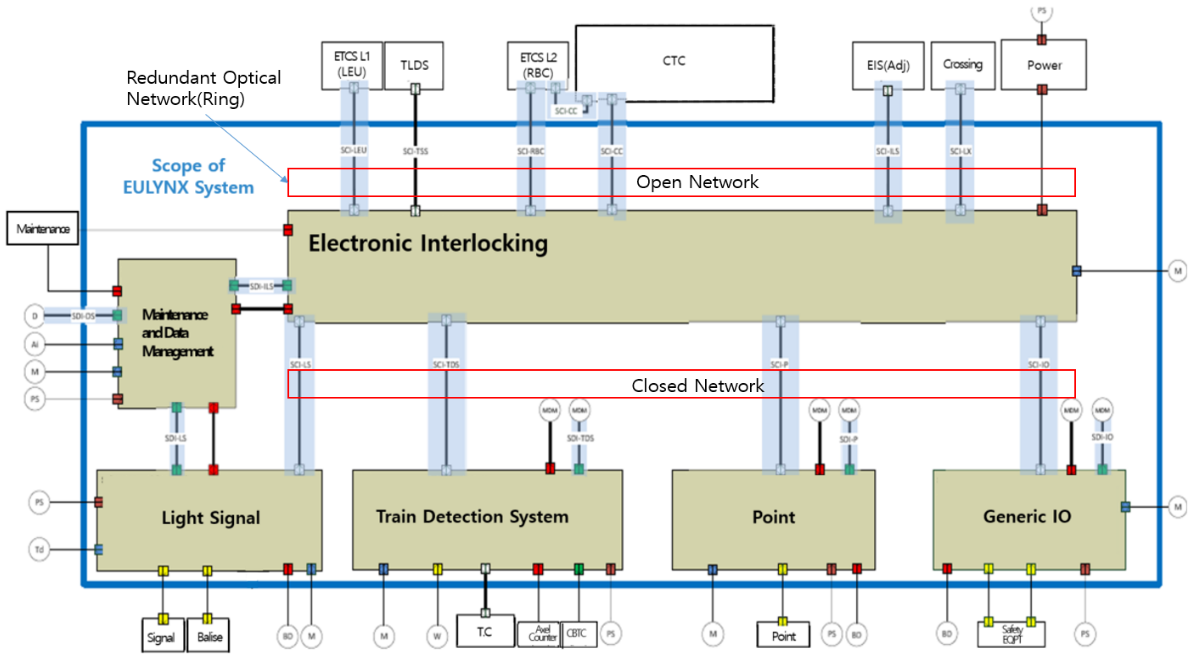
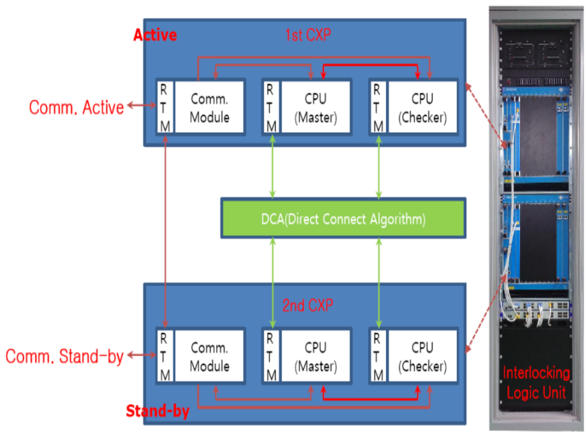


Figure 1: IP-based Railway Interlocking System

2.2.2 Interlocking Logic Unit

The interlocking logic unit mainly performs control and monitoring for local signaling devices through the IP control unit. When the IP-based railway interlocking is developed, the interlocking logic software can maintain functions of a manufacturer-specific interlocking logic software as it is a black-box. The MPU (Main Processing Unit) of the interlocking logic unit is configured in a redundant system with ARTESYN's CXP (H/W) and VxWorks (O/S), which are certified with SIL 4. Figure 2 shows the diagram of the interlocking logic unit and its main specification is specified in Table 1.



Item	Performance & Specification
CPU	64bit (1㎓)
RAM	1GB DDR3-800 SDRAM, ECC
Comm.	GbE(Gigabit Ethernet) comm.
Front display	Active/Standby lamp, Communication (Health) lamp, Power lamp
Power	DC 12V
Others	RS 232 for maintenance, Ethernet port

Figure 2: Redundant Interlocking Logic Unit *Table 1: Major Specifications*

The safety and reliability of the interlocking logic unit can be acknowledged by applying SIL 4 certified product and in this way the reliability of data can be guaranteed.

2.2.3 IP Control Unit (Object Controller)

The IP control unit (object controller) which controls various trackside signalling equipment (e.g. point, light signal, track circuit, safety facilities, etc.) at trackside cubicle or from a signalling room can control and monitor one or more signalling devices (objects) using one IP address. The IP control unit using COTS (Commercial Off The Shelf) consists of point, light signal, track circuit and generic I/O and was designed to have interoperability only by exchanging an Internet cable. In this study, IP control units for point and light signal, which are main parts of the IP control unit, are described.

- IP Control Unit for Point

The IP control unit for point integrates an output relay, current detection and feedback for output into one card and is intended to control two points in a redundant system. In addition, it is possible to identify all processing statuses through feedback for each output, connect with existing systems using a standard VME bus, and use an individual watch dog for input and output respectively, which consequently makes a fail-safe operation possible if there is no input/output for a certain period of time.

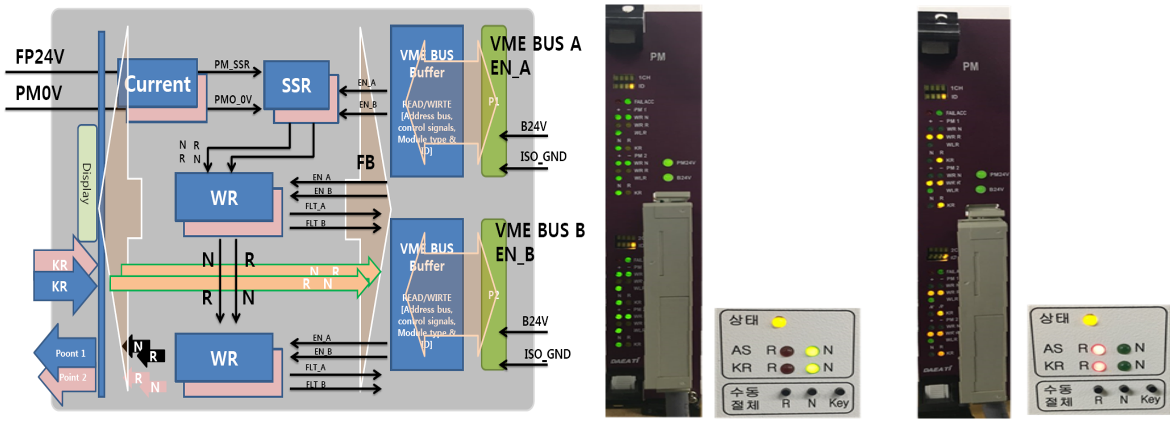


Figure 3: IP control unit for Point

- IP Control Unit for Light Signal

The IP control unit for light signal is intended to control five aspect signals and has several functions including signal control, overcurrent detection and watch dog in redundancy. It is possible to monitor modules and identify processing statuses through feedback signals for each output when the control is done inside modules of light signal through information received from CPU modules. This IP control unit also controls light signal and provides status information from CPU modules using VME bus. Besides, it is intended to provide status information to maintenance staff and users using LED placed on the front of the signal module in order to provide information on a current status of a module and signal controlling status to the outside.

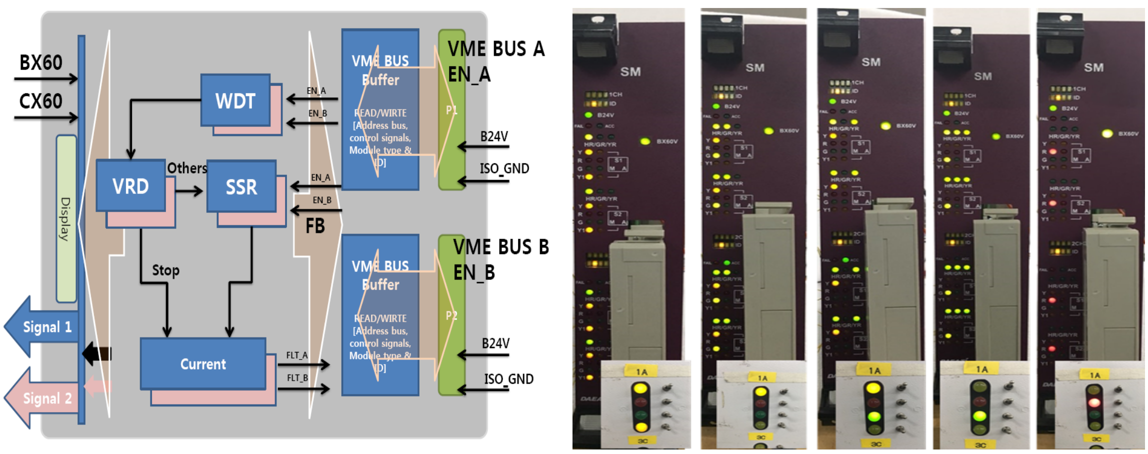


Figure 4: IP control unit for Light Signal

2.2.4 Standard Interfaces

Interlocking system exchanges information with main facilities such as CTC, RBC, adjacent interlocking, trackside equipment (point, light signal, TVPS, etc) and maintenance equipment. In developing the IP-based railway interlocking, various operating rules, pecuniary interests and different interface methods among manufacturers will be integrated into one standard specification based on a standardized interface specification for railway signalling system. A standard interface specification is divided into three categories, i.e., SCI, SDI and SMI. SCI, SDI and SMI are based on TCP-IP layered structure. The following figure describes a communication layer in comparison with OSI 7 Layer.

- SCI (Standard Communication Interface)
- SDI (Standard Diagnostic Interface)
- SMI (Standard Maintenance Interface)

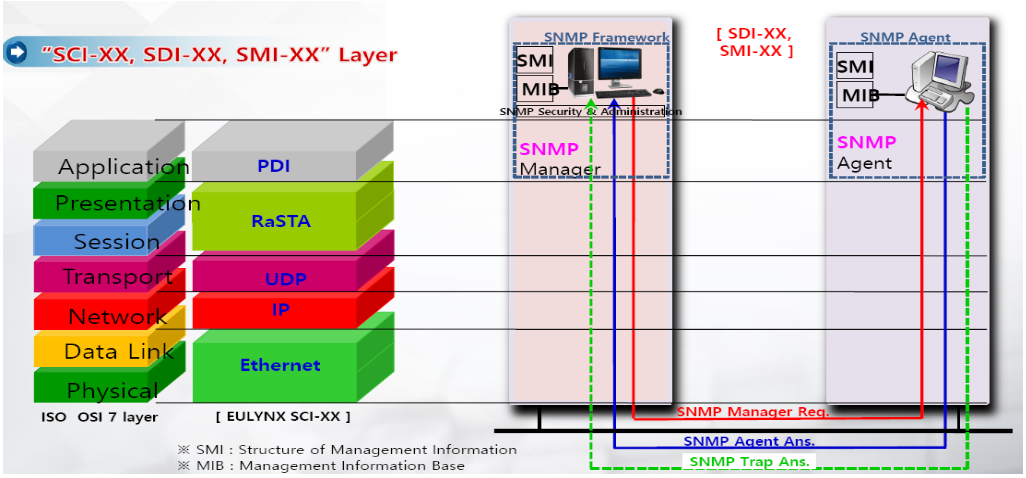


Figure 5: SCI/SDI/SMI Communication Layer

In the standardized interface specification, a communication protocol and a modelling language, which are used for SCI, SDI and SMI interfaces, were presented. RaSTA (Rail Safe Transport Application) that has been used in the European railway was also applied to increase the safety of communications.

Protocol	Used for
UDP (User Datagram Protocol)	System Architecture
	IT-Security
	SCI-P
	SCI-LS
	SCI-IO
	SCI-TDS
	SCI-RBC
	SCI-ILS
	SCI-LEU
	SCI-CC
	SCI-LX
	SMI
	SDI
OPC-UA (OLE for Process Control -Unified Architecture)	SDI

Protocol	Used for
RaSTA (Rail Safe Transport Application)	System Architecture
	SCI-P
	SCI-LS
	SCI-IO
	SCI-TDS
	SCI-RBC
	SCI-ILS
	SCI-LEU
	SCI-CC
	SCI-LX
NTP (Network Time Protocol)	SMI
TFTP (Trivial File Transfer Protocol)	System Architecture
	SMI
SNMP (Simple Network Management Protocol)	SDI

Modelling Language / Protocol	Used for
SysML (OMG Systems Modeling Language) - Ver 1.4 OMG : Object Management Group **UML** (OMG Unified Modeling Language) - Ver 2.5	Light Signal
	일반 IO
	Point
	TDS
	ILS
	MDM
	SCI-P
	SCI-LS
	SCI-IO
	SCI-TDS
	SCI-RBC
	SCI-ILS
	SCI-LEU
	SCI-CC
	SCI-LX
HTTPS (Hypertext Transfer Protocol over Secure Sockets Layer)	SMI
	SDI

Figure 6: Communication Protocol & Modelling Language

The telegram structure has been unified for each interface of SCI, SDI and SMI. The following figure shows an example of a standard message structure related to SCI-XX.

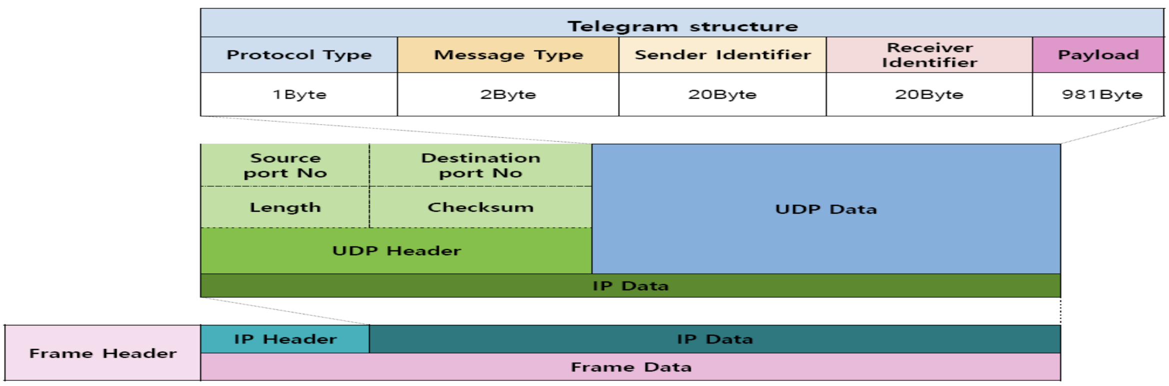


Figure 7: SCI-XX Telegram Structure

A standard telegram for interface of each signalling device is defined for each device. SCI-P telegrams for the interface of point control information are descried in the following tables.

Byte-Nr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00	Protocol Type: 0x40 (1 Byte binary)							
01..02	Message Type: 0x000B (2 Bytes binary)							
03..22	Sender Identifier (20 Bytes ASCII)							
23..42	Receiver Identifier (20 Byte ASCII)							
43	Point Position (1 Byte binary)							

Table 2: Telegram for Command "Move Point"

Byte-Nr.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00	Protocol Type: 0x40 (1 Byte binary)							
01..02	Message Type: 0x0001 (2 Bytes binary)							
03..22	Sender Identifier (20 Bytes ASCII)							
23..42	Receiver Identifier (20 Byte ASCII)							
43	Point Position (1 Byte binary)							

Table 3: Telegram for Message "Point Position"

3 INTEROPERABILITY TEST AND ON-TRACK TEST

3.1 Interoperability Test

To secure interoperability of the IP control unit, the interoperability test has been performed with products from three manufacturers, after the condition for a testing environment has been arranged in a lab. Also, to secure interoperability, communication is done with a simulation server using the IP-based data link module (iDLM). The server controlled in a way to be connected with each IP control unit of three manufacturers. The operating test for the IP control unit of light signal and point that was performed in a lab was successfully finished.

Figure 8: Diagram & Pictures _ Interoperability Test

Through the lab test for the IP control unit for signal and point to secure interoperability, a normal operation status has been confirmed.

3.2 On-Track Test & Verification

This study has been performed for the purpose of verifying functions and safety of the IP-based railway interlocking through the on-track test and commercializing this system in both domestic and foreign markets. The on-track test has been implemented so far on the integrated railway test track in O-song, which was opened in 2019. The on-track test is scheduled from January to December 2019 and a regular inspection will be performed 10 times for 12 months.

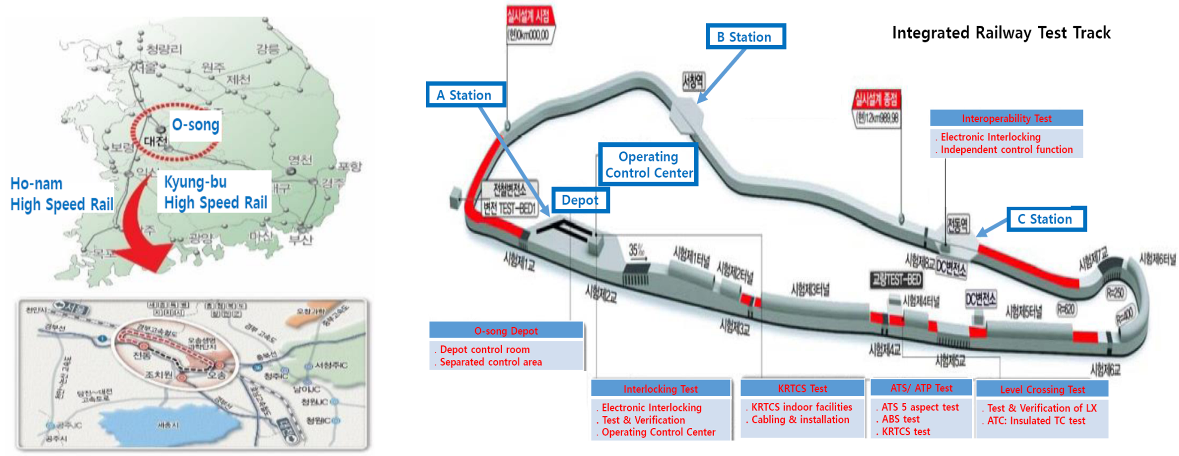


Figure 9: Integrated Railway Test Track (O-song)

The network under test was installed according to its functions both in the interlocking station and the non-interlocking station and the test was implemented following a test procedure.

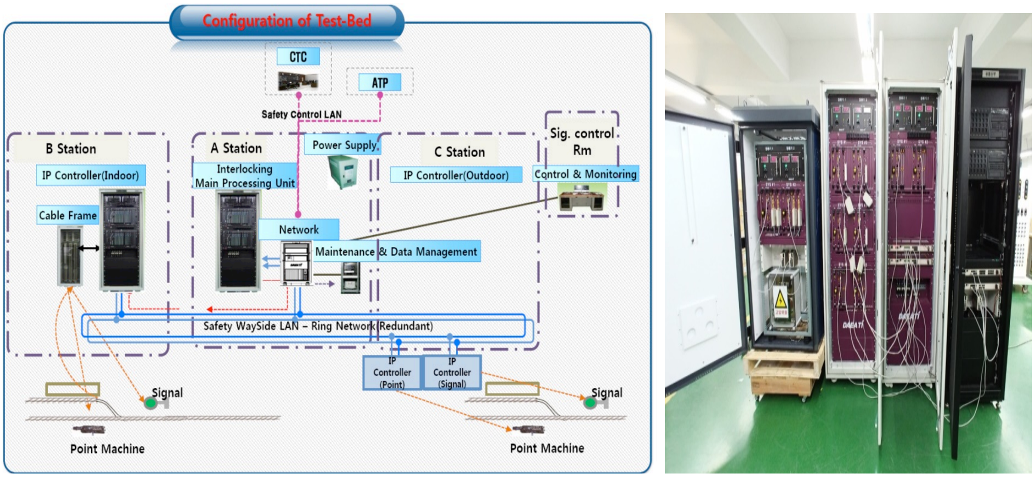


Figure 10: Network Configuration of Interlocking and Non-Interlocking Stations

3.3 Test Results

As described above, the test for the IP-based railway interlocking has been performed in a way that a functional test for closed/open network interface, a functional test for distributed control and a performance test for logging data of maintenance unit and network equipment have regularly been checked. In the early stage of the regular inspection, complementary actions were necessary due to poor communication of network, faulty contact, etc. but later it came to function normally.

Target	Location	Functions under Test & Verification	Test Result
Interlocking Logic Unit	Interlocking Station	. Interface test (Open network) . Distributed control of interlocking logic unit	Normal
Maintenance & Data Management Unit	Interlocking Station	. Integrated management of maintenance information . Data logging/NMS function	Normal
IP Control Unit	Non-Interlocking Station	. Interface test (Closed network) . Interoperability test for IP control units	Normal

Table 4: Results of On-Track Test

4 CONCLUSION

In the development and commercialization of the IP-based railway interlocking, those keywords such as 'IP-based', 'standardization', 'distributed', and 'interoperability' have important meanings. There are some advantages that can be brought by this study; First, the standardization is possible through the implementation of interface using the IP control unit, without making public a manufacturer's technology; Second, the maintenance cost can be reduced as it uses fewer relays or cables in comparison with existing system; Third, a simple configuration of the communication network can lead to improvement of availability. For example, if manufacturer A becomes bankrupt while the interlocking system supplied by manufacturer A is in operation, system can immediately be replaced with the system of manufacturer B. Finally, if the following purpose can be achieved by development and commercialization of the IP-based railway interlocking, LCC (Life Cycle Cost) can be reduced and the safety can be improved at the same time.

- Commercialization of network-based interlocking system and standardization of interface
- Improvement of maintainability by fulfilling interoperability through COTS
- Verification and safety fulfilment through an on-track test in the context of CENELEC safety requirements.

Also, if the standardization of specifications is achieved, domestic railway operators can benefit from this standardization in terms of cost reduction as follows.

- Can keep the price of interlocking system at an appropriate level due to cost reduction at manufacturers' side
- Can minimize maintenance cost caused by changes in versions of hardware and software
- Can simplify the purchasing process of interlocking system and to reduce the cost paid by railway operators

5 ACKNOWLEDGMENT

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