

Development and Commercialization of IP-based Railway Interlocking in Korea

ASPECT2019///

Oct. 23. 2019



Railway Signal Research Association

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I

IP-Based Railway Interlocking

Introduction

The “IP-based Railway Interlocking System Development and Commercialization” project has been developing as a Korean model by applying technology based on Internet Protocol (IP) to the communication method connected to each subsystem in the railway signalling system.

RSRA has been participating in the project for commercialization of IP-based railway interlocking system in collaboration with KNRA, an Infrastructure Manager (IM) of Korea, and also in charge of interface standardization of signalling system based on Internet Protocol (IP).

 **RSRA** : Railway **S**ignal **R**esearch **A**ssociation

 **KNRA** : Korea Rail **N**etwork **A**uthority

2. IP-based Railway Interlocking – Purpose

♣ Purpose of Research and Development

This task aims to 1) **standardize interface between various signalling systems on the basis of the interlocking system** that directly controls trains in different service environments as well as in diverse operating environments of conventional, metropolitan and high speed railways, 2) **verify its safety and reliability in a way that develops it into an IP-based networked system** 3) finally put it into an actual service.

♣ Development Model of IP-based Interlocking, Abroad Technologies and Industrial Trends

In Europe, a phased program for standardization and commercialization of interface between signalling systems has been implemented around electronic interlocking system for about 20 years and recently, the development of EULYNX Project, led mainly by railway operators, has been in progress as an open source.

The standard interface specification of the IP-based interlocking system is based on Baseline3, the version released in December 2018.

Project name	Period	Participant	Description	Remark
EURO Interlocking	1999 ~ 2008	UIC	<ul style="list-style-type: none"> ● Collaboratively developed the electronic interlocking system agreed in Europe when ETCS (Levels 1, 2 and 3) started to be virtually applied ● Reduced Life Cycle Cost, improved performance and optimized suitability with ETCS 	
INESS (Integrated European Signaling System)	2008 ~ 2012.3	Signalling Manufacturer	<ul style="list-style-type: none"> ● Developed a collective and essential specification agreed and verified for the next generation electronic interlocking of Europe ● Aimed to enable a mutual operation by several countries, enhance competitiveness and shorten the certification process 	
EULYNX	2014 ~	Railway operator	<ul style="list-style-type: none"> ● To standardize and commercialize the IP-based signalling system interface focusing on the IP-based railway interlocking system ● To aim at definition of common processes for technical cluster and implementation of win-win strategies for all partners ● Baseline1 documents released in July 2017 ● Baseline2 documents released in December 2017 ● Baseline3 documents released in December 2018 	Ongoing

♣ KRLYNX System : Overview

KRLYNX network configuration is largely consisting of a closed network and an open network, exchanges standardized information of standard communication interface (SCI) and standard diagnostic interface (SDI).

♣ Scope of system

Subsystem Configuration

- Subsystem - Electronic Interlocking
- Subsystem - Light Signal
- Subsystem - Point
- Subsystem - Generic IO
- Subsystem - Train Detection System
- Subsystem - Maintenance and Data Management
- Subsystem - Traffic Control System

▶ System Configuration Diagram

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

- The redundant network is consist 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.

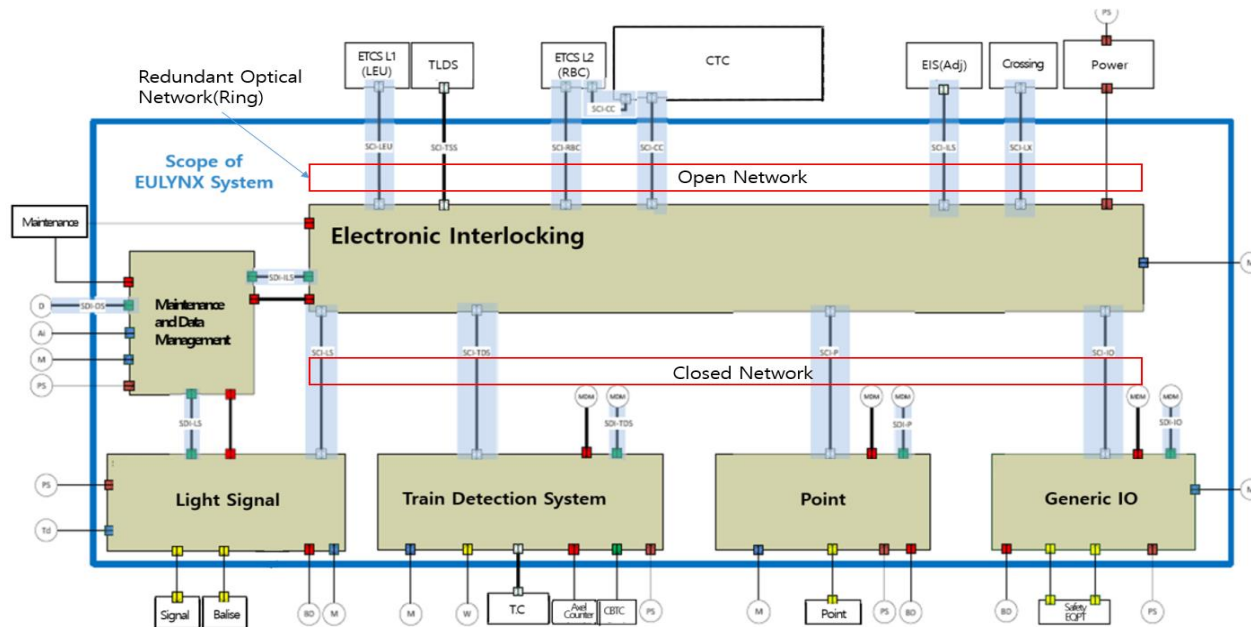


Figure 1: IP-based Railway Interlocking System

▶ IP-based Railway Interlocking Design & Features

1. 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.
2. The local IP control unit controls local devices such as light signal, point by directly connecting with the network using a redundant optical communication.
3. It is also designed to control multiple stations at a distant interval by extending the interlocking control distance up to 40 km.
4. All the systems are configured in a redundancy to increase availability and each system control is comprised of CPU certified with SIL 4.

▶ Interlocking Logic Unit

1. The Interlocking logic unit controls and monitors local signaling devices through the IP control unit.
2. In developing the IP-based railway interlocking system, the functions of existing interlocking logic software, developed by various manufacturers, are to be maintained, as the interlocking logic software is a black box.
3. The MPU (Main Processing Unit) of the interlocking logic unit is configured in a redundant way, using CXP (HW) of ARTESYN with SIL 4 certification and VxWorks (OS).

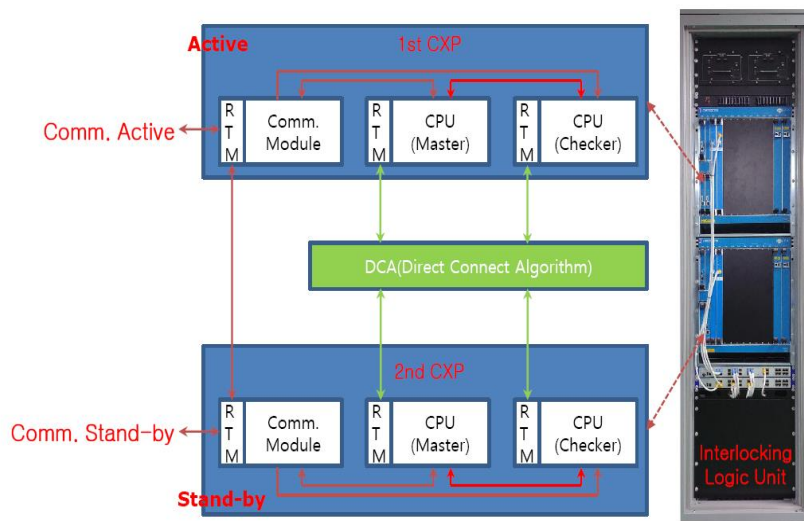


Figure 2: Redundant Interlocking Logic Unit

Item	Performance & Specification
CPU	64bit (1GHz)
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	RS232 for maintenance, Ethernet port

Table 1: Major Specifications

8. IP-based Railway Interlocking – IP Control Unit (Object Controller)

▶ IP Control Unit (Object Controller)

1. The IP control unit (object controller) which controls various trackside signalling equipment (For example. 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.
2. The IP control unit using COTS (Commercial Off The Shelf) consists of point, light signal, track circuit, generic I/O and was designed to have interoperability only by exchanging an Internet cable.
3. 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

1. The IP control unit for point integrates output relay, current detection and feedback for output into one card.
2. It is configured to control two redundant points.
3. It checks all processing statuses with feedback for each output.
4. It is allowed to connect with an existing system using a standard VME bus.
5. The use of a watchdog exclusively for input/output enables a fail-safe operation in case of no input/output for a certain period of time.

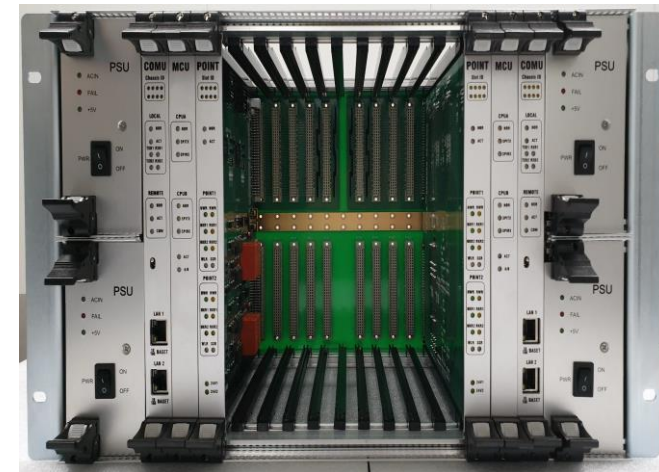
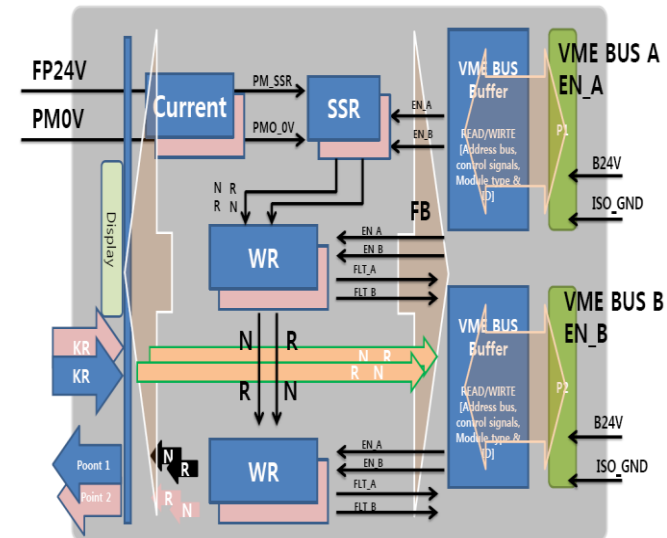


Figure 3: IP control unit for Point

▶ IP Control Unit for Light Signal

1. The functions of light signal control, overcurrent detection and watchdog are configured in a redundant way for fail-safe operations.
2. It is to monitor status of the module and check its processing status for each output using a feedback signal when executing control in the module of light signal using the information received from CPU module.
3. It is to control light signal and provide status information from CPU module using VME bus.
4. It is configured to enable maintenance and provide a user with status information using LED on the front of the module of light signal.

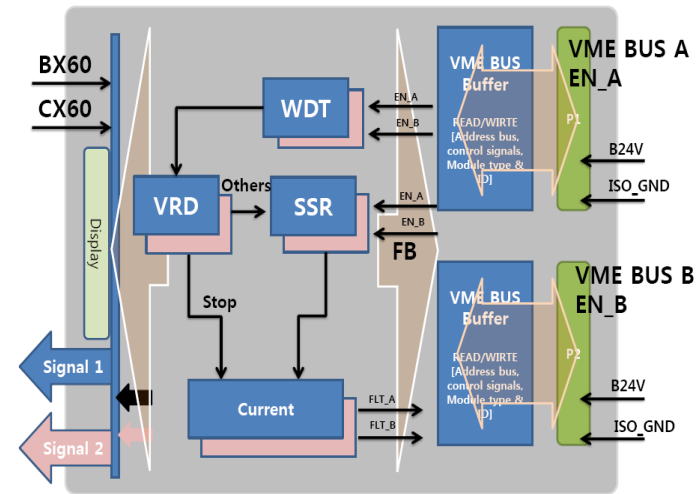


Figure 4: IP control unit for Light Signal

II

Standard Interfaces

Standard Interfaces SCI/SDI/SMI

▶ Interlocking system exchanges information with main facilities such as CTC, RBC, adjacent interlocking, trackside equipment (point, light signal, TVPS, etc) and maintenance equipment.

▶ 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)

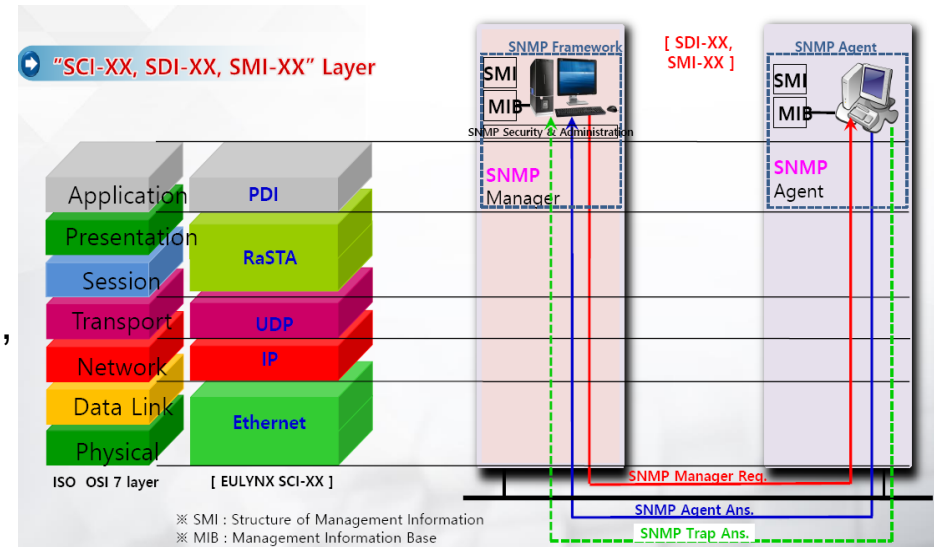


Figure 5: SCI/SDI/SMI Communication Layer

SCI/SDI/SMI Applicable communication protocol according to the interface

▶ 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.

UDP (User Datagram Protocol)	System Architecture	OPC-UA (OLE for Process Control -Unified Architecture)	SDI	SysML (OMG Systems Modeling Language) - Ver 1.4 OMG : Object Management Group UML (OMG Unified Modeling Language) - Ver 2.5 [EN 50128, EN 50129] (SCI-LX제외)	Light Signal
	IT-Security				일반 IO
	SCI-P				Point
	SCI-LS				TDS
	SCI-IO				ILS
	SCI-TDS				MDM
	SCI-RBC				SCI-P
	SCI-LS				SCI-LS
	SCI-LEU				SCI-IO
	SCI-CC				SCI-TDS
SCI-LX		SCI-RBC			
				SCI-LS	
				SCI-LEU	
				SCI-CC	
				SCI-LX	
RaSTA (Rail Safe Transport Application) [EN 50159 : 2010]	System Architecture	SNMP (Simple Network Management Protocol)	SDI		
	SCI-P				
	SCI-LS				
	SCI-IO				
	SCI-TDS				
	SCI-RBC				
	SCI-LS				
	SCI-LEU				
	SCI-CC				
	SCI-LX				
		HTTPS (Hypertext Transfer Protocol over Secure Sockets Layer)	SDI		
			SMI		
		TFTP (Trivial File Transfer Protocol)	System Architecture		
			SMI		
		NTP (Network Time Protocol)	System Architecture		
			SMI		

Figure 6: Communication Protocol & Modelling Language

→ SCI-XX Telegram Structure

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.

1. The maximum telegram length shall be 1023 bytes.
2. A telegram shall consist of the telegram header, followed by the telegram payload.
3. The telegram header shall have a length of 43 bytes (bytes 00 until 42). It shall consist of:
 - Protocol Type (1 byte)
 - Message Type (2 bytes)
 - Sender Identifier (20 bytes)
 - Receiver Identifier (20 bytes)
4. The telegram payload may be empty or consist of a sequence of payload parameters.

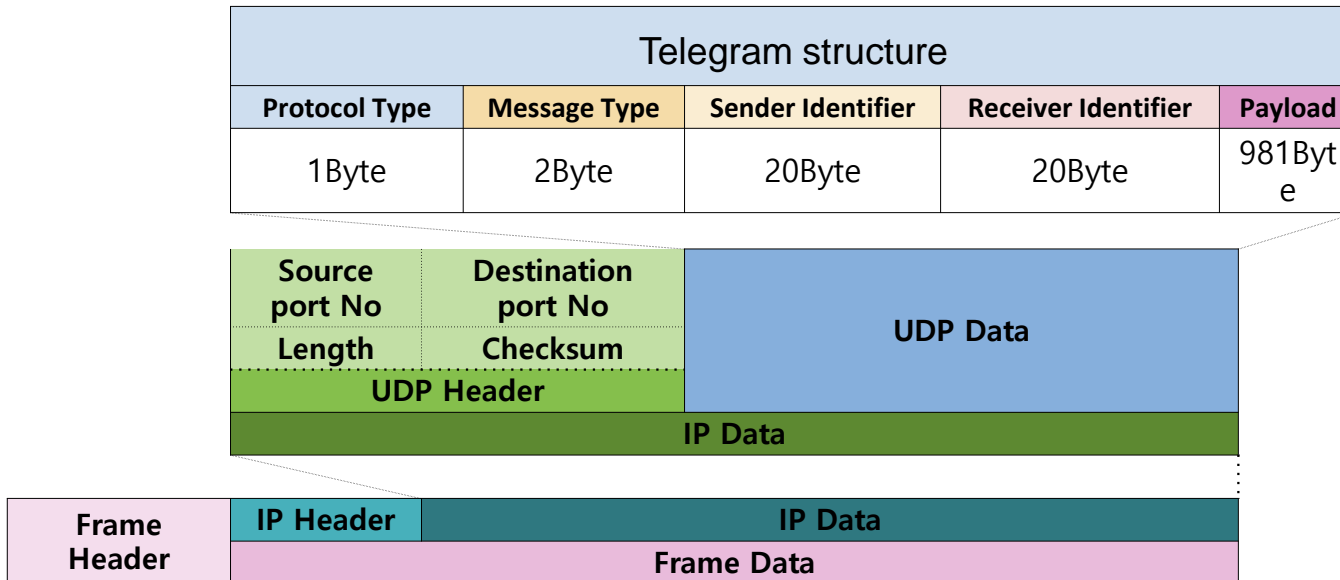


Figure 7: SCI-XX Telegram Structure

► SCI-P Telegrams for the interface of point

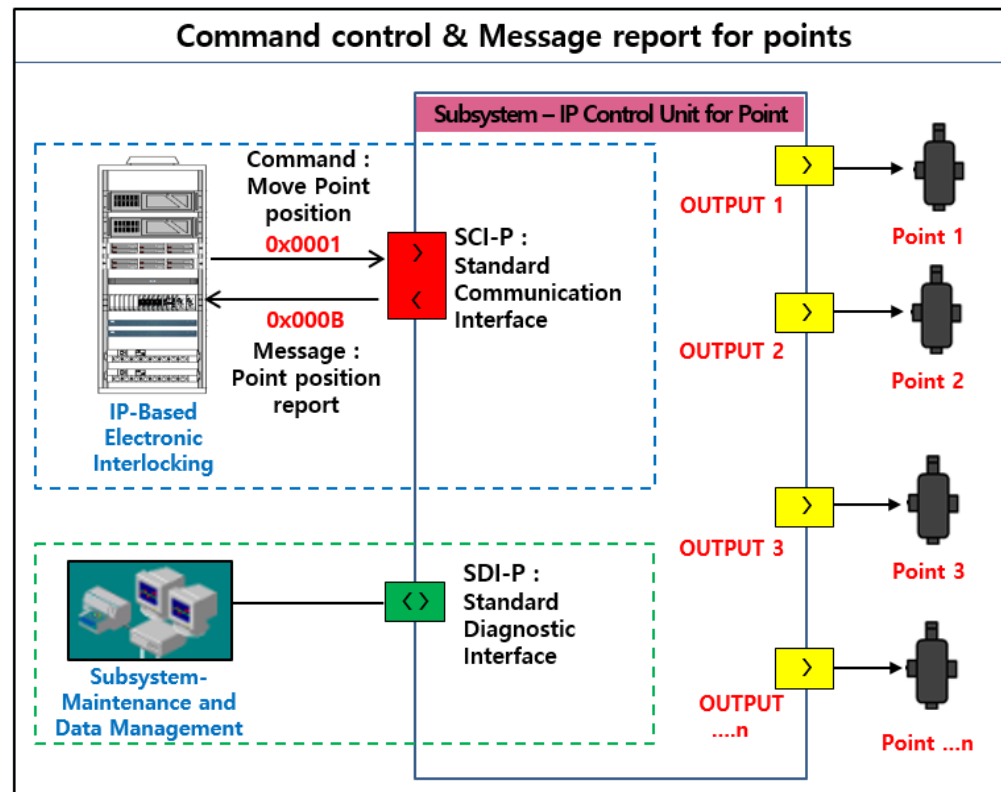
A standard telegram for interface of each signalling device is defined for each device. SCI-P telegrams for the interface of point control information are described in the following tables.

Bite-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 ISO IEC 8859-1:1998)							
23..42	Receiver Identifier (20 Bytes ISO IEC 8859-1:1998)							
43	Commanded Point Position (1 Byte binary)							

Table 2 Telegram for Command “Move Point”

Bite-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 ISO IEC 8859-1:1998)							
23..42	Receiver Identifier (20 Bytes ISO IEC 8859-1:1998)							
43	Reported Point Position (1 Byte binary)							

Table 3 Telegram for Message “Point Position”



III

Interoperability Test and On-site Test

➔ 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. 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.

2. Interoperability Test and On-site Test – Interoperability Test

Interoperability Tests picture



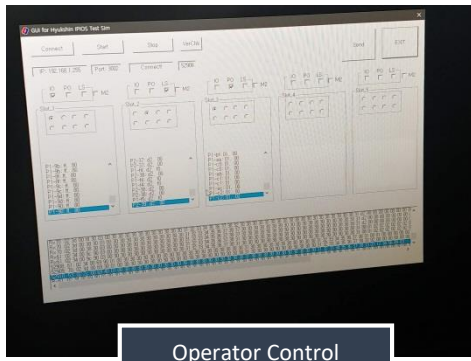
IP-based Interlocking System



Control Command to IP Control Unit (Object Controller)



Control Operation of Wayside Equipment

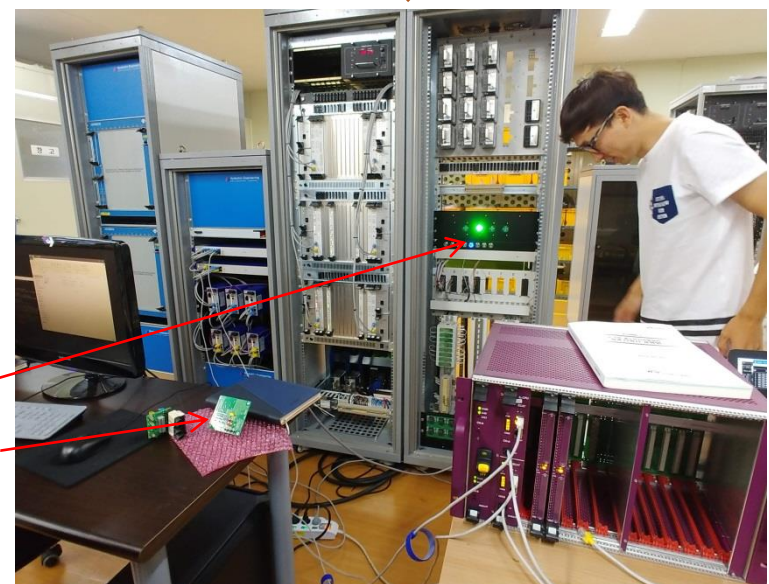


Operator Control Display for HMI



Light Signal Indicator

Point Machine



3. Interoperability Test and On-site Test – Test Location & Verification

➔ On-site Test & Verification

■ This study has been performed for the purpose of verifying functions and safety of the IP-based railway interlocking through the on-site test and commercializing this system in both domestic and foreign markets.

■ The on-site test has been implemented so far on the integrated railway test track in O-song, which was opened in 2019. The on-site test is scheduled from January to December 2019 and a regular inspection will be performed 10 times for 12 months.

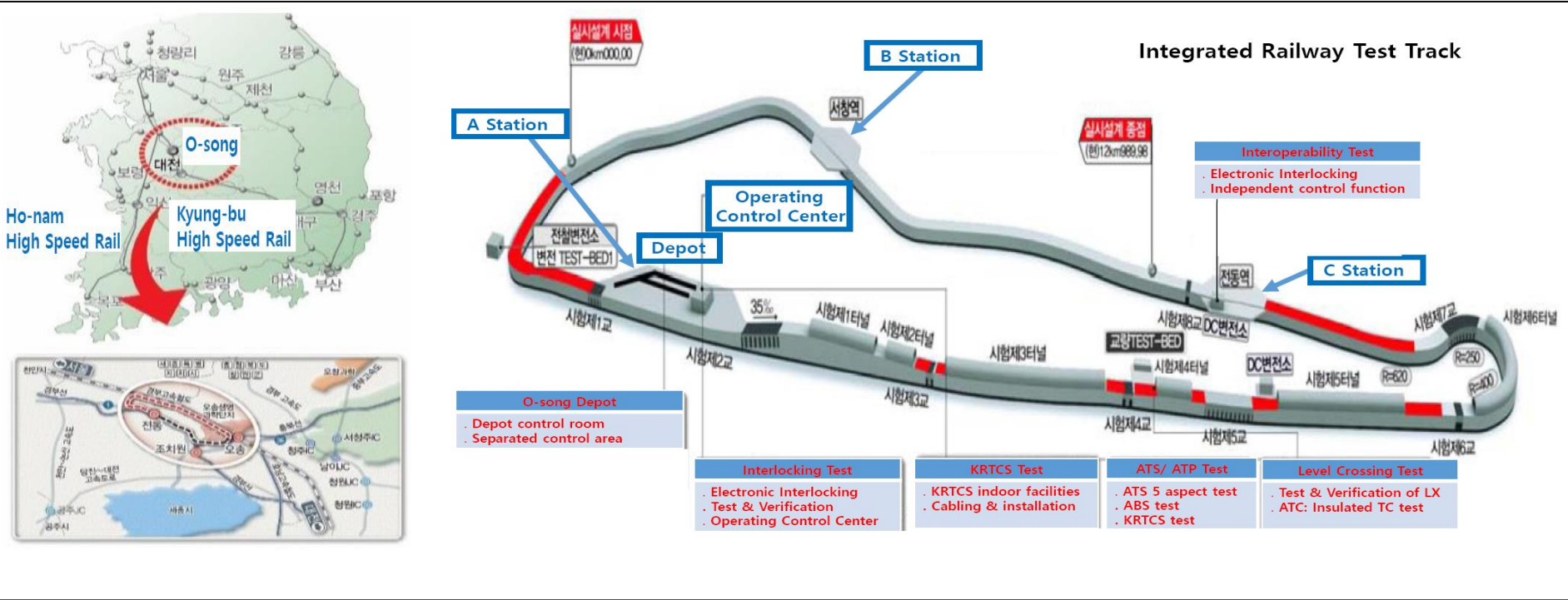


Figure 9: Integrated Railway Test Track (O-song)

4. Interoperability Test and On-site Test – System Configuration

➔ System configuration for On-site tests

■ 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.

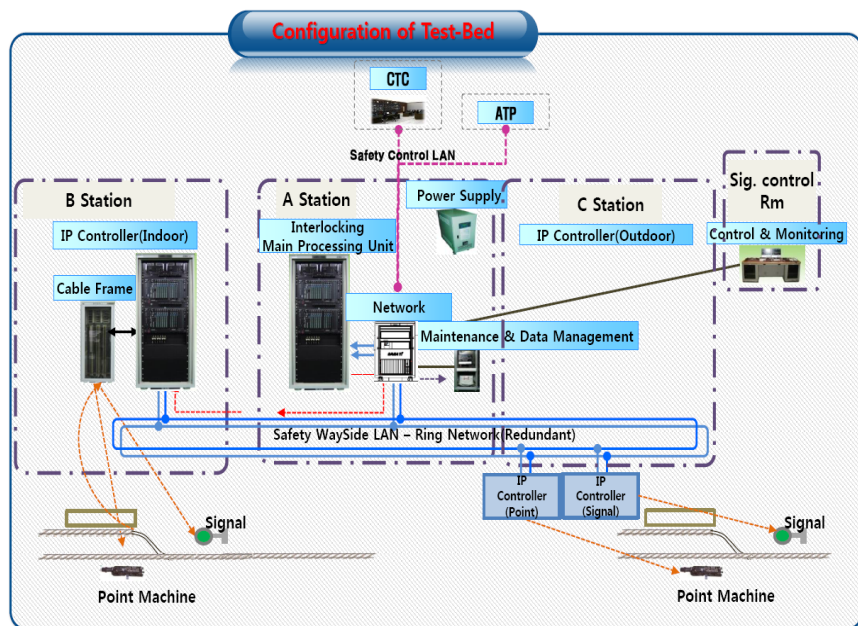


Figure 10: System Configuration of Interlocking and Non-Interlocking Stations

5. Interoperability Test and On-site Test – Test Results

➔ 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	<ul style="list-style-type: none"> . Interface test (Open network) . Distributed control of interlocking logic unit 	Normal
Maintenance & Data Management Unit	Interlocking Station	<ul style="list-style-type: none"> . Integrated management of maintenance information . Data logging/NMS function 	Normal
IP Control Unit	Non-Interlocking Station	<ul style="list-style-type: none"> . Interface test (Closed network) . Interoperability test for IP control units 	Normal

Table 4: Results of On-site Test

IV

Conclusion

Conclusion

♣ Expected Effects of Interface Standardization of IP-based Railway Interlocking System

The railway operators in Korea can benefit from interface standardization as follows:

Firstly, as the interface standardization between subsystems (including the IP control unit) is implemented, manufacturers do not have to make public their own technologies for standardization.

Secondly, the system is configured with generic software (application of interoperability) and thus, if a supplier goes bankrupt or fails to supply the system for some reason while its interlocking system is applied, it can be replaced with another supplier seamlessly and immediately.

- As it enables a supplier to reduce its cost of production, interlocking system can also be supplied at a reasonable price,
- An additional cost due to change in HW or SW can be minimized,
- As the purchasing process of interlocking system is simplified, a railway operator can reduce purchasing costs (it is able to control multiple stations from one station).

Ultimately, interface standardization of the IP-based railway interlocking system enables to reduce Life Cycle Cost (LCC) and improve the safety.

THANKS



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