Remote Terminal Unit (RTU) over Internet Protocol (IP) for Railways

IP, Electric railroad, Network, PMCN

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Abstract

Meidensha Corporation developed the Remote Terminal Unit (RTU) over Internet Protocol (IP) for Railways. With this equipment, supervisory control and data acquisition of devices installed in remote locations can be made by way of IP networks using fiber optic cables or metallic cables.

The system uses the Protocol for Mission Critical industrial Network (PMCN) use developed by the Japan Electrical Manufacturers' Association (JEMA). PMCN enhanced the functions of continuity checks and error detection and correction. This ensures high reliability of the RTU under Internet Protocol.

1. Preface

The Remote Terminal Unit (RTU) for Railways has the time-line shown in Fig. 1. In early times, the RTU provided a supervisory control function at a substation only and was not available from a remote location.

After that the Type B RTU (relay transmission type) was developed. It can transmit ON/OFF signals to a remote location, which enabled supervisory control from a remote location.

Thanks to the progress of electronics development, module units went LSI, compact design with multi-functions and various methods of data transmission were developed. RTU in substation became more systematic by using computer technology. At that time, the transmission line was a metallic cable and the transmission rate was 1.2-19.2kbps.

Recently, the transmission line is moving toward a networked environment and RTU is about to move toward the next generation based on Information Technology. Additionally, a robust communication protocol was developed, and under such circumstance, we came to develop the RTU for a networked environment.

This paper introduces our RTU over IP for Railways.

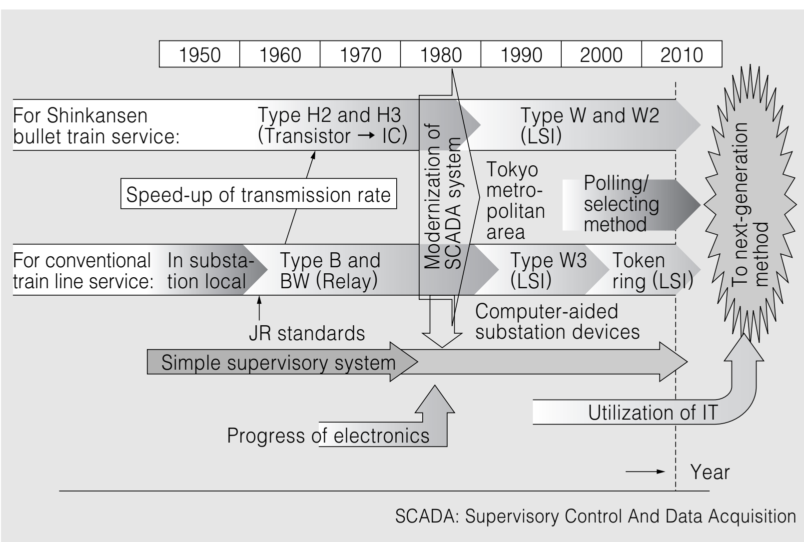

Fig. 1 Time-Line of RTU for Railways
This chart traces the history of RTU for railways.

2. Outline of the Equipment

The RTU consists of three principal units, i.e., Network Connection Unit, Remote Function Unit, and External I/O Unit (see Fig. 2). The RTU supports both fiber optic and metallic cable networks.

2.1 Network Connection Unit

Fig. 3 shows a schematic diagram of a remote control network. The network configuration of both the star and ring topologies can be used. The star topology is a method of configuring a network in a star where remote units are directly connected individually to a central monitoring station. So, the number of lines required is the number of substations. Because of the one-to-one connections, a separate line is required as backup for line fault.

In the case of the ring topology, the number of lines required is one for all substations. In the case of a line fault, the loop-back function will work to reconfigure the ring by returning the signal from each end RTU connected to the fault point. This function will ensure quick recovery and the integrity of data.

Fig. 4 shows a diagram of how the ring configuration changes. Under normal conditions, the farthest RTU in the ring (point A) is automatically detected, and two logical rings are made. If there is a line fault at

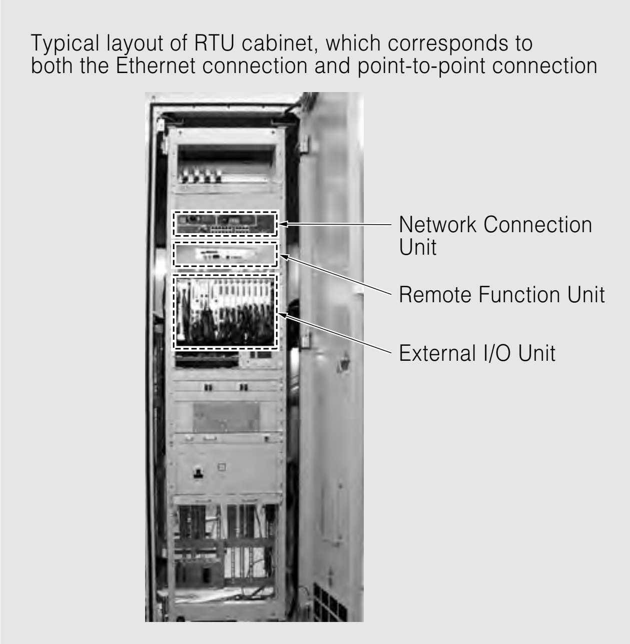

Fig. 2 Typical Layout of RTU over IP for Railways
This unit consists of the Network Connection Unit, Remote Function Unit, and External I/O Unit.

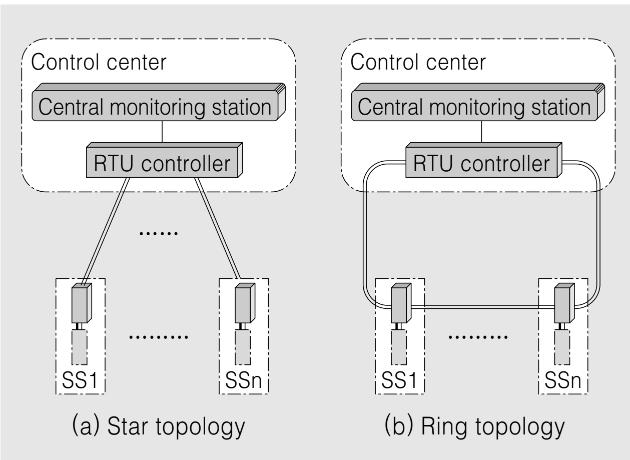

Fig. 3 Remote Control Network
The diagram shows the difference between the (a) Star topology and (b) Ring topology. The Ring topology has the advantage of economy because the number of lines can be reduced.

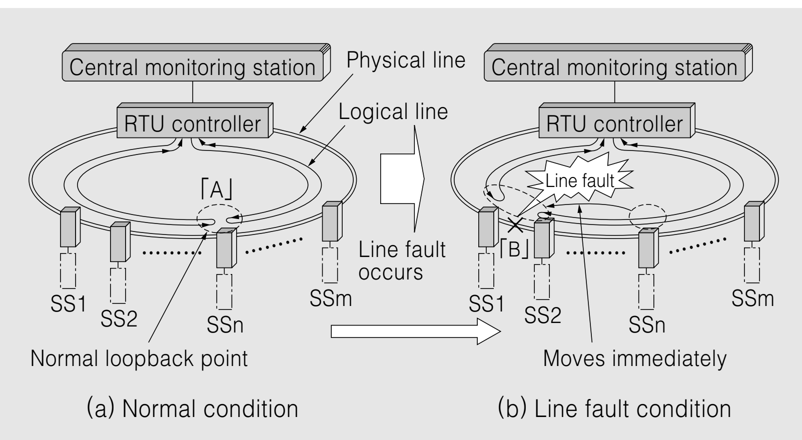

Fig. 4 Loop-Back Function
If a line fault occurs at Section B, the line is immediately reconfigured for continuous operation.

point B, the loop-back point is immediately transferred to reconfigure the logical rings for continuous operation.

2.2 Remote Function Unit

The Remote Function Unit performs the data processing of railway specific data and data communication to the central monitoring station. The Protocol for Mission Critical industrial Network (PMCN) use is adopted for data communication between the central monitoring station and the RTU. It constantly monitors the continuity and integrity of the data.

The Digital Input (DI) function, the Select Before Operate (SBO) function, the Electrical Energy Measurement function, the Health Check function, the Time Synchronization function, etc., are part of the functions.

2.3 External I/O Unit

The external I/O unit is available for both point-to-point connection and Ethernet connections. So, the provisions for an Ethernet connection can be incorporated for the future, even if a point-to-point connection is adopted to meet with the interface of supervised devices.

3. Features

3.1 Cost Reduction of Data Transmission Lines

By using RTU over IP, the number of lines for the RTU can be reduced.

In the case of metallic cable connection, it can be configured with a pair (two cores) of wires and for a transmission rate of 192kbps.

In the case of fiber-optic network, it can be configured with an optical fiber cable and its transmission rate is 1Gbps (1000Mbps) .

Therefore, an additional new cable is not required if a spare wire is available.

3.2 Space-Saving for RTU Controller

Fig. 5 shows the number of RTU controllers in the conventional method and the IP based method. The number of RTU controllers can be reduced when IP based method is used.

In the conventional method, the number of RTUs that can be connected to a single ring is limited to seven (7) due to restrictions on the transmission rate. Because one RTU controller is required for each ring, when 30 substations, for example, are involved, five RTU controllers are required.

In the IP based method, when a fiber-optic network is used, the restriction on the transmission rate is eliminated and the RTUs for all of 30 substations can be connected in a single ring.

Accordingly, only one RTU controller is required for 30 substations. In addition, one RTU controller requires one cabinet, so that it will provide space savings in the installation of the cabinet for the RTU controller.

3.3 Performance Improvement for Conventional Metallic Cable

Fig. 6 shows the differences between transmission rates using the conventional method and the IP based method. Applying the RTU over IP on an existing metallic cable network, the transmission rate can be increased. Communication response between the RTU and the RTU controller is improved, which provides a performance enhancement.

The conventional methods included a method to transmit all data from the respective substations together and a method to transmit data from each substation separately (see Fig. 6 (a)). The transmission rate by such method is 1.2-19.2kbps.

When an IP based method is used, the metallic cable transmission rate improves to 192kbps and the fiber-optic transmission rate is 1Gbps (1000Mbps). Even when the data for the respective substations are transmitted simultaneously, data congestion will not occur and performance of the system will improve (see Fig. 6 (b)).

As shown in Fig. 6, if we put a conventional method into an image it looks like the train moves along collecting people at each station, or, some trains move along a single-track line. But in an IP based method, trains can move multiple tracks in parallel.

3.4 Better Communication Continuity

Fig. 7 shows how the RTU receives power. The most important point, when the RTU is used in a ring, is to avoid a shutdown of the Network Connection Unit of the RTU even during maintenance.

This RTU over IP is designed to have a separate power supply for both its main unit including the Remote Function Unit and the External I/O Unit, and the Network Connection Unit. Switch A will supply power for the Remote Function Unit and the External I/O Unit and Switch B will supply power for the Network Connection Unit.

Accordingly, even when Switch B

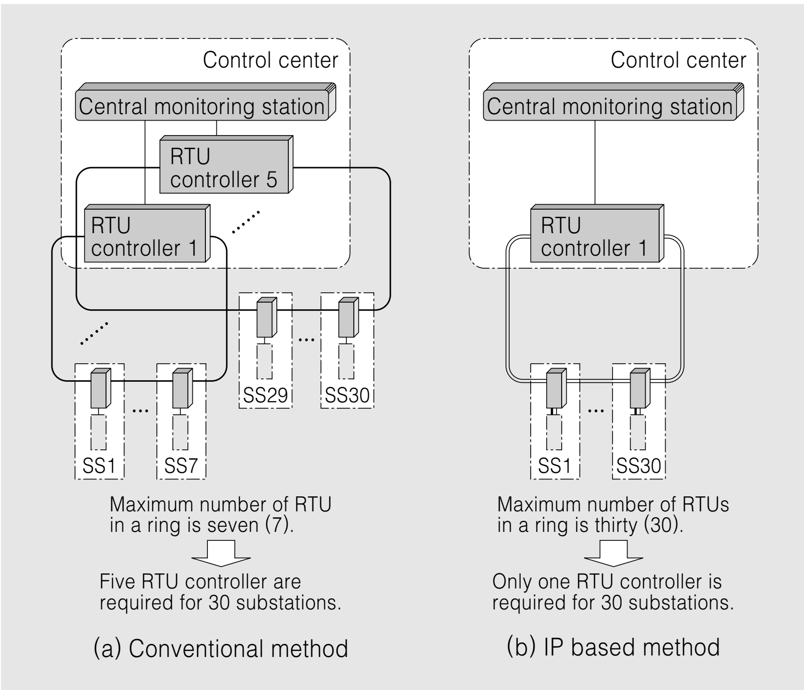

Fig. 5 Difference of Number of RTU Controllers
In the case where 30 substations are in the system, five RTU controllers are required in the conventional method but only one in the IP based method.

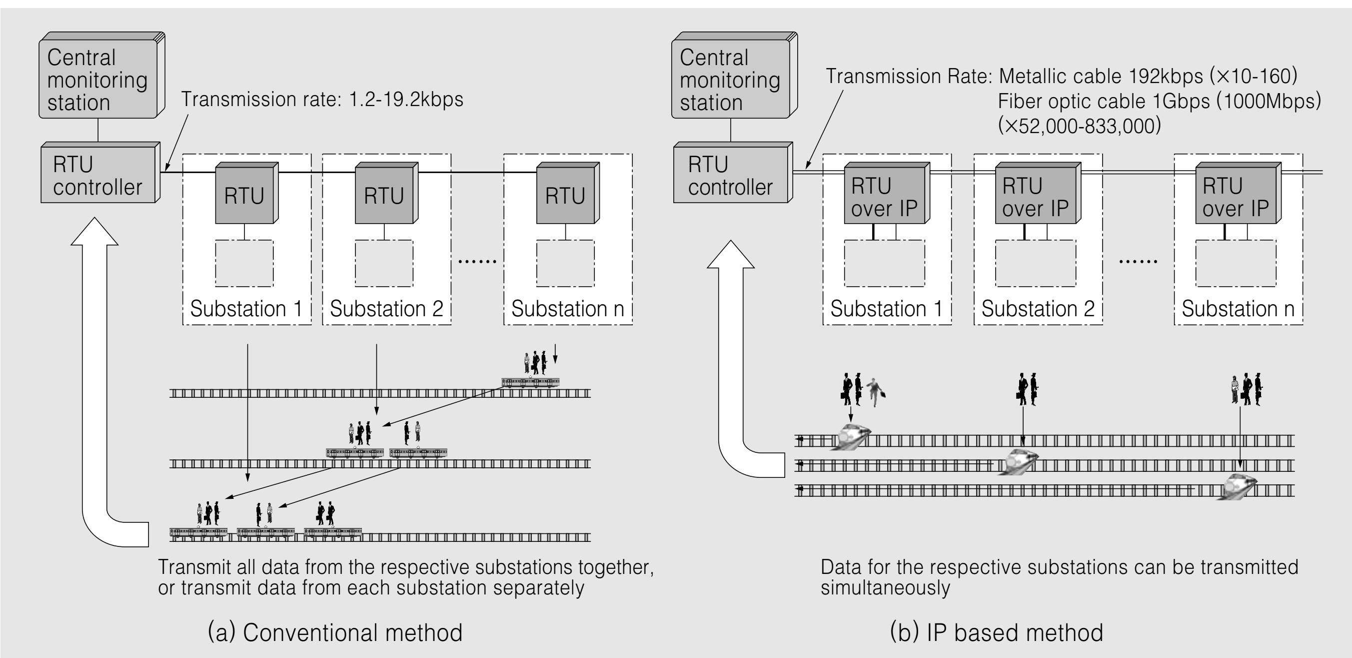

Fig. 6 Difference of Transmission Rate
In the conventional method, a train moves along collecting people at each station, or some trains move along a single-track line. But in an IP based method, trains can move along multiple tracks in parallel.

turns off for maintenance for example, the Network Connection Unit can get power via Switch B and the ring configuration will not be interrupted.

Furthermore, the power supply used for the Network Connection Unit is dual power supply by both AC and DC.

3.5 Use of Robust Transmission Protocol

Fig. 8 shows the communication format of the RTU over IP for Railways. PMCN developed by JEMA is used as the communication protocol. The PMCN enhances the functions of continuity checks and error detection and correction. This ensures high reliability of the RTU, under Internet Protocol.

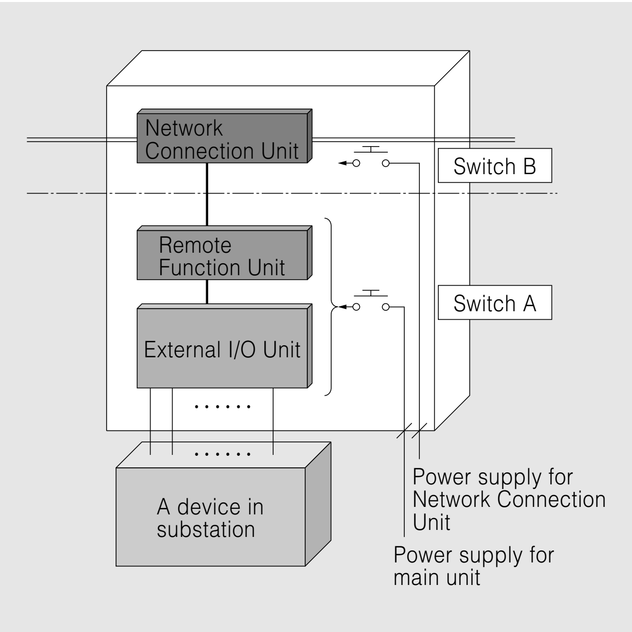

Fig. 7 Power Supply of the RTU over IP for Railways
It is designed so that the power supply for the Network Connection Unit will continue receiving power, even when the power supply for the main unit is turned off, to keep the ring network normal.

4. Specifications

4.1 Hardware Specifications

As shown in Table 1, the power supply for the RTU main unit in particular is compatible with DC80 to DC143V. The power supply for the Network Connection

Table 1 Hardware Specifications
Hardware specifications of the RTU over IP for Railways are as shown below.

Hardware specifications		Description
Environmental specifications	Place of installation	Indoors
	Ambient temperature	−5℃ to +40℃
	Ambient humidity	30% to 90% (RH)
	Atmosphere	Comparable to those in electrical rooms in general
	Device cooling method	Natural air cooled
	Grounding method	SG non-grounded
	Elevation	1000m or less
Power supply specifications	Supplied power	DC80 to DC143V
	For transmission line	DC80 to DC143V, AC100V
	Rush current	Not exceeding five times the power supply rating
	Power supply interruption	No malfunctioning and error indications in the case of a 10ms interruption
Withstanding voltage specifications	Insulation resistance	5MΩ or more (DC500V megger testing)
	Withstanding voltage	AC2000V (50Hz) for 1 minute
	Lightning impulse resistance	4.5kV (Lightning impulse)

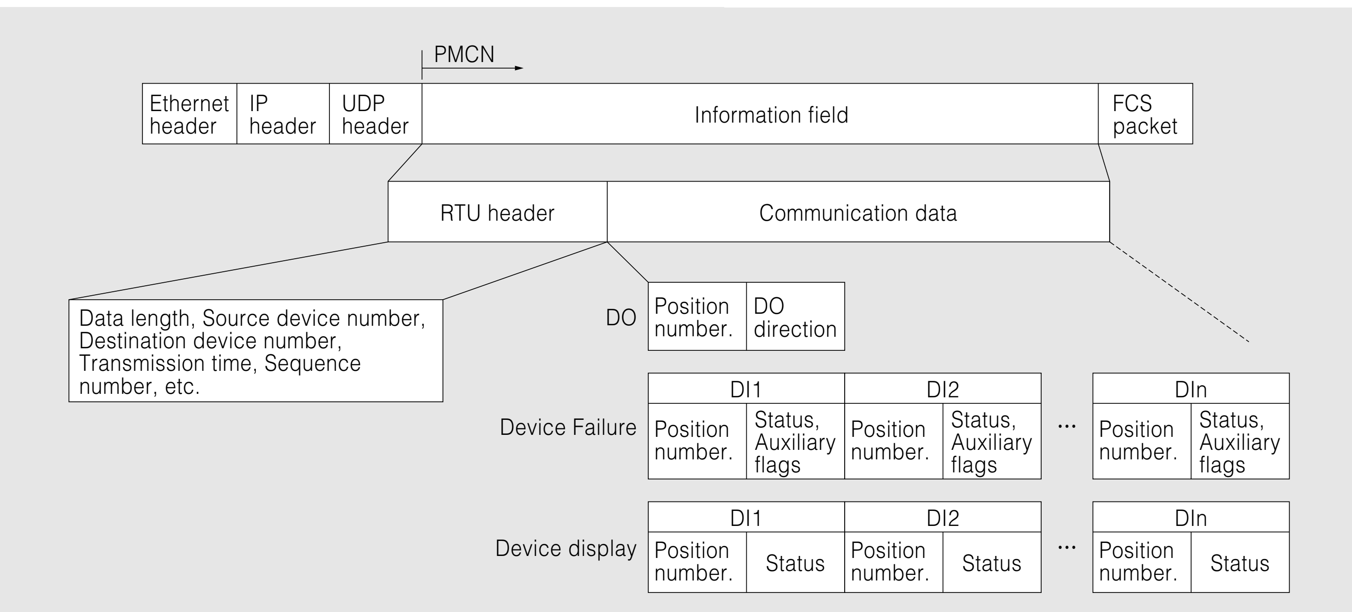

Fig. 8 Transmission Format of the RTU over IP for Railways
This shows the outline of the transmission format of the RTU over IP for railways using the PMCN protocol developed by JEMA.

Table 2 Communication Specifications

Communication specifications of the RTU over IP for Railways are as shown below.

(1) Communication network specifications

Item	Metallic cable network	Fiber optic network
Line classification	Private network	Private network
Communication line	City Pair Polyethylene PVC (CPEV) 0.9mmϕ, 1P	Single-mode optical fiber cable (1.31/1.55μm)
Transmission distance between devices※1	Up to 20km	Up to 40km
Maximum number of RTUs	30 stations (in ring configuration)	30 stations (in ring configuration)
Applicable standards	ITU-T G. 991.2 Annex A compliant	IEEE 802.3x (full duplex)
Transmission method	G.HDSL and G.HDSL bis	STP, RSTP, RTP (Original)

Note: ※1.devices = RTU controller, RTU

(2) Protocol

Item	Specification	Remarks
Application layer	Dedicated monitoring/ control protocol	
Presentation layer	—	
Session layer	PMCN	Developed by JEMA
Transport layer	UDP	
Network layer	IP	
Data link layer	Ethernet	
Physical layer		

Table 3 Performance Specifications

The specifications of the CPU used in the RTU over IP for Railways are as shown below.

Performance/ Functional specifications		Description
Performance	CPU	32bit
	Communication method	IP based method
	Topology	Star / Ring
	Transmission protocol	UDP/IP (PMCN protocol)
	Transmission line rate	Metal cable: 192kbps, Fiber optic cable: 1Gbps (1000Mbps)
	Code verification	CRC
Number of items	DO	192 points (point-to-point connection)
	DI	1575 points (point-to-point connection)
	AI	10 points Electrical energy data: Number of lines

Table 4 Functional Specifications

Outline of the software specifications used in the RTU over IP for Railways is as shown below.

Function name	Outline
IP communication	Handles the communication between the RTU controller and RTU with PMCN protocol.
DI	Detects DI when the input signal maintains 10ms or more.
SOC	Stores SOC information taken for a certain period of time and transmits it to the RTU controller. If another SOC occurs while in the period of time, transmits it in the same packet.
Current status	Transmits the current status when receiving a request from a RTU controller.
SBO	Outputs "Select" signal followed by "Control" signal to a connected external device when receiving a DO signal from a RTU controller.
DO management	Checks the DO signal data received from the RTU and responds in the event an error is detected. Number of items for SOC monitoring by DO is maximum 100.
Electric energy measurement	Stores up to 12 hours when the RTU controller stops and transmit the data when receiving a request after restoration of the RTU controller.
Health check	Returns a response to the RTU control unit on demand.
Time synchronization	Synchronizes the time of the RTU with the time of the RTU controller.
Sequence management	Returns the appropriate data to the RTU controller on demand. Requests the all current status of DIs to the Current Status function when receiving the SBO command from the RTU controller and makes the matching status with the one in the RTU controller.
System manager	Monitors the RTU itself condition in a regular cycle. In the event of an abnormal condition where the unit cannot continue, automatically self-resets.

Unit is compatible with DC80 to DC143V and with AC100V as a DC/AC dual power supply system.

4.2 Communication Specifications

Table 2 shows the communication specifications. The PMCN developed by JEMA is used as the communication protocol for stable operation in an IP based communication environment. The distance between substations for which the RTU can communicate is 20km for a metallic cable network and 40km for a fiber optic network.

4.3 Performance Specifications

Table 3 shows the performance specifications. A 32-bit CPU is used with a transmission rate of 192kbps on a metallic cable network and 1Gbps (1000Mbps) on a fiber optic network.

4.4 Functional Specifications

Table 4 shows the functional specifications. The RTU has functions like Digital Input (DI) function, State Of Change (SOC) function, Current Status function, Select Before Operate (SBO) function, Digital Output (DO) management function, Electrical Energy Measurement function, Health Check function, Time Synchronization function, DO Sequence Management function, System Manager function, etc.

4.5 External I/O Specifications

Table 5 shows the External I/O specifications. In the point-to-point connection method, a DO signal isolated by a relay is output with DC100V. A DI signal isolated by a photo coupler is input with DC100V.

In an IP based method, the transmission rate is 10/100Mbps.

Table 5 External I/O Specifications

External I/O functions of the RTU over IP for Railways are as shown below.

(1) Point-to-point connection

Item	DO	DO/Device failure
Contact type	Wet contact	Wet contact
Isolation method	Relay	Photo-coupler
Voltage	DC100V	DC100V
Load current	Up to 250mA	Up to 20mA
Pulse width	100ms to 300ms	50ms or more

(2) Ethernet connection

Item	Specification
Transmission rate	10/100Mbps
Application layer	Dedicated program
Transport layer	TCP
Network layer	IP
Data link layer	Ethernet
Physical layer	

5. Postscript

Networking of data transmission lines is rapidly in progress, and RTU must keep up with the progress of network technologies.

The RTU over IP for Railways explained here responds to such changes by using a robust protocol developed by JEMA, which offers safe, reliable communication from the functions of continuity checks and error detection and correction.

The network technology world will continue to progress. We would like to develop safe, reliable products using the latest network technologies.

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