Electric Power Management System Contributing to Safe and Stable Railway Transportation

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ABSTRACT

The electric power management system centrally manages the power system to feed power from railway substations and sectioning posts to trains and railroad stations. In addition to stable, continuous power supply, it is required to deliver the functions to improve the efficiency of the operation and maintenance of the power system including railway substations. Fuji Electric offers the electric power management system that meets these needs to enhance functionality such as failure recovery, improve screen visibility, and streamline the system configuration, contributing to safe and stable railway transportation.

1. Introduction

Railways are a highly public mode of transportation, and delays and cancellations of trains have a significant social impact. Accordingly, railway substations and sectioning posts play an important role in the continuous supply of stable power. In addition, the need for efficient power system operation and maintenance of substations has recently been increasing. Electric power management systems are very important systems that assume these roles.

This paper describes a power management system that contributes to safe and stable railway transportation and is capable of enhanced functionality to improve the operational stability of the system and the efficiency of recovery processes at substations.

2. Overview and Issues of Power Management Systems

For electric railways, substations generally receive electric power from electric power companies, perform step-down and rectification, and feed the power to trains and stations. The power system configuration for supplying power to electrical train lines is composed of local control centers, such as substations and sectioning posts set up along railway lines, which section the power supply in the event of an accident or during maintenance work. Therefore, the Ministerial Ordinance to Provide the Technical Standard on Railways (Article 49 Paragraph 4) states: "Monitored substations (meaning automated, remotely controlled and monitored substations, and portable substations without stationary operators) and switching stations shall be provided with a control post with the surveillance and control equipment, and shall be able to deal with any accident, disaster and failure."

A power management system for electric railways comprehensively carries out these electric power dispatching operations in a centralized location, such as a dispatching center.

2.1 Conventional system configuration

This system consists of console processors, a central processor and a remote control master station equipment installed in a control center (control room and equipment room) and remote control slave station equipment installed in local control centers, such as substations and sectioning posts. Figure 1 shows an example of a system configuration that uses an Internet Protocol (IP) network.

A remote control slave station equipment collects information about the substation and other equipment and operation conditions and transmits the information to the remote control master station equipment via a remote control line. Computers of the central processor and console processors work together to process and record the information and display it on consoles.

Operators in the control room monitor the power system based on the displayed information and use consoles as required to issue operation and equipment switching control commands to the substation. Based on these commands transmitted to remote control slave station equipment via remote control lines, the substation equipment is activated.

While High-Level Data Link Control (HDLC) protocol communication using metal lines was the mainstream for remote control lines, TCP/IP communication and PMCN*[1] communication have also become available in tandem with the popularization of IP net-

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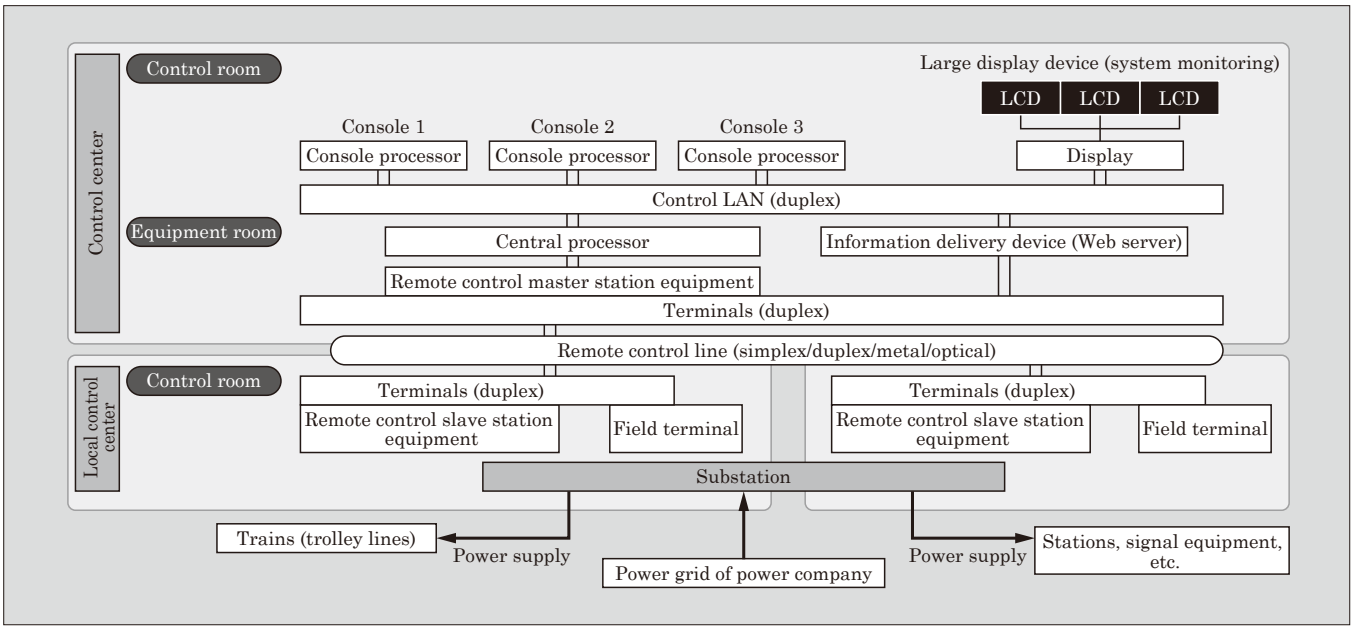

Fig.1 Example of system configuration using an IP network

works.

When configured with multiple central processing units to provide redundancy, the system is operated as a main system, a secondary system, and a standby (stopped) system, respectively. When an error occurs in the main system, the secondary system is automatically switched to the main system and operation is continued.

2.2 Overview of functions of conventional systems

Power management systems consist of essential basic functions as well as extended functions that can be selected according to customer needs.

2.2.1 Basic functions

(1) System monitoring function
  (a) Displays the operation status and measurement information of substations on the system screen (screen showing a diagram of the power system) of a console.
  (b) When a failure occurs, an alarm sounds and information such as the system screen of the relevant substation is displayed on a console.
  (c) Displays graphical representations of the electric energy of substations on a 30-minute scale (demand monitoring). Sounds a demand alarm when the actual value exceeds the warning value or contract value.
  (d) Displays sticky notes on the system screen. They can be used to transfer monitoring operations between shift operators.

(2) System control function
  (a) Turns the power on and off and switches between modes of the substation equipment via operation of the system screen of a console to control the power.
  (b) In normal operation, automatic operation that realizes the equipment switching pattern set (registered) in advance is enabled.
  (c) When an emergency occurs in a substation or a route, an emergency stop command and feeding stop command are output from a console to the substation.

(3) Recording function
  (a) Records and stores state changes, failures, operation information and automatic control operation status of the substation equipment.
  (b) Collects the electric energy, voltage and current data of each substation and maintains and stores these data in the form of daily, monthly, and annual reports.
  (c) The measurement data are not only displayed as trend graphs on the console, but this graphical data can also be extracted and utilized.

(4) System management function
  (a) Regularly checks the state of component devices of the power management system and informs an operator of any abnormalities detected, such as failures.
  (b) When an abnormality occurs in the central processor, it automatically switches between the main and secondary systems.

2.2.2 Extended Functions

Extended functions are functions that can be selected according to customer needs. They include failure response automation and maintenance efficiency improvement. Functions are extended by adding equipment or changing the programs of the console

*1 PMCN (Protocol for Mission Critical industrial Network use): An industrial mission critical network protocol of a Japan Electrical Manufacturers' Association (JEMA) standard (established in October 2005).

and the central processor.

(1) Large screen display function

Displays information about the entire power system on a large display device in the control room to facilitate the visualization and sharing of information.

(2) Interlinked breaking device backup control function

In the event of an accident involving the DC feeder, a protection relay and interlinked breaking device installed in the substation are instantaneously activated to stop feeding in the same feeding section as the feeder in which the accident occurred. In addition, in preparation for failure of the interlinked breaking device, the central processor outputs an opening command to the same feeder breaker to more reliably stop feeding.

(3) Failure recovery function

Judges a failure based on the information about state changes such as activation of a protection relay or tripping of a breaker at the substation, and the following automatic control is performed by the central processing unit as a recovery process in response to the failure.

- ○ Power receiving system switching control (substation with two-line power receiving system)
- ○ High-voltage distribution automatic switching control
- ○ Feeder re-closing control
- ○ Rectifier re-closing control
- ○ Rectifier transfer control

(4) Information delivery function

Distributes power system information to substations and field devices of the maintenance department connected to the network and displays the information.

(5) Work planning, management, and control function

When planning work schedules for operations such as power receiving and high-voltage distribution system switching and maintenance, and if the work involves power interruption, the procedure (control details) can be registered in advance to enable automatic control of the equipment according to the details. Power interruption and accidents due to operational errors can be avoided.

In addition, the operation of pushbuttons of a telephone from the site by a maintenance worker allows the work progress status, such as arrival on site and start and completion of work, to be displayed on the console. The work progress can be shared by the site and the control room, which is effective for preventing accidents involving workers caused by errors in operation timing.

(6) Simulation function

Allows scenarios for abnormality response training of operators to be created based on the records of responses and recovery operations performed when actual accidents occurred. In addition, simulations can be run for operation training of the system and prior confirmation of the planned control operation.

2.3 Issues with conventional system

2.3.1 Simplification of software management and updates

In the conventional system, the relationship between a console processor and the central processor is based on the client-server model, with a control system package group*2 and a power management function software*3 distributed in each. While this allows a stable system to be constructed, the division of functions between the two is unclear and any system remodeling intended to improve functions requires dealing with both the client and the server. Not only are these tasks time-consuming, but software management and updating were complicated.

2.3.2 Data display and management level enhancement

In recent years, the need for data display that combines images, videos, audio and other information has been increasing. Accordingly, there is a demand for enhanced data display that enables the system status and the presence of abnormalities to be accurately grasped visually and aurally.

In addition, as automated offices become widespread, there has been an increasing need to digitize forms (operation information of substations) for long-term storage and to print and refer to these digitized forms. There is also demand for an enhanced data management level, such as by providing the ability to link data to general-purpose software such as Excel*4.

2.3.3 Making systems more compact

The conventional system required an information delivery device to distribute field power system information and an alarm device issue alarms when emergencies occur. At the same time, customer needs have diversified, leading to demand for simple systems and remote response. Given these circumstances, there is a need to make the entire system, including the ancillary facilities, more compact.

3. Features of the New System

3.1 Simplification of software management and updates

The power management function software of the new system is based on the Model-View-Controller (MVC) model. The MVC model divides software into model, view, and controller roles, and its clear division of functions makes it easy to develop new software and customize it. Figure 2 shows the software models of the conventional system and the new system.

In the new system, which uses this MVC model, system modifications for the purpose of function im-

*2 The monitoring and control system package: PFILE, FSINET, ROSE and fenster, provided by Fuji Electric.

*3 Power management function software: Application software that achieves the various functions of a power management system.

*4 Excel is a trademark or registered trade mark of Microsoft Corporation.

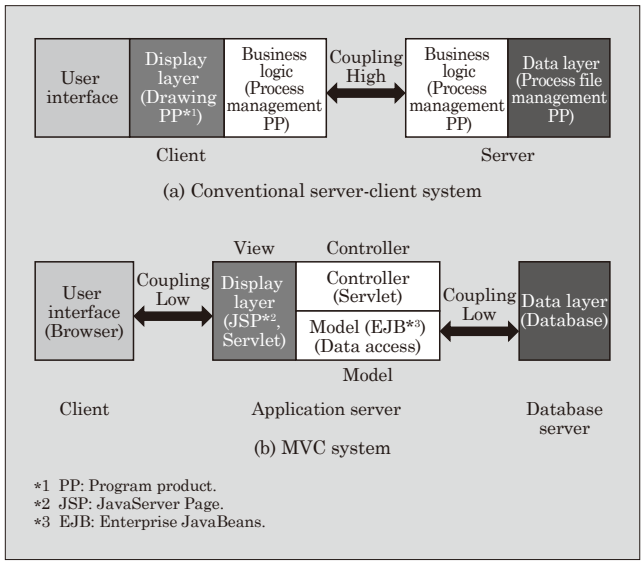

Fig.2 Software models of the conventional system and the new system

provement are performed only on the application server. This eliminates the need for management of the client software, facilitating the updating work.

3.2 Data display and management level enhancement

For the software of the new system, we have used the Java*5 platform to accommodate any OS. In addition, the system has been designed to consolidate data into managed databases (DBs) and synchronize the distributed DBs through replication to improve data operability.

Figure 3 shows the software configurations of the conventional system and the new system.

The new system can run in both Windows*6 and Linux*7 environments. It is now possible to combine Linux for the server with an emphasis on reliability, and Windows for the console with an emphasis on display for operators and on operation.

In the screen shown on the console (Web screen), information is updated in units of components and displayed in real time (every 1 to 2 seconds). In addition to the use of color changes and flickering to indicate abnormal conditions, it is also possible to display animations and pop-up camera images of faulty substation locations on the grid screen. Restrictions on the background color of the system screen and the size and color of symbols have been eliminated to improve visibility.

Daily, weekly, and monthly reports can now be

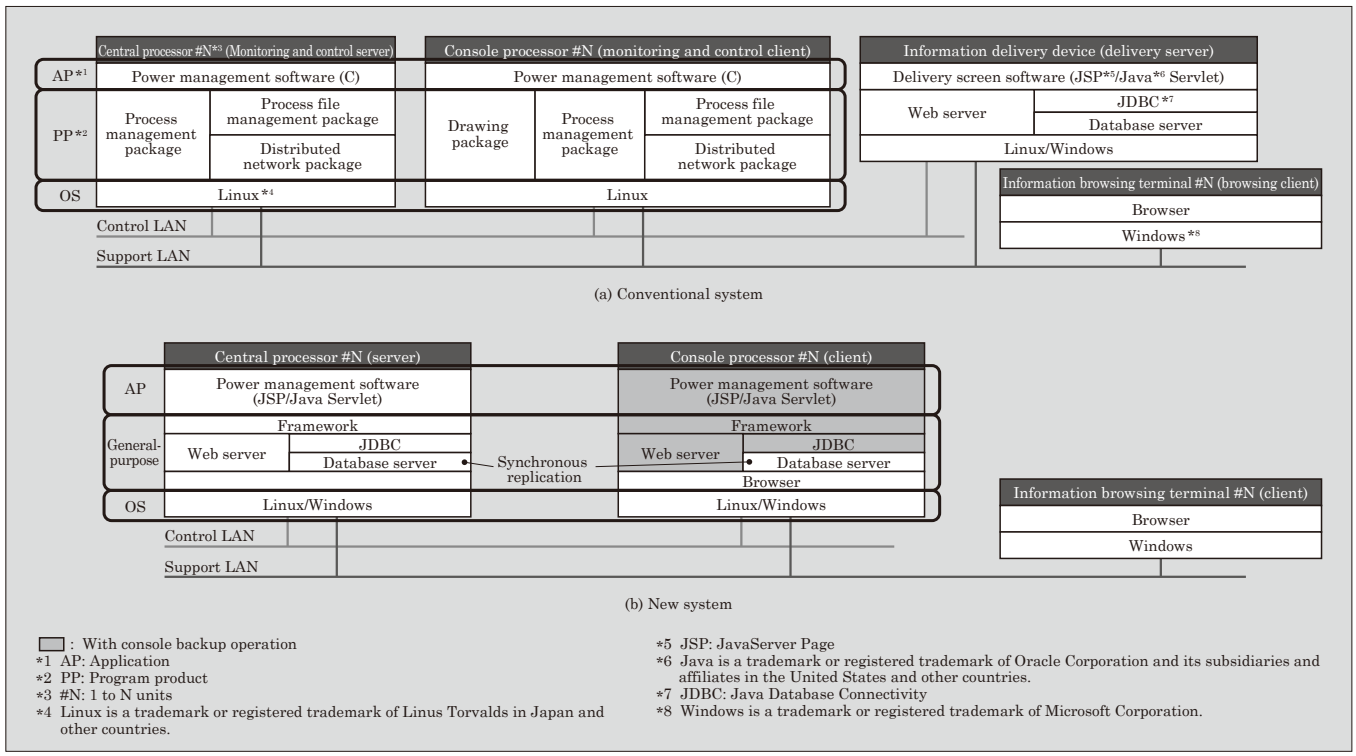

Fig.3 Software configurations of the conventional system and the new system

*5 Java is a trademark or registered trademark of Oracle Corporation and its subsidiaries and affiliates in the United States and other countries.

*6 Windows is a trademark or registered trademark of Microsoft Corporation.

*7 Linux is a trademark or registered trademark of Linus Torvalds in Japan and other countries.

previewed as PDF files, and integration with Excel has expanded the versatility of data utilization.

3.3 Making systems more compact

The new system employs Web service-based centralized management, which eliminates the need for a dedicated information delivery device to distribute information such as system status. Consideration is also given to information security as access to the delivery screen can be restricted through the use of permissions.

It is also possible to build the console processor and the central processor on a single piece of hardware. In addition, WAV files can be used for alarm sounds, and no external alarm device is necessary. As a result of these changes, the entire system has become more compact.

Based on these features of the new system, Fuji Electric has further implemented functions that meet the requirements of individual power management systems. Chapter 4 presents the power management systems of the Tobu Tojo Line and the Tobu Ogose Line of Tobu Railway Co., Ltd. and the Minatomirai Line of Yokohama Minatomirai Railway Company as examples of the introduction of these power management systems.

4. Introduction Examples and Features of Power Management System

4.1 Tobu Railway Tojo Line power management system

The power management system of the Tojo Line is responsible for remote centralized monitoring and control at 17 locations, including 15 substations and 2 sectioning posts between Ikebukuro Station and Yorii Station on the Tobu Tojo Line and between Sakado Station and Ogose Station on the Tobu Ogose Line.

Fig.4 Tojo Line electric control room

Figure 4 shows the appearance of the Tojo Line electric control room and Fig. 5 the configuration of the Tojo Line power management system.

In addition to the basic functions and extended functions described in Section 2.2, this system has the following features.

4.1.1 Strengthened measures against abnormal situations and improved system robustness

The configuration includes three consoles. There are three main computers (control servers). In addition to two control servers, a control server and a monitor device have been provided away from the Tobu Tojo Line and the Tobu Ogose Line. By enabling each control server to play any role, whether it be the main system, secondary system or the standby (stopped) system, they can monitor the operational status of the

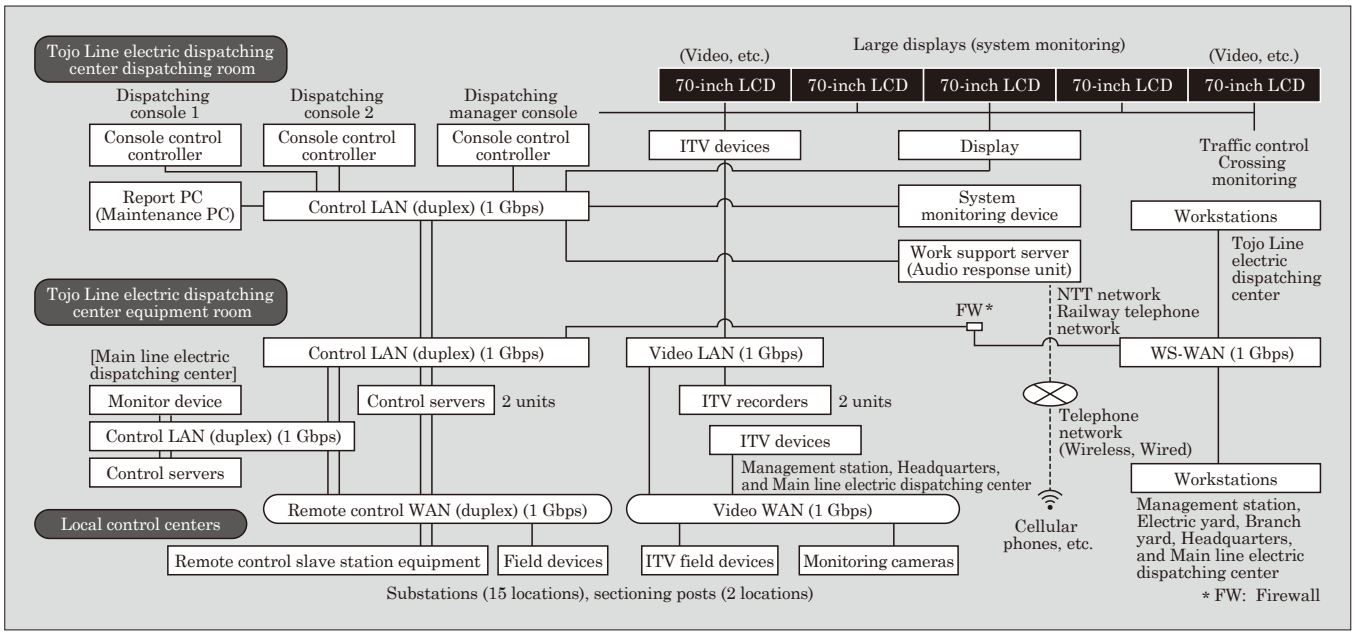

Fig.5 Tojo Line power management system configuration

Tojo Line substation even when the Tojo Line electric dispatching center is disabled due to a disaster or other reasons.

4.1.2 High-speed transmission and improved reliability

The remote control line is a single-loop duplex optical line and, by using the TCP/IP communication system, the number of remote monitoring and control master stations (telemeter control masters, or TCMs) has been reduced. The communication devices connected in a ring are equipped with a loopback function (bypass function) used in the event of an abnormality, which provides a higher-reliability remote control line than simple line duplexing.

4.1.3 Video monitoring

The status inside and outside the substations can be monitored through camera images with monitoring devices at the Tojo Line electric dispatching center control room and the maintenance department. Images are constantly video-recorded and can be traced back up to a week. In the Tojo Line electric dispatching center control room, the images can be displayed on a large display device and, when a fire or an intrusion by an outsider is detected, images of the relevant substation are automatically displayed. It is also possible to turn and zoom the camera and make alert announcements from the microphone of the dispatching console.

4.1.4 Fault current waveform display

Current waveform data observed when a feeder current fault occurs can be collected from the feeder fault selector of local control centers and displayed on a console.

4.2 Yokohama Minatomirai Railway Minatomirai Line power management system

The power management system of the Minatomirai Line of Yokohama Minatomirai Railway carries out monitoring and control of two substations, one switching station and six distributing stations between Yokohama Station and Motomachi-Chukagai Station. Figure 6 shows the configuration of the power management system of the Yokohama Minatomirai Railway Minatomirai Line. The system has the basic functions and failure recovery, information delivery and simulation functions described in Section 2.2. It also has the following features.

4.2.1 Ensured operational continuity during failure due to redundancy of facilities

Two control consoles are installed at the power monitoring station, both with the same configuration. When one fails, the other is used to ensure operational continuity. Aside from the power monitoring station, two monitoring consoles are installed in the power management equipment room and one maintenance console in the headquarters.

4.2.2 Emergency power distribution function during interruption of power reception

The two substations have generator equipment in case an interruption of power reception occurs. The power management system, which is equipped with an emergency power distribution function that controls the generator equipment and applies load restrictions to the power distributing stations under its control, automatically applies load restrictions to the power distributing stations in response to the power interruption status in order to control power distribution from the power generation equipment.

4.2.3 Improved recognizability of power distribution status

The power management system receives the train running position information from the operation management system, and the train position is superimposed over the overall system diagram. Figure 7 shows a sample screen of the overall system diagram.

4.2.4 Reducing the footprint of the remote control slave station equipment and switching panel

Due to the space constraints of the equipment room in which to install the remote control slave station equipment, the remote control slave station equipment is stacked on the switching panel required for switching between the old and the new systems. Fig-

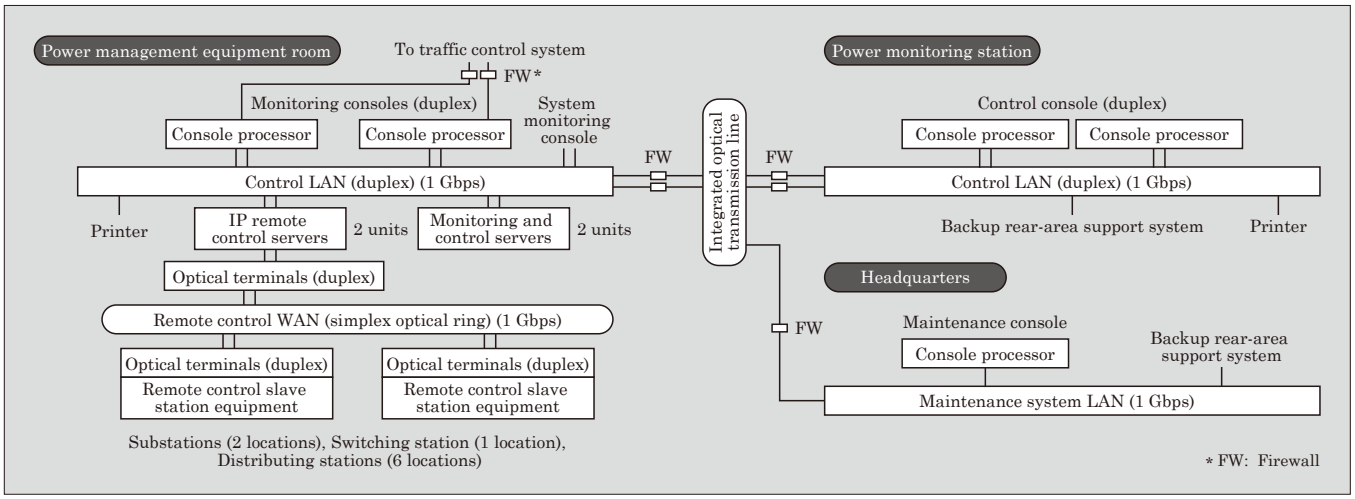

Fig.6 Yokohama Minatomirai Railway Minatomirai Line power management system configuration

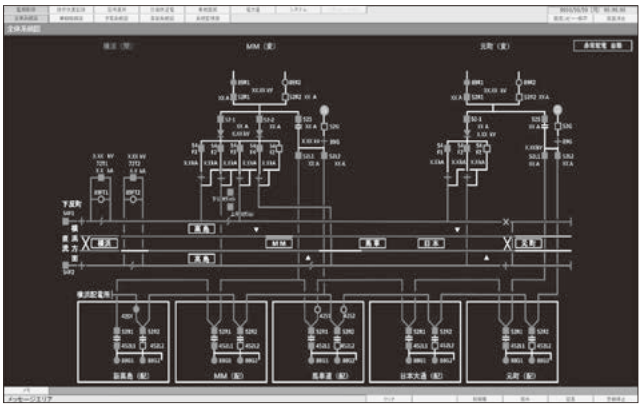

Fig.7 Screen example of an entire systems diagram

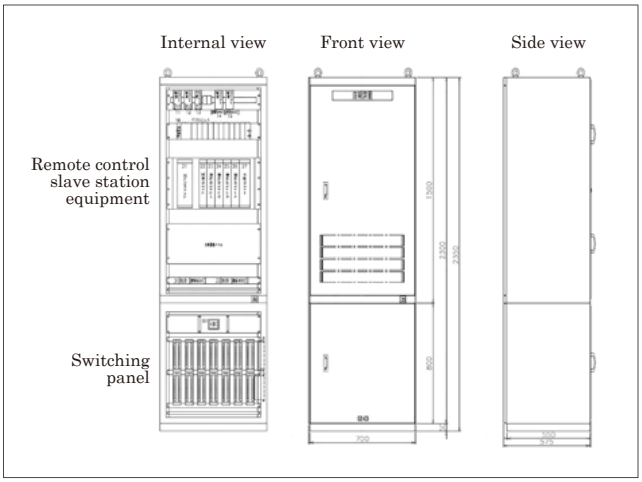

Fig.8 Remote control slave station and switching panel (outline drawing)

ure 8 shows the external appearance of these devices. If the switching panel is installed at the site first, the on-site work can be accelerated. We have adopted a structure with the switching panel separated from the remote control slave station equipment to allow the switching panel to be used for the upcoming system switching work.

5. Postscript

This paper has described a power management system that contributes to safe and stable railway transportation.

In addition to efficient operation, future power management systems will require labor-saving for inspection operations, management level enhancement through computerization of form management, detection of signs of failure in substation equipment, security measures for critical infrastructure, and other extended functions.

Fuji Electric intends to contribute to safe and stable railway transportation by developing a deterioration diagnosis function using multivariate analysis technology and implementing security measures in accordance with the guidelines of the Ministry of Land, Infrastructure, Transport and Tourism.

Finally, we would like to express our heartfelt gratitude to all those who have provided guidance on the implementation of updated systems.

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