ISSN 1345-3041

Sep.2017 / Vol.159

Mitsubishi Electric

ADVANCE

Future Prospects of Transportation Systems

MITSUBISHI ELECTRIC
Changes for the Better

Sep. 2017 / Vol. 159

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Future Prospects of Transportation Systems

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Mitsubishi Electric Advance is published on line quarterly (in March, June, September, and December) by Mitsubishi Electric Corporation.

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Technical Reports

Mitsubishi Electric Corporation has a long history of providing railway operators with electric appliances and systems for railway vehicles since the 1920s. With customer demands evolving from the functionality of equipment and vehicles to focusing on systems and solutions for railways, we have improved our technological capabilities for comprehensive railway management systems. We have exported railway electric devices to about 30 countries since 1960s. In addition, recently, for overseas expansion, we have established manufacturing bases in India and Italy, and have started cooperating with MEDCOM (Poland).

Overview

Author: *Takeshi Oshima**

Railway systems are environment-friendly and important part of the social infrastructure, helping individual nations to grow. The overseas railway market is growing in Europe, North America, South America, Asia, Africa, and other parts of the globe, particularly in developing countries. To help resolve environmental issues caused by traffic congestion and other problems, new railway lines and vehicles are being built for urban area projects, and many countries also have high-speed railway plans. These initiatives are gradually starting to commence service.

Mitsubishi Electric has been actively exporting electric appliances and systems for railway vehicles since the 1960s. Our products are used for a wide range of vehicle types including electric locomotives, diesel locomotives, suburban trains, subway trains, LRV, and vehicles for Automated Guideway System and have been shipped to about 30 countries to date including India, Spain, Australia, the United States, Mexico, China and other main destinations.

The demands of overseas railway projects are shifted from satisfying the technical specifications of individual equipment and ensuring the traveling performance of vehicles, to securing overall transportation quality and entire system maintenance from a management perspective.

In response, the technological competence to cover an entire system is required, in addition to ensuring equipment performance. In the field of rolling stock equipment, Mitsubishi Electric possesses integrate technologies that cover all vehicle system components and elements, in addition to technologies for equipment such as propulsion control systems, auxiliary power supply systems, and HVAC. Our technologies now include integrated control functions and devices for onboard transmission and information, and linkage between on the ground and trains, as well as vehicle maintenance support.

These technologies have won us orders for overseas projects to systematize railways. Recently, we manufactured electric equipment for vehicles in the United States, India, Hong Kong, etc. We have also been upgrading equipment for Germany's ICE2 traction converters. For ground systems, we have provided substation systems to Singapore and other countries. We also received an order from New York City Subway to conduct verification testing on CBTC signaling systems using wireless technology, which is now underway.

We have been steadily setting up localization bases in line with the expansion of our overseas business. Since 2014, we have opened new manufacturing plants in India and Italy, and commenced collaboration with MEDCOM, a Polish electric equipment manufacturer.

This special issue introduces Mitsubishi Electric's system solutions and technical advantages that apply power electronics technology, control and transmission technology, wireless technology, etc. to railway systems, together with the latest technological trends. It also outlines the recent situation and technological prospects for the overseas development of Mitsubishi Electric.

**Senior General Manager, Overseas Marketing Div.*

Overseas Expansion and Technological Prospects of Rail Systems

Authors: *Yoshiyasu Hagiwara** and *Naoto Masuda***

1. Introduction

Mitsubishi Electric has been manufacturing electrical equipment for railway vehicles since 1922, its second year in business, and presently holds an estimated 50% share of the domestic market for onboard electrical equipment for the Shinkansen, conventional, and subway trains, and for locomotives, etc. Japan's railway operators value our products' reliability, durability, energy-saving performance, ability to meet diverse user needs, and flexibility of design, as well as advanced functions and operating performance.

Mitsubishi Electric has also been active in overseas railway business. After delivering electrical equipment for Indian Railways' electric locomotives in 1960, the business has continued to expand globally, with shipments now being made to 30 countries including India, Spain, Australia, Mexico, and the United States.

As an integral part of the social infrastructure, railway systems help sustain the growth of individual nations. The overseas railway market is expanding, particularly in developing countries. To help resolve urban environmental issues such as traffic congestion and air pollution, new railway lines are being built, and plans are underway for high-speed railways for intercity mass transportation.

As a leading manufacturer of electrical equipment, Mitsubishi Electric possesses advanced technologies in diverse areas including power electronics, information and communications, and control instruments, plus the technological expertise to cover the requirements for an entire railway system. The onboard electrical equipment we supply includes those for propulsion control systems, train control and monitoring systems, auxiliary power supply systems, brake systems, passenger information systems, and air conditioning systems. We also provide ground-to-vehicle linking systems and wireless train control systems, as well as vehicle maintenance support services.

As a result of such versatility, Mitsubishi Electric has increased its presence both in and outside Japan and has become a leading name in railway equipment and technologies. Our latest overseas projects include the production of electrical equipment for railway vehicles in the United States, India, Hong Kong, etc., and the upgrade of Germany's ICE2 traction converters. We have also delivered substation systems and other ground systems to Singapore.

In response to the expansion of overseas business, we have set up additional overseas bases. Since 2014, we have opened new manufacturing plants in India and Italy, and commenced collaboration with MEDCOM, an electronic device manufacturer in Poland.

This paper outlines the latest status of Mitsubishi Electric's overseas expansion, technological prospects, and an overview of the transportation system issue.

2. Overseas Business Expansion

The major moves we made as part of our overseas expansion are described in the context of the latest overseas market trends. We have set up manufacturing plants in the United States, Mexico, Australia, and China, in addition to sales bases around the world. Since 2014, we have opened new manufacturing plants in India and Italy, expanding overseas according to regional needs (Fig. 1).

The following describes our latest moves in the major overseas markets.

(1) Europe

Europe is the world's largest railway market, and solid demand growth is expected to continue in the future.

In particular, there is a growing demand for air conditioners due to rising outside temperatures and passenger service upgrades. After obtaining International Railway Industry Standard (IRIS) certification in 2010, we founded Mitsubishi Electric Klimat Transportation Systems S.p.A. in Italy in 2014, aiming to expand production and maintenance services for air conditioners. Since then, the business in Europe has been growing, including receiving an order for air-conditioning equipment for the new Rhein-Ruhr Express cars in Germany.

For traction systems, we received an order for propulsion control equipment for German Railway's ICE2 high-speed trains in 2014. In 2016, we obtained IRIS certification for railcar traction transformers, and also commenced collaboration with MEDCOM, a Polish railcar electric equipment manufacturer, in the form of equity participation, thus strengthening the business foundation.

(2) United States

In North America, orders for electrical equipment for over 6,800 trains have been completed to date with the

**Public Utility Systems Group* ***Itami Works*

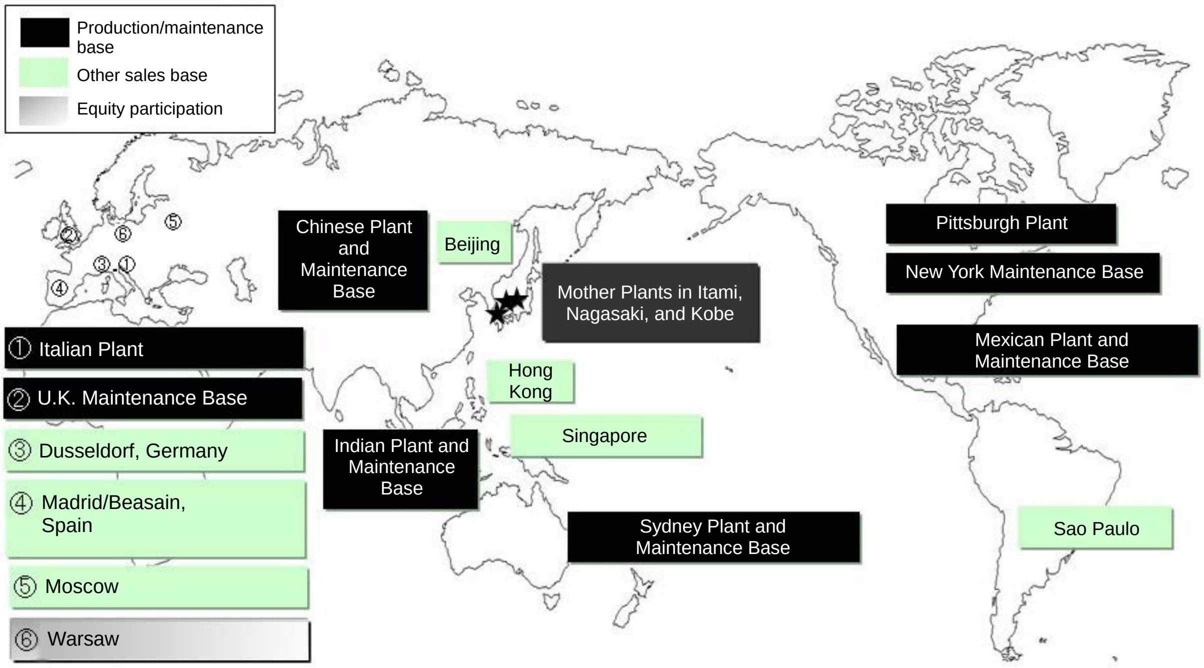


Fig. 1 Mitsubishi Electric's overseas bases

New York City Transit Authority (NYCT), Long Island Rail Road, Metro-North Railroad, and others. In 2004, Mitsubishi Electric Power Products Inc. (MEPPI), our U.S. subsidiary, started manufacturing propulsion control equipment. In 2012, we established a new plant to strengthen the air-conditioning equipment business for North America. In 2014, the plant production capacity was reinforced to meet the local demand and to improve the product quality. In the same year, we set up the MEPPI Rail Service Center (MRS) to focus on the maintenance business.

In 2015, we received another order from the NYCT, this time for verification testing on the communication-based train control (CBTC) system's interoperability with the existing systems, taking a step toward qualifying as a CBTC supplier to the NYCT. Since then, we have sought global expansion of the railway signal system business, while working to expand the entire railway system business including electrical equipment for railway vehicles.

(3) India

Our railway business in India started in the early 1960s with the delivery of electrical equipment for locomotives. Since fully entering the Metro market in the 2000s, we have become highly regarded for the quality and performance of our products. Our Metro propulsion control equipment is currently being used in major cities such as Delhi, Bangalore, Mumbai, marking up a significant share of the market.

In 2015, we set up a new plant in Bangalore for railway vehicle electrical equipment in order to handle large projects for subways and locomotives in India, where the demand for railway infrastructure is growing, as well as to expand the maintenance business. We are ready to contribute to Japan's nationwide efforts in future high-speed railway projects.

3. Development of Railway Vehicle Systems to Meet Overseas Market Needs

For overseas markets, we provide railway vehicle systems in accordance with regional needs such as reduced energy consumption, improved service quality and transport density, and labor-saving operation. Our latest development initiatives to meet these diverse needs are outlined below.

(1) Propulsion control systems

For propulsion control equipment for running vehicles safely and steadily, we introduced AC motor control using VVVF inverter control units in the 1980s, assisted by the advancement of power electronics and microelectronics technologies, leading to maintenance savings. AC motor control has also enabled regenerative

Fig. 2 Exterior of the new plant in India

braking, which saves energy.

Recently, a new propulsion control system has considerably improved efficiency and increased the regeneration range, achieving further energy savings. This system combines a highly efficient, totally enclosed induction motor with an inverter controller using silicon carbide (SiC) devices capable of minimizing power loss and operating under high temperatures.

For the detailed initiatives involved in propulsion control systems, please see *Propulsion Control System Using SiC Power Modules* in this special issue.

(2) Brake and train protection systems

For braking systems to safely and securely stop a railway vehicle, we have significantly reduced the size and weight using a brake control unit that integrates the electronic control and air control units. For onboard train protection systems, we have digitized and multiplexed the transmission signals, substantially improving the performance and reliability. We are presently developing a radio-based train control system.

(3) Train control and monitoring systems

A train control and monitoring system (TCMS) plays a central role in train control. With a TCMS, information on individual devices installed on a train is centrally controlled in the operator's cab by means of high-speed transmission by microcomputer. In an emergency, the TCMS displays the measures to be taken to assist the train crew. By managing all the instruments on the entire train, the overall train system can be optimized, including improving train energy efficiency, reducing outfitting wiring, and reducing overall train cost through optimal function positioning.

(4) Automatic train operation systems

We have developed automatic train operation (ATO) systems and already have a solid track record. Our ATO systems recently achieved optimal train operation that allows both traveling comfort and energy savings, while maintaining safety and punctuality considering the route conditions.

4. Comprehensive Railway Solutions that Utilize Ground-to-Train Linkage

Advances in mobile communications have made it possible for railway systems to handle huge data traffic in real time between the ground and trains, using various wireless communication systems such as digital train radio, millimeter wave communication, and Wi-Fi.

We consider it is important to optimize the entire railway system and improve the functions to ensure faster emergency response, improved maintenance efficiency, passenger service upgrade, etc., by enhancing the ground-to-train communication linkage. The following outlines the concepts of the solutions we are working on using ground-to-train linkage.

(1) Energy and environmental solutions

At the COP21 held at the end of 2015, the Paris Agreement was adopted by the consensus of many countries to mitigate global climate change. For railways to remain a sustainable and competitive means of transportation in the future, further energy conservation and environmental load reduction are required.

Our SiC inverter control units and other train equipment provide world-leading energy efficiency, and also help optimize energy efficiency throughout the rail line by establishing a link between the trains on the demand side and the substations on the supply side, utilizing ground-to-train linkage technology and ICT.

For details of the energy and environmental solutions, please see *Railway Energy and Environmental Solutions to Support a Low-Carbon Society* in this issue.

(2) Train control solutions

Conventional train control systems based on ground facilities are being replaced by communication-based train control (CBTC) systems using radio transmission to link the ground with trains to set up safety functions. The use of CBTC systems is becoming increasingly commonplace. With this system, the train detects its position on the railway track and wirelessly transmits the information to the ground, which eliminates the need for on-rail train detectors (track circuits) conventionally installed on the ground. This allows a reduction in ground facilities, which will improve maintenance efficiency and reduce life-cycle costs. In addition, CBTC systems can more precisely detect train positions compared to conventional systems, and therefore allow the use of the moving block train control method, which makes higher density operation possible by shortening the headway between trains. Therefore, CBTC systems will likely constitute major train control systems worldwide in the future.

For details of the train control solutions, please see *Up-to-date Communication-Based Train Control System Technologies* in this issue.

(3) Maintenance solutions

It is important to strike a balance between reliability improvement and cost reduction for customers in the railway business. Among vehicle and infrastructure facility costs, which account for a large percentage of the total cost, the maintenance cost in particular should be reduced in the future through technological innovation.

To improve train maintenance efficiency, Mitsubishi Electric has provided maintenance support functions and systems that utilize train information saved in TCMSs. We are presently researching maintenance solutions to achieve faster emergency response, higher periodic inspection efficiency, and long-awaited condition-based maintenance, by utilizing the rapidly-advancing ICT and ground-to-train linkage technology.

For details of the maintenance solutions, please see

Evolution of Railway Vehicle Maintenance Assistance Systems and TCMS in this issue.

(4) Passenger service solutions (air conditioning and PISs)

To enable air conditioners to provide comfort for passengers on the train, we are improving the environment and energy saving through a control method using temperature settings and occupancy for each season, time zone, and vehicle; making the train speed adjustable by fan and compressor inverter; and introducing heat pumps capable of high heating performance in cold regions, etc.

For passenger information systems (PIS), we are developing a universal design liquid crystal train information display unit easy for everyone to understand, a personal information service system using mobile terminals, etc.

Furthermore, given the increasing number of onboard security cameras, we are developing more advanced systems toward the 2020 Tokyo Olympics/Paralympics.

5. Conclusion

For more than half a century, Mitsubishi Electric has been providing electrical equipment for railway vehicles in overseas markets. Overseas railway markets, particularly in developing countries, are likely to continue expanding, helping to solve urban and environmental problems, and improving convenience through high-speed mass transportation between cities.

Mitsubishi Electric will continue to contribute to the growth of countries by providing railway electrical equipment and systems of world-class quality, reliability, efficiency, and functionality.

Railway Energy and Environmental Solutions to Support a Low-Carbon Society

Authors: *Akihiro Murahashi** and *Masahiko Miyakawa***

1. Introduction

At the COP21[1] held in Paris at the end of 2015, the Paris Agreement was adopted by consensus of many countries to mitigate global warming. Countries are required to further reduce the burden on the global environment, starting in 2020. In response, Mitsubishi Electric Corporation is working on railway energy and environmental solutions aimed at conserving energy for an entire railway system achieved by building energy management systems (EMSs) in the following four areas (Fig. 1).

(1) Train energy management (TEMS)

Pursues energy conservation in units of a train involving improvement of the efficiency and functions of electric equipment for trains brought by our industry-leading SiC power modules, and improvement of energy efficiency through coordinated control of battery-powered trains and multiple devices, etc.

(2) Railway line energy management (REMS)

Pursues effective maximization of regenerative energy use throughout the entire railway line including trains and wayside facilities, using a Station Energy Saving Inverter (S-EIV), Feeder Voltage Optimization System, and other equipment.

(3) Station energy management (SEMS)

Pursues energy conservation by reducing the increasing use of electric power for station ancillary facilities through visualization of energy, demand control, etc.

(4) Factory energy management (FEMS)

Manages the energy used throughout the train depot facilities including inspection equipment and repair lines.

2. Railway Energy and Environmental Solutions

Mitsubishi Electric has contributed to the energy conservation of railway vehicles by improving the efficiency of train equipment, which constitutes our flagship products, and sophisticating their control functions, upgrading regenerative braking systems, and developing train control and monitoring systems (TCMSs) for all-inclusive control. We have also developed a regeneration inverter that allows wayside facilities to absorb surplus regenerative electric power for effective use of regenerative power and improved energy utilization.

The goal of these new solutions is to optimize energy demand and supply throughout the entire railway system, as with the case of a smart grid in an electric power supply system.

We seek energy conservation for an entire railway system using real-time information on the fluctuating supply-demand relationship and the four EMSs working together by making the best use of information and communication technology (ICT), also called the Internet of Things (IoT) and Machine-to-Machine (M2M) technology, which has recently made rapid progress.

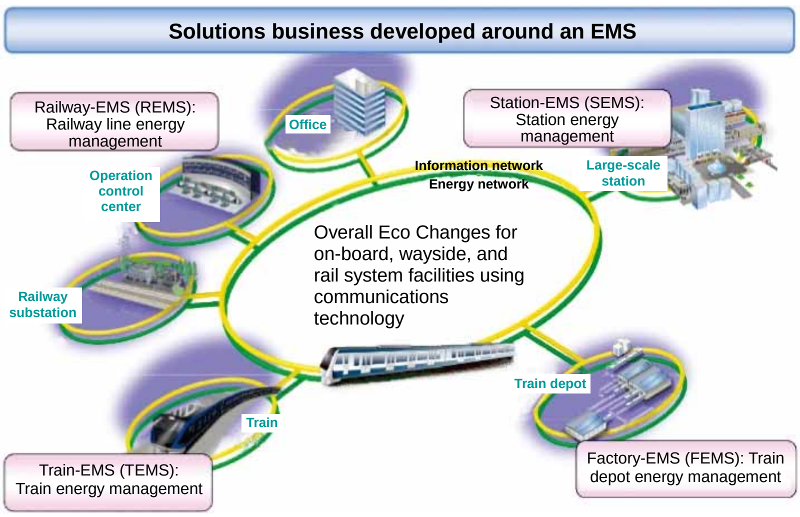


Fig. 1 Energy management system (EMS) development

[1] The 21st Conference of the Parties to the United Nations Framework Convention on Climate Change

*Itami Works **Kobe Works

3. Initiatives for Energy Management Systems

3.1 Train energy management system (TEMS)

A TEMS performs energy optimization for a railway vehicle.

We work on TEMS development in two main directions: energy efficiency improvement by improving the efficiency and functionality of electric equipment; and energy efficiency improvement through the coordinated control of multiple devices.

For the improvement of electric equipment efficiency and functionality, we have applied two systems that each use different devices to railway vehicles operating on existing lines. One is the main circuit system that combines propulsion control equipment using a silicon carbide (SiC) power module[2] with a highly efficient, totally enclosed induction motor. The other system includes a power storage device and aim to increase the use of regenerated electric power, reduce noise in unelectrified sections, and attain zero emissions.

As an example, the above-described main circuit system is installed in the refurbished 1000 Series of Odakyu Electric Railway Co., Ltd. Our variable-voltage variable-frequency (VVVF) inverter that is compatible with 1,500 V DC overhead lines and comes with an SiC power module was adopted for the refurbished Odakyu 1000 Series vehicles (each with four cars) as shown in Fig. 2. Service with the VVVF inverter unit was launched in January 2015, marking the world's first adoption of a railway inverter rated at 3.3 kV/1,500 A with a high-capacity SiC power module. With its low-loss characteristics, the VVVF inverter has reduced train electric power consumption by approx. 40% compared to a conventional train, and is also approx. 80% smaller and lighter than a conventional inverter unit.

An example application of the system with a power storage device is for the EV-E301 Series vehicles of East Japan Railway Company. Figure 3 shows the appearance of an EV-E301 train and the power converter used for the vehicle.

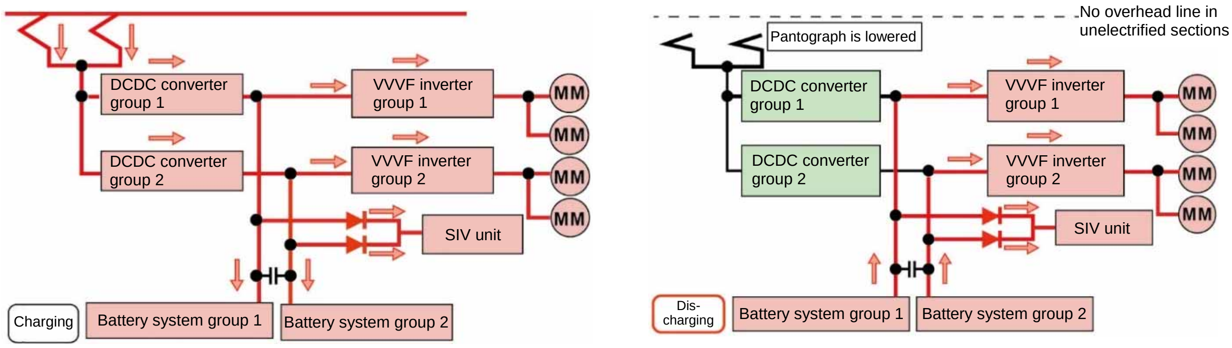
The power converter was applied to the EV-E301 Series based on the achievement of the NE-Train experimental battery-powered vehicle for which development was started in 2008. Service of the EV-E301 Series with the power converter was launched in March 2014, and has since brought the following benefits.

(1) As shown in Fig. 4, power is supplied from the overhead lines when a train is traveling in an electrified section, while power is supplied from batteries when traveling in an unelectrified section. This allows for direct service, which is more convenient for passengers.

(2) The same performance as that of an electric train

Fig. 2 Refurbished Odakyu 1000 Series vehicle and the VVVF inverter

Fig. 3 EV-E301 Series vehicle and the power converter



(a) When traveling in an electrified section

(b) When traveling in an unelectrified section

Fig. 4 Main circuit operation when a train is moving

2 For the development of the SiC power module, we used part of the research results commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

can be obtained even in an unelectrified section and improves the acceleration compared with that of a conventional diesel train.

(3) Even in an unelectrified section, the recovery and reuse of energy for regeneration, noise reduction, and exhaust gas elimination are achieved.

Furthermore, in pursuit of improvement through coordinated control of multiple devices, we are working on the visualization of energy in a railway vehicle. This involves collecting vehicle electric power data by train car composition using ground-to-train networks (wireless communication), in addition to providing blended brake control for each car composition using the TCMS and energy-saving equipment control by optimizing the equipment operation timing control.

3.2 Railway energy management system (REMS)

An REMS performs energy optimization for the entire rail line. Regenerated energy in a railway vehicle is increasing every year with the adoption of VVVF vehicles and increasing use of SiC power modules in train inverters. This also increases the energy that fails to be flexibly used in response to the needs of accelerating trains via DC electric-car lines and thus is wasted. The challenge to achieving further energy conservation throughout the entire rail line is to effectively utilize the redundant energy that trains cannot conventionally accommodate. In this section, we describe representative equipment and systems that are used for minimizing/optimizing the energy in the feeder system that supply the energy for train operation.

3.2.1 Station Energy Saving Inverter (S-EIV)

The Station Energy Saving Inverter (S-EIV) is an energy conservation device that converts the regenerated energy that becomes redundant when a train comes to a stop at a station to AC power to be supplied to the electric facilities of the station building. Figure 5 shows the redundant energy recovery flow by an S-EIV. Table 1 shows the product specifications. The S-EIV is installed at the nearest location to the station building where train drivers brake their train and generate recoverable regenerated energy. The energy is recovered, converted to AC electric power and utilized as power for the station building. This mechanism reduces transmission losses and enables efficient local production and consumption of redundant regenerated energy. Table 2 shows the commercialization history of the S-EIV. From August to December 2012, we conducted field verification tests using prototypes during the development. We used the findings of the tests to improve the product and verified its functions and energy-saving effect. In June 2014, the first model was delivered to a customer, and an energy-saving effect of approx. 600 kWh per day was confirmed.

We subsequently delivered the product to several railway operators to accumulate data, and continued developing the product. In February 2016, we delivered a downsized, high-functionality model with a 40% smaller footprint than conventional equipment, which also offers reinforced features such as a ground fault detection circuit. In the future, we will continue to expand the product lineup, while promoting the S-EIV to railway operat ors both in and outside Japan to help reduce the burden on the global environment.

3.2.2 Feeder Voltage Optimization System

The Feeder Voltage Optimization System currently under development is intended to reduce overhead line energy losses and efficiently use regenerated energy

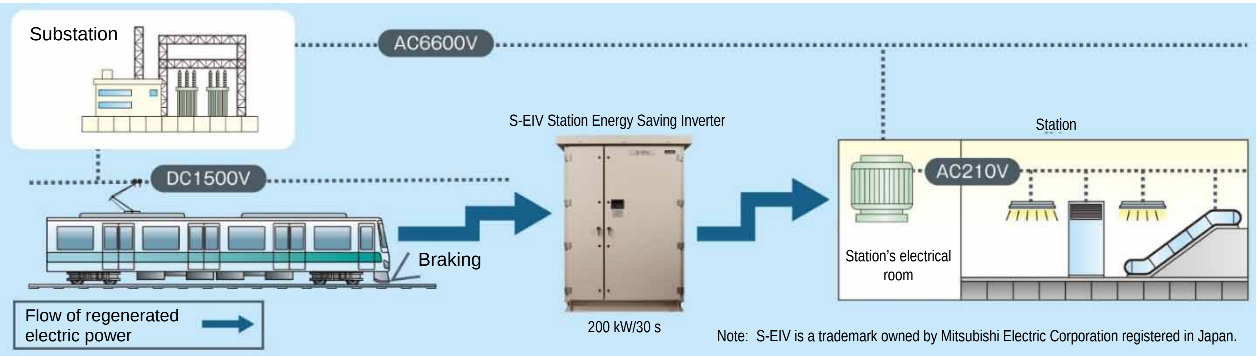


Fig. 5 Recovery flow of redundant regenerated energy by S-EIV

Table 1 S-EIV specifications

Rated capacity	200 kW; 30 s to charge, 2 min and 30 s to stop
Input voltage	1,500 V DC, 750 V DC, 600 V DC
Output voltage	210 V AC, three-phase, 50/60 Hz
Cooling System	Natural air-cooling

Table 2 Commercialization history of the S-EIV

Period	Main event
August to December 2012	Field verification testing using prototypes
June 2014	Delivery of the first model
February 2016	Delivery of a downsized, high-functionality model

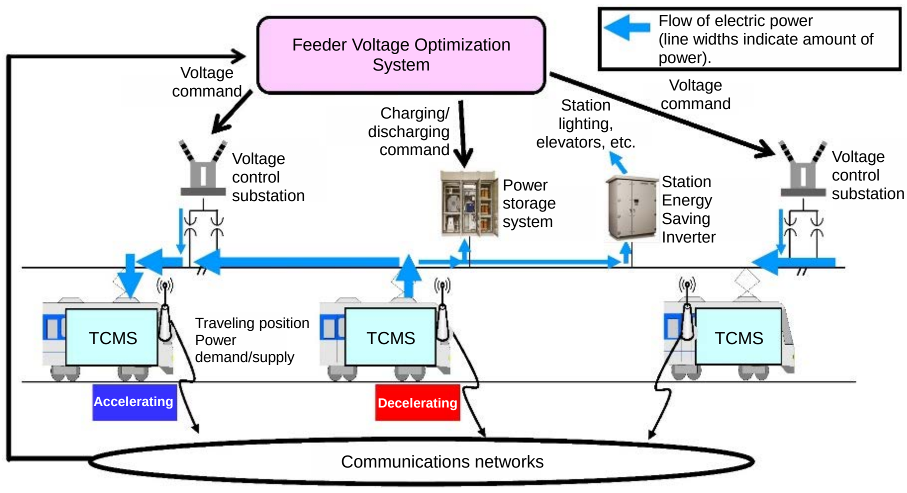


Fig. 6 Feeder Voltage Optimization System

through real-time control of substation output voltage in accordance with the position and operation conditions of a train, to reduce train line loss. Figure 6 shows a schematic view of a Feeder Voltage Optimization System. Information regarding the current position on the route and the power demand/supply (amount of required power or of recoverable power for regeneration) is transmitted from a TCMS to the Feeder Voltage Optimization System via communications networks. The Feeder Voltage Optimization System controls the voltage control substations such that the maximum amount of regenerated power is flexibly fed to trains in order to optimize the output voltage and reduce the substation power supply. We simulated this power feeding mechanism using a railway line model in a section with a tight train schedule in a metropolitan area. The results showed that the amount of power conventionally discarded as heat as a result of limited regeneration due to the absence of a feeding destination could be reduced by up to 80%, and that the power supply from substations could be reduced by up to 5%. In the future, we will continue developing technologies for the Feeder Voltage Optimization System and related equipment in coordination with vehicle technological development using ICT, with the aim of further energy conservation throughout the entire rail line.

3.3 Station energy management system (SEMS)

An SEMS optimizes energy in a train station. The incidental facility power consumption of stations is increasing due to the increase in commercial station facilities, subway air-conditioning systems, etc., so it is important to reduce the power used for such incidental facilities in order to conserve energy. We have delivered a station facility management system that optimally controls individual station facilities to balance comfortable services and energy conservation, in addition to refurbishing air conditioning, lighting, and other facilities by replacing them with leading-edge energy-saving facilities (high-efficiency air conditioners, LED lights, etc.). Furthermore, to stably and effectively use power generated from photovoltaic systems that would be introduced in accordance with the size and local conditions of existing stations, we are working on the application of smart grid technologies including power storage to SEMSs for further energy optimization.

We are also focusing on an approach, based on our energy-saving systems for individual stations, involving saving energy for each station group by monitoring and coordinating the demand levels of multiple stations.

3.4 Factory energy management system (FEMS)

An FEMS optimizes energy in a train depot (including a vehicle factory and other facilities). Equipment and facilities operating at a train depot are managed in a sophisticated manner using a programmable logic controller (PLC) and networks to also allow management of maintenance work progress, energy consumption, etc., thereby conserving energy of the entire train depot. The FEMS introduces a specific energy consumption management approach using a database of collected information on the operation status of individual equipment and facilities, progress in inspection/repair work, energy consumption, etc., with the aim of improving inspection and repair work.

4. Conclusion

We have described our railway energy and environmental solutions in pursuit of energy optimization for an entire railway system.

With the growing international effort to mitigate global warming and improve the energy supply conditions in Japan, especially since the Great East Japan Earthquake, it is becoming increasingly important to bring about a low-carbon society. Using a wide range of accumulated technologies, we will continue developing solutions that improve railway systems, which are vital low-carbon infrastructure for society in the future.

Propulsion Control System Using SiC Power Modules

Authors: *Yoshinori Yamashita** and *Takanori Tanaka**

1. Introduction

In the battle against global warming, the number one priority is the reduction of carbon dioxide (CO_2) emissions, particularly from the transport sector. However, railway transport has a lower environmental impact compared to other transportation modes and contributes to reduced CO_2 emissions. Thus, railway construction is being promoted both in and outside Japan.

In February 2012, we delivered the world's first propulsion control equipment with an SiC-hybrid power module (using SiC diodes) for a rail line in operation. We have since applied SiC-hybrid power modules to numerous railway propulsion control units and auxiliary power supply units both in Japan and abroad, thereby helping to reduce the impact on the global environment.

Taking our energy-saving and environmental conservation initiatives one step further, we developed an inverter system for railway vehicles using an all-SiC power module (SiC diodes and switches), and led the world in commercializing the system.

By applying the optimal design using the all-SiC power module and other energy-saving measures to propulsion control systems for railway vehicles (inverter and traction motor units), we have reduced the power consumption by approx. 30–40% compared to conventional propulsion control systems.

This article describes the characteristics of the all-SiC power modules along with the energy conservation technology in the propulsion control system using SiC devices.

2. Characteristics of the All-SiC Power Module

Figure 1 shows schematic views of the structure of an Si-MOSFET and SiC-MOSFET. An SiC-MOSFET can operate at higher temperatures and has about ten times the breakdown electric field strength compared to an Si-MOSFET, allowing the use of a thinner semiconductor substrate for significantly lower on-resistance than the conventional Si-MOSFET, thereby providing low conduction loss.

Conventional Schottky barrier diodes (Si-SBDs) are not suitable for increased voltage resistance due to the large leakage current. However, an SiC-SBD allows for increased voltage resistance, leading to lower diode

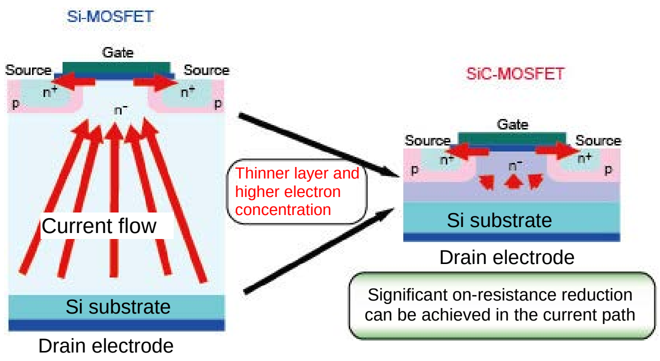


Fig. 1 Comparison of MOSFET structures

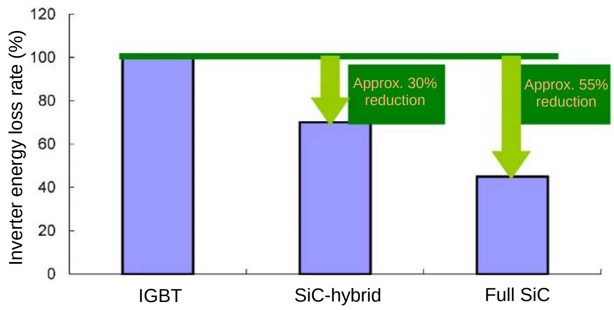


Fig. 2 Comparison of inverter energy loss

recovery loss and lower switching device turn-on loss. Furthermore, the use of an SiC-MOSFET as a switching device eliminates the minority carriers in a conventional IGBT device, thus preventing the generation of tail current when turned off. This significantly reduces the turn-off loss, achieving a 55% reduction in inverter energy loss compared to a conventional device (Fig. 2).

3. Propulsion System with a Power Module Fully Using SiC Devices

3.1 Analysis of electric power consumption

Figure 3 is a schematic view of the energy conversion flow together with the energy loss during railway vehicle operation. The energy loss is classified into that due to heat generated at individual mechanisms during energy conversion and loss of thermal energy due to running resistance and friction braking when the train is slowed down. All energy loss must be considered in order to reduce the power consumption of railway vehicles.

The pie chart in Fig. 3 shows a breakdown example of energy loss during train operation. A large portion of the energy loss involved in the running mechanisms can

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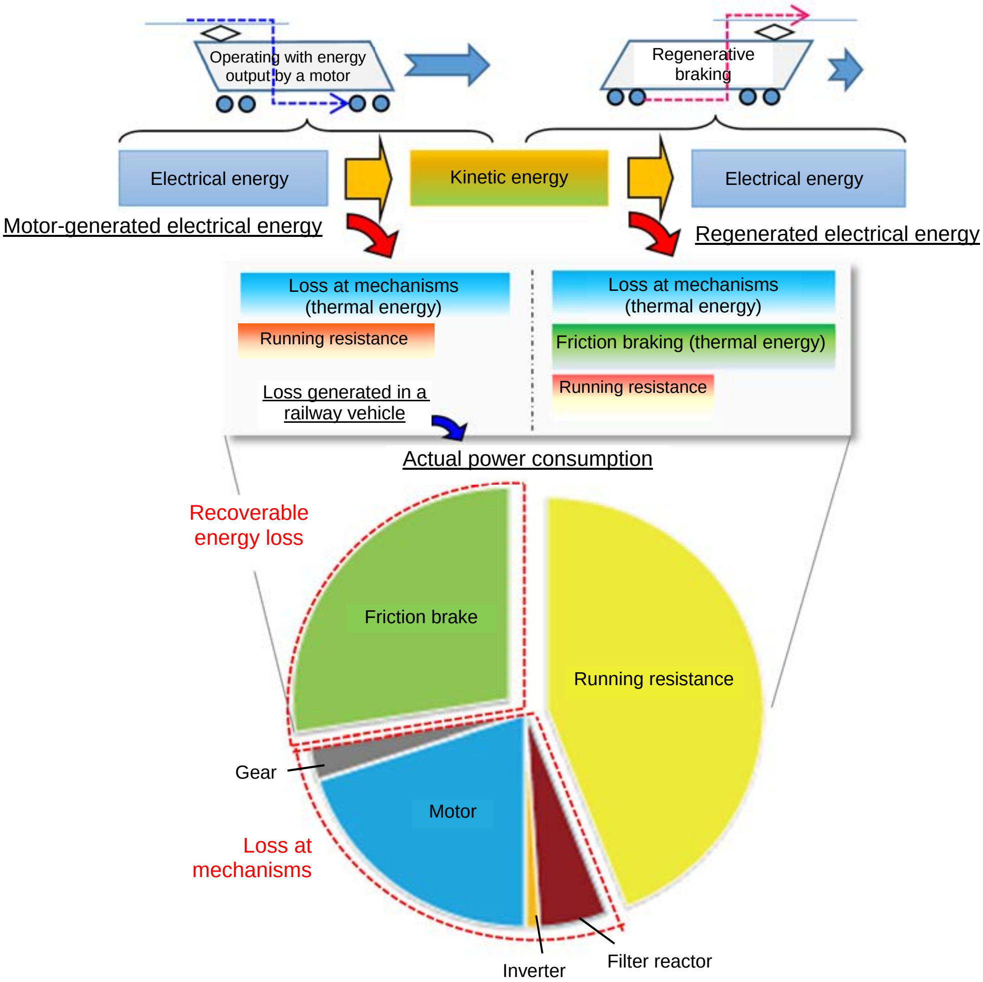


Fig. 3 Railway vehicle energy loss (electric power consumption) and breakdown

be recovered, such as heat loss from friction (air) braking and other heat loss in the traction motor, etc.

On the other hand, energy loss generated at the inverter accounts for a small proportion of the total loss of the entire vehicle, and so simply replacing Si devices with SiC devices is not likely to significantly reduce the energy loss of the entire railway vehicle.

Therefore, in addition to reducing the loss at the inverter, we worked on reducing the use of the friction brake by expanding the speed range covered by regenerative braking and improving the efficiency of the traction motor.

3.2 Energy conservation measures

(1) Expansion of the regenerative braking range

(i) Inverter

With an inverter that uses conventional Si devices, it is difficult to increase the motor current in the high-speed range due to the limitation in device loss reduction. This in turn limits the regenerative braking range, and so friction braking is used to further decelerate a railway vehicle.

On the other hand, an inverter that uses SiC devices significantly reduces device loss, and so the traction motor current can be set higher than that of a conventional Si device inverter even in the high-speed range, as shown in Fig. 4. For this reason, substantial energy conservation can be achieved by increasing the regenerative braking range while decreasing the supplemental friction braking range.

(ii) Traction motor

In accordance with the high level of current to which the inverter with SiC devices can raise in the high-speed range, we have increased the maximum output (stalling torque) of the traction motor in order to recover recoverable kinetic energy to improve the regenerative output (Fig. 5).

The measures described in (i) and (ii) for the propulsion control system enable the recovery of all recoverable kinetic energy, which was not previously possible. This results in an approx. 25% reduction in energy loss in a railway vehicle (with a slight variation in the reduction rate depending on the vehicle structure).

(2) Improvement of the traction motor efficiency

By using SiC devices in the inverter it is possible to set both a high traction motor current and a high switching frequency due to the low energy loss properties of SiC. In view of the low energy loss, we implemented optimal traction motor design by taking the following measures:

(i) Rotor slot shape optimization
(ii) Increase in conductor cross-sectional area
(iii) Harmonic loss suppression
(iv) Use of low-loss materials

The result was a reduction of both fundamental wave loss and harmonic loss, lowering the entire traction motor energy loss due to heat generation by 51%, as shown in Fig. 6.

To reduce traction motor energy loss due to heat generation, the inverter responsible for driving the traction motor must be considered. Through the optimal current and voltage control using the characteristics of SiC devices, we have reduced the energy loss generated in the entire propulsion control system by 10%.

3.3 Application to actual projects

The inverter mounted with the all-SiC power module (Fig. 7) and the high-efficiency traction motor (Fig. 8) have been adopted by many railway operators. The results of actual railway vehicle test runs have shown that the electric power consumption of the entire vehicle has been reduced by approx. 40% compared to an existing vehicle equipped with GTO inverter control equipment.

4. Conclusion

We have described the characteristics of the latest power module using SiC devices. We have also

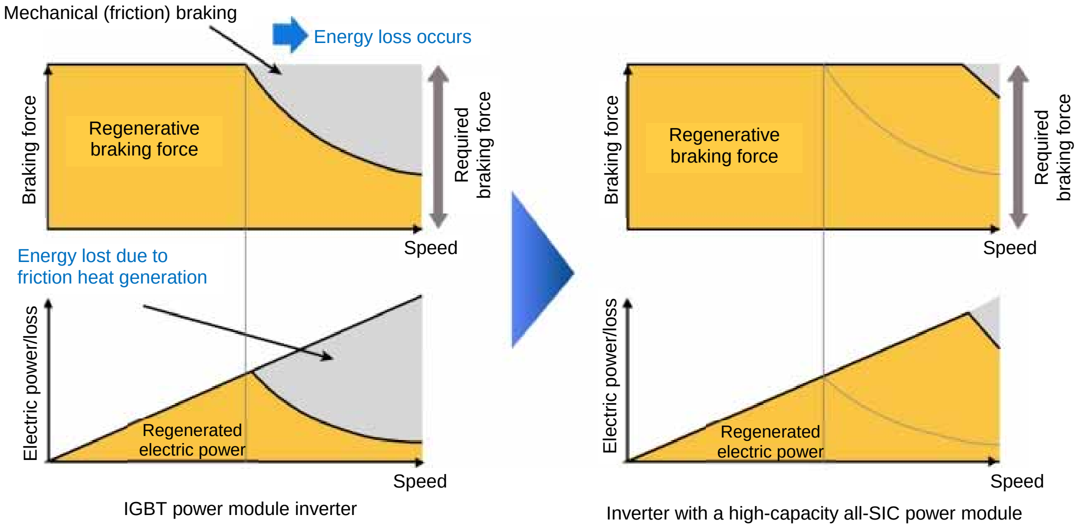


Fig. 4 Energy conservation by increasing regenerative braking in the high-speed range

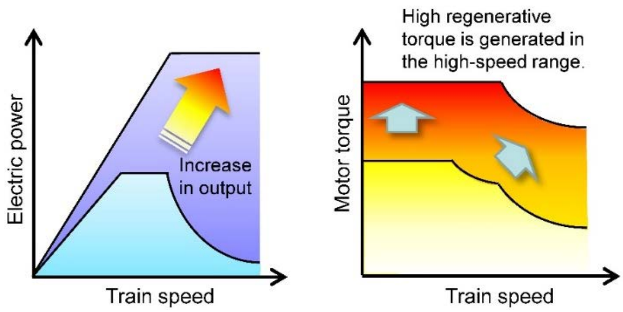
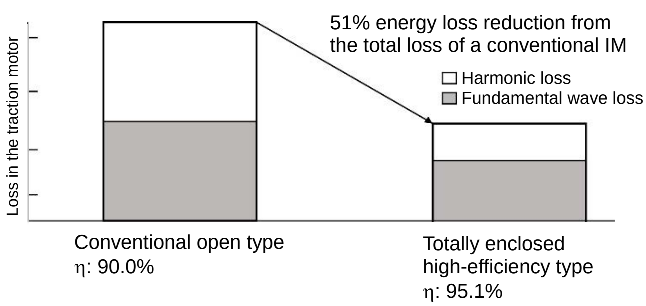


Fig. 5 Concept of increasing the output and torque of a traction motor

Fig. 7 Inverter with all-SiC power module



IM: Induction motor, η: Efficiency when the inverter is under actual loads

Fig. 6 Comparison of loss generated in a traction motor

Fig. 8 High-efficiency traction motor

explained the energy-saving technology in a propulsion system that combines the railway vehicle inverter mounted with the power module and the high-efficiency traction motor, together with the current status of actual project application.

Amid global efforts to conserve energy and reduce environmental impact, there are high expectations for railway systems, which may lead to increased use of propulsion control systems for railway vehicles. To make railways, which are a highly efficient means of mass transportation, even more environment-friendly, we will further improve the performance of the SiC power module and commercialize the propulsion control system that combines the railway vehicle inverter mounted with the improved SiC power module and the high-efficiency motor.

In developing the SiC power module, we used part of the research results commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

Up-to-date Communication-Based Train Control System Technologies

Authors: *Makoto Nagashima** and *Tatsuya Fukawa***

1. Introduction

Communications-based train control (CBTC) systems are being introduced mainly for subways and other urban transportation authorities in various countries around the world. A CBTC system involves establishing a secure link between the on-board controller (OBC) and wayside zone controller (WZC) via a radio unit to ensure the safety of train operation. According to the definition by IEEE 1474.1, which specifies CBTC functions, a CBTC system has the following characteristics:

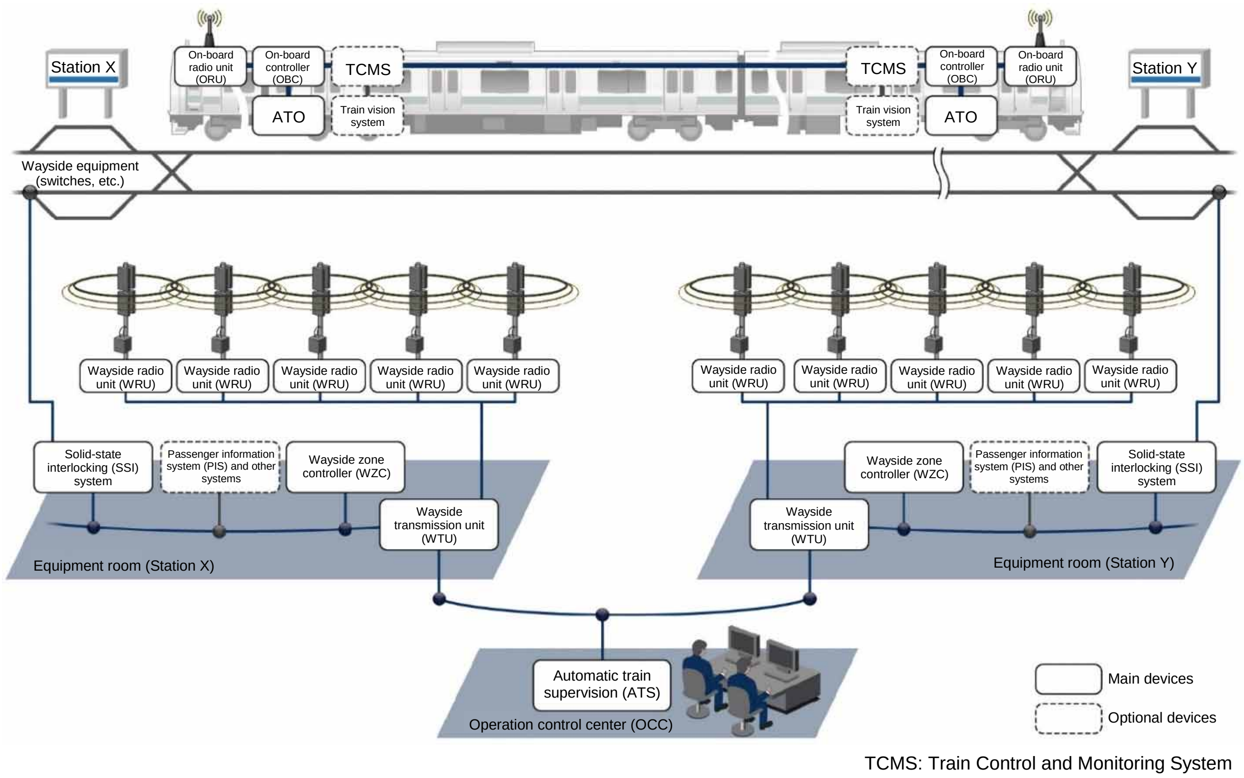
a) High-resolution train location determination, independent of track circuits
b) Continuous, high-capacity, bidirectional train-to-wayside data communications
c) Train-borne and wayside processors performing vital functions

IEEE 1474.1 defines a CBTC system in the context of automatic train operation (ATO) and automatic train supervision (ATS) functions, in addition to automatic train protection (ATP) functions.

Mitsubishi Electric Corporation has developed CBTC systems by using half a century's knowledge and experience in the design and manufacture of on-board controller for ATP systems, achievements in the field of train automatic operation systems and signalling systems, and wireless technologies used in various fields. This article presents an overview of the CBTC system and the anticipated effect, and describes Mitsubishi Electric's technologies used for the ATP, ATO, and ATS functions, which make up a CBTC system, as well as those for the radio subsystem.

2. CBTC System

Figure 1 shows a schematic view of the CBTC system generic configuration. The CBTC system consists of on-board controllers (OBCs), wayside zone controllers (WZCs), and solid-state interlocking (SSI) systems,



Standard configuration of a CBTC system
Mitsubishi Electric has a proven track record and expertise regarding each of the CBTC system's basic components, i.e., signalling devices (WZC, OBC, and SSI), radio units, ATO devices, ATS devices, and WTUs. We use a combination of assets to offer sophisticated CBTC systems of the highest quality.

Fig. 1 CBTC system configuration

*Itami Works **Kobe Works

arranged on both the trains and the wayside in order to implement the ATP functions. A wireless system consisting of on-board radio units and wayside radio units connects on-board and wayside. ATO devices for the ATO functions are also installed on the train, and ATS devices for the ATS functions are installed on the ground.

2.1 CBTC system train control

Figure 2 shows a schematic view of the train traffic control flow (safe train seperation control) using a CBTC system.

(1) Train location determination: The OBC calculates the position of the train based on the location information from the transponder and the speed information from the speed sensor.
(2) Data transmission (train location): The ORU transmits the train location information to wayside equipment.
(3) Train location supervision and movement authority setting: The WZC supervises all train locations on the lines based on the train location information transmitted by each train, and sets the movement authority for each subsequent train (limit within which a train is allowed to move).
(4) Data transmission (movement authority): The WRU transmits the movement authority to the ORU.
(5) Braking profile setting: The OBC sets the braking profile (curve that shows the upper limit of the speed that allows a train to stop before the movement authority by train position) starting from the movement authority.
(6) Brake control: The OBC constantly compares the speed of its train with the braking profile. Upon detecting a train speed exceeding the braking profile, OBC applies the brakes.

2.2 Effect of CBTC system introduction

(1) Reduction of wayside equipment

Conventional train control systems require the installation of signal equipment such as track circuits and signals along the rails for detecting train locations and controlling the operation. The introduction of a CBTC system eliminates the need for such equipment, thus reducing equipment, maintenance work, and life-cycle cost.

(2) Higher train traffic density

Conventional train control systems permit incoming trains for each track circuit (fixed block). In a CBTC system, the movement authority can be set at any position behind the preceding train, which allows a shorter interval between trains compared to that in a conventional train control system (moving block).

(3) Efficient route setting and cancellation

In a conventional train control system, when a route is to be cancelled while the following train is approaching, the cancellation must be waited a sufficient time for the following train to stop (approach locking). In contrast, in a CBTC system, the WZC can be informed by the OBC if the following train comes to a stop. Upon detecting that the following train is at a stop, the approach locking can be cancelled, enabling the next route to be quickly set. This can shorten the interval between trains, contributing to high-density operation.

(4) More useful fall-back operation in the case of failure

Conventional train control systems require the installation of signals, speed limit signal transmitters, etc. for each train travel direction. However, in a CBTC system, as long as wireless communication is established, the travel direction can be changed without restriction from the wayside equipment. Therefore, when a failure occurs on a track in a double-track section, single-track parallel operation that provides inbound and outbound train services using the other track alone can be easily carried out. CBTC systems thus allow for securing transportation despite a failure.

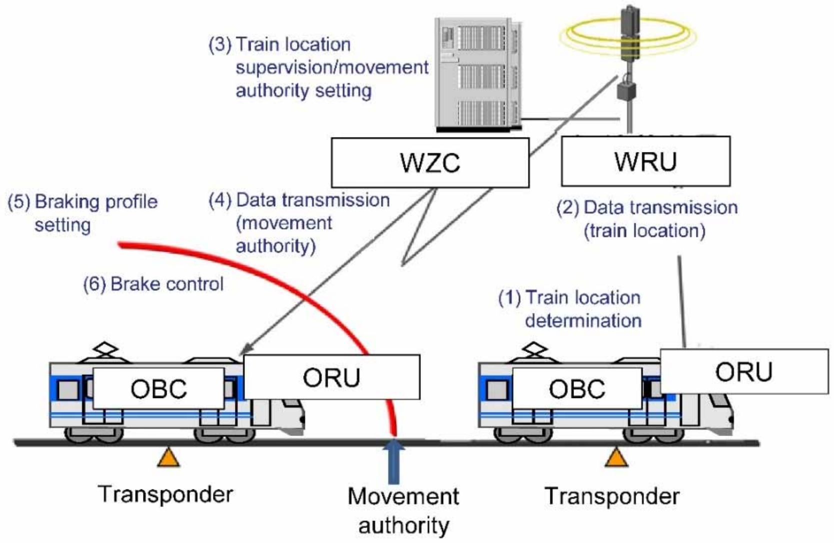


Fig. 2 CBTC system train control

3. ATP Subsystem

Our ATP devices to be applied to the ATP subsystem have obtained IEC SIL4 certification. Figure 3 shows a schematic view of the ATP system architecture concept that we apply. In the architecture, the same safety functions are carried out in parallel in system A and system B, and the control outputs of both systems are integrated at the final output unit. The processing statuses of both systems are compared at the diagnostics circuit. The comparison results are used to stop the system so that the control outputs can be secured. This architecture is used for both WZCs and OBCs.

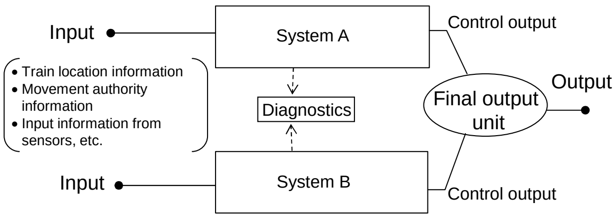


Fig. 3 ATP device system architecture

3.1 Wayside zone controller

Figure 4 shows the WZC appearance. In the case of random failure on the printed circuit board, the failed printed circuit board can be replaced in a system during operation. Ethernet[1] is used for the interface with other equipment for enhanced interconnection versatility.

Fig. 4 WZC

3.2 On-board controller

Figure 5 shows the OBC appearance. The controller adopts a compact standard 3U rack that can reduce the mounting space on the vehicle. Furthermore, to support conducting mutual direct operation and system change, the architecture allows a conventional train control system to be equipped in addition to the CBTC system.

Fig. 5 OBC

[1] Ethernet is a trademark owned by Fuji Xerox Co., Ltd. registered in Japan.

4. ATO Subsystem

The ATO subsystem is responsible for automatic train operation, i.e., departure, acceleration, deceleration, and stopping at stations under the protection of the ATP function. Our ATO function is capable of operating a train in a pattern with the optimum energy efficiency for running between stations within the specified time. Train operation on a revenue line in Japan using the energy-saving operation control function confirmed the reduction in power consumption compared with operation without the function. By linking with the ATS subsystem described in the next section, the workload on dispatchers and train operators can be minimized, while flexible train operation such as shuttle services can be provided.

5. ATS Subsystem

Basically, conventional ATS functions control train operation according to prepared timetables. However, using the accurate train location information and speed information provided by the CBTC system and combining the ATO functions achieve flexible train service in accordance with the current conditions regarding the line, train operation, and passenger load. The following functions are now being developed:

(1) Automatic high-density operation through group control of trains

When a train is delayed on a line without ample intervals between trains, all the following trains are likely to suffer from stop signals before the next station, resulting in snowballing delays. This phenomenon can be prevented by adjusting the start timing of the preceding train and instructing trains in an optimum running profile to avoid subsequent trains having to stop before stations, thereby equalizing the intervals between trains and preventing an increase in train delays. The implementation of this method essentially involves quick and accurate prediction of each train's movements, which has been made possible by Mitsubishi Electric's train operation simulation technology. Although conventional ATS functions include a similar function, its control accuracy is made higher by using accurate train location information and speed information obtained through the CBTC system.

(2) On-demand dispatching according to crowded/less crowded conditions

With passenger load information based on the number of persons who pass through the ticket gates or board the trains, the real-time passenger flow can be simulated. If the results deviate significantly from the planed number of passengers, quickly dispatching by increasing/decreasing the number of trains in operation, etc. can avoid train overcrowding as well as delays.

(3) Even headway controls without a timetable

In combination with the control functions described above, train services on a simple line can be provided without a timetable by specifying the number of trains operated per hour. The additional introduction of train depot automation allows for automatically increasing/decreasing the number of trains in operation as well.

(4) Linkage with other systems

By providing other systems with accurate train location information and speed information obtained through the CBTC system, more efficient and passenger-friendly train services are achieved. For example, a power management system enables forecasting of power loads based on the information, leading to flexible substation facility control. For a passenger information system, it is possible to guide passengers at a more accurate and appropriate timing.

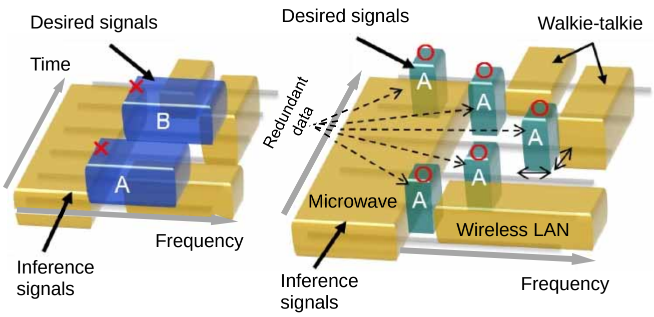
6. Radio Subsystem

The radio subsystem uses the 2.4 GHz band which is known as the industrial, scientific, and medical (ISM) radio band, which does not require a license and is convenient. The 2.4 GHz band ensures a wide frequency bandwidth and sufficient transmission distance, but requires the elimination of interference by wireless LANs, microwave etc., which operate in the same frequency bandwidth. To solve this issue, a communication method with improved interference immunity has been developed using our own technology for the radio subsystem, thereby achieving reliable and stable information transmission.

6.1 Communication scheme with improved interference immunity

(1) Interference avoidance function

The interference avoidance function controls the transmission signals and interference waves to prevent them from colliding with each other. Figure 6 shows a comparison of the concepts between a conventional scheme and the interference avoidance function. Since the conventional scheme takes time to send the transmission signals (desired signals) and occupies a wide frequency band, the transmission signals are likely to collide with the interference signals. In view of this, the newly developed scheme involves repeatedly transmitting signals in a shorter time for narrowed band occupancy while changing the frequency, and selecting on the receiver side a signal that has not undergone collision with an interference wave, thereby carrying out stable data transmission.



(a) Conventional scheme (b) Newly developed scheme

Fig. 6 Concept of the interference avoidance function

(2) Interference suppression function

In a radio wave environment with many interference sources, the above-described interference avoidance function alone may not be enough to receive all signals without fail. To maintain stable transmission quality under such conditions, we have developed an interference suppression function as shown in Fig. 7. The function involves measuring the interference wave power level first represented as (1) in the figure, and then calculating the coefficient corresponding to the measured interference wave power as (2). The coefficient is weighted such that the smaller the interference power wave is, the larger the coefficient becomes; after that, synthesizing the received signal by multiplying it by the coefficient allows for improvement of the S/N ratio of the received signal as (3).

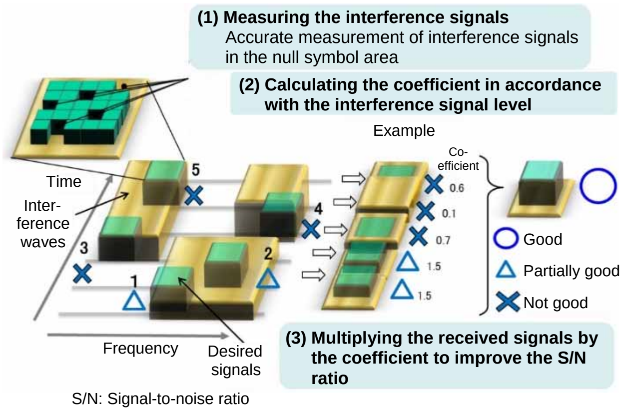


Fig. 7 Concept of interference suppression function

6.2 Radio wave environment monitoring function

Since the ISM band does not require a license, it is important to take measures for changes in the radio wave environment due to the start of a new radio service and other causes of an increase in wireless devices. The radio wave environment monitoring function has been provided to resolve such situations.

7. Conclusion

This article described our up-to-date CBTC technologies that are the future of train control systems. We will continue developing CBTC systems to provide railway authorities with sophisticated solutions that meet their needs.

Evolution of Railway Vehicle Maintenance Assistance Systems and TCMS

Authors: *Tetsuo Komura*, Eisho Ando** and *Yoshihito Takigawa**

1. Technological Changes in Maintenance Assistance Systems

Under abnormal conditions or during a periodic inspection, in order to quickly conduct a detailed analysis, it is necessary to collect as much real-time data as possible by using sophisticated devices that can handle large amounts of sampled data with shorter data sampling intervals.

The use of Train Control and Monitoring Systems (TCMSs) has allowed technological evolution in monitoring, ground-to-train communication systems, integrated train control, and high-capacity and high-speed transmission, realizing various breakdown maintenance (BM)/time-based maintenance (TBM) assistance functions that meet the needs of individual customers (Fig. 1).

1.1 Monitoring

The increase of on-board equipment that can transmit data by being connected to a TCMS has made it possible to recognize failures and other operation statuses of all equipment on a train. Accordingly, we are providing BM assistance functions for the train crew, such as condition monitoring and failure reporting.

1.2 Ground-to-train communication system

Monitoring has made it easy to identify a failure location and understand the incident that occurred. On the other hand, the advancement of vehicle systems has increased the amount of information available, making information exchange between the crew on board and command personnel on the ground complicated and cumbersome. A function for sharing vehicle monitoring information with command personnel is needed.

In response, we developed a ground-to-train communication system that transmits vehicle monitoring information to a wayside server via wireless communications. The system provides BM assistance functions that enable monitor screen transmission and troubleshooting assistance for command personnel, which contributes to early recovery from failure.

1.3 Integrated train control

At the request of railway operators and vehicle manufacturers, the role of TCMSs has expanded to integrated management of an entire train, in addition to monitoring, control, and data transmission regarding individual cars and equipment. For instance, the TCMS integrated management provides functions to assist in conducting predeparture inspections and periodic inspections at a train depot, shortening the inspection time.

1.4 High-capacity and high-speed transmission

The latest TCMS adopts Ethernet[1] transmission that allows high-speed communication with individual vehicle equipment in order to collect real-time data on equipment statuses and detailed data on failures. This has allowed the collection of a large volume of real-time information. The wireless communication networks used for the ground-to-train communication are public general-purpose high-speed wireless services such as Long-Term Evolution (LTE) offered by telecommunications carriers.

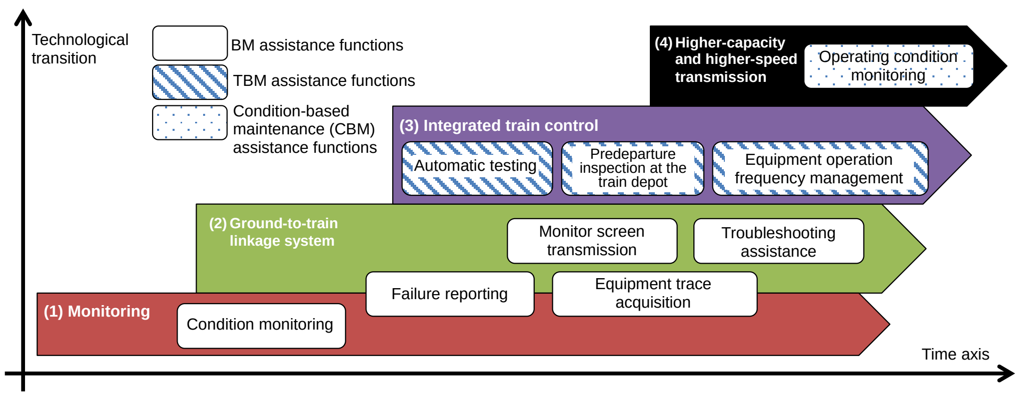


Fig. 1 Technological changes in maintenance assistance systems using TCMSs

[1] Ethernet is a trademark of Fuji Xerox Co., Ltd. registered in Japan.

*Itami Works

This has minimized the communication networks required by customers. However, for security, virtual private network (VPN) communication functions are used for general-purpose lines.

Using these technologies, we have commercialized a Wayside Monitoring and Diagnostic System (WMDS) (Fig. 2). The WMDS allows wayside facilities to obtain detailed operational data from on-board equipment, in addition to the provision of monitoring screen transmission and troubleshooting assistance. This has enabled more detailed and sophisticated analysis of the equipment status and failure. It also allows on-board equipment settings to be changed from the ground, reducing the workload on the train crew.

2. Latest TCMS Technologies

In pursuit of safety and passenger service improvement, TCMSs require a wide range of functions, not only for equipment monitoring and control, but also for energy-saving operation and maintenance assistance based on communication with wayside facilities (ground-to-train communication).

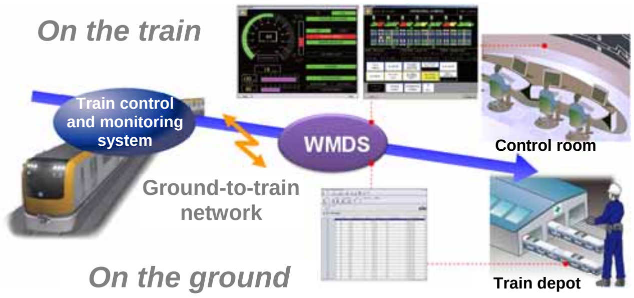


Fig. 2 Maintenance assistance using a WMDS

2.1 TCMS system configurations

Using high-speed transmission by Ethernet (100BASE-TX) to change the system from decentralized to centralized control, an entire train can be controlled without losing real-time capabilities. The characteristics of the system are described below.

(1) Computing functions are consolidated to the central control unit (CCU) for redundancy within a train.

(2) Ethernet is used to make up the transmission network, and a ring topology and dual homing are used for redundancy.

In conventional systems, different methods are used for data transmission between vehicles and that between equipment. As these mixed transmission methods have been standardized by Ethernet (100 Mbps), the terminals in each vehicle use communication nodes (CNs), which are specialized for packet forwarding and data transmission. All control functions and computing functions of a train are consolidated into the CCU. When an equipment-specific transmission method is required, protocol conversion for Ethernet transmission is performed at a CN (Fig. 3).

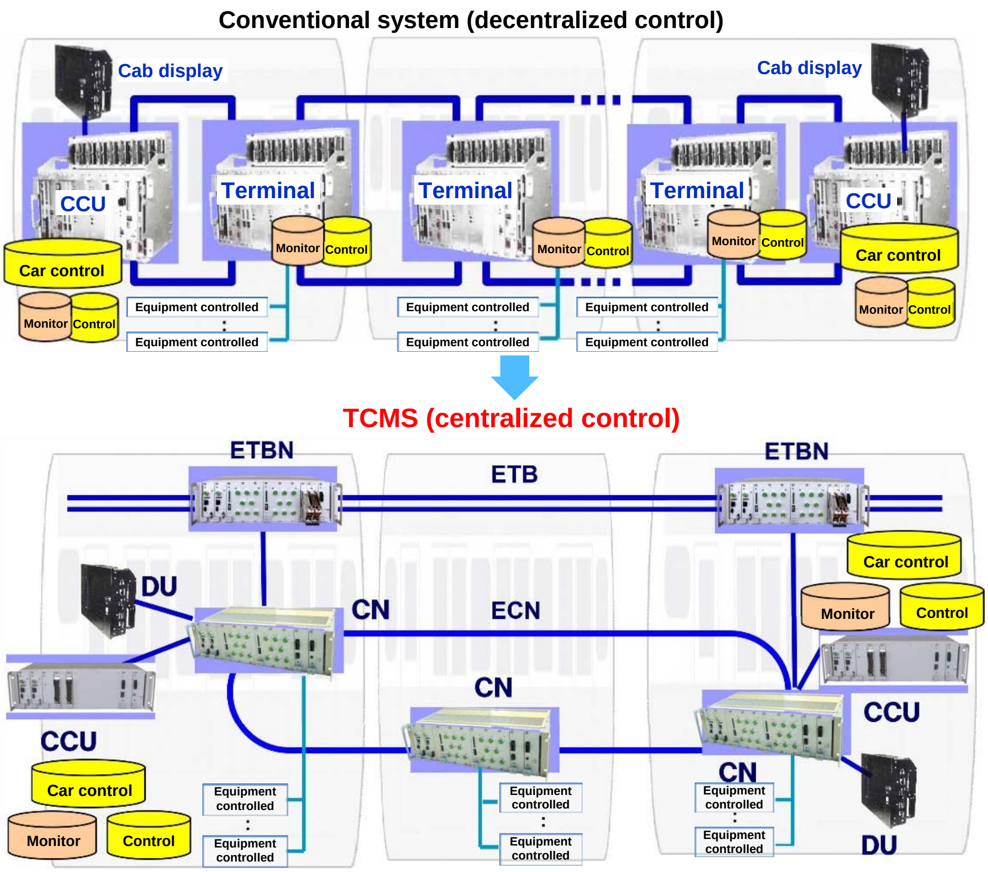


Fig. 3 Comparison between a conventional system and TCMS

International standards for the train communication network (TCN) architecture specify a two-layer structure consisting of the Ethernet Train Backbone (ETB) for data transmission between trains with a fixed car composition that prevents uncoupling and the Ethernet Consist Network (ECN) for data transmission in a train with a fixed car composition that prevents uncoupling. Table 1 shows a comparison between the TCN specifications defined in the IEC 61375 international standard and those used by Mitsubishi Electric. The TCN used in our TCMS adopts IEC 61375 compliant ETB and ECN. For the transmission protocol (including the format), IEC 61375-2-3 compliant Train Real-time Data Protocol (TRDP) is used for both ETB and ECN. Although it is not required to use TRDP for ECN, we have followed the market trend in which TRDP used in ETB is also applied to ECN (horizontal deployment) in order to secure versatility.

2.2 Open-source software

In response to the need for open-source software, we developed a failure database function in 1998, which has since been provided as standard for our systems for overseas. The failure database is compiled with failure-related functions separated from the programs. The following changes can be made to the database by setting parameters from a terminal in a wayside facility.

(1) Failure detection logic
(2) Types of signals to be recorded for data tracing
(3) Name of failure
(4) Troubleshooting guidance contents to be displayed on the driver cab screen
(5) Failure level (action level to be taken upon failure detection, such as only keeping a record or displaying the failure screen)

The latest TCMS follows the concept and allows a terminal on the ground to change the settings by entering parameters. Furthermore, in addition to software developed using conventional programming languages, a development environment using Programmable Logic Controller (PLC) tools is applied to the latest TCMS. The development targets using PLC tools are vehicle control logic, which was realized in a vehicle circuit by relay or wiring, and fault detection logic, which was conventionally modified in the database.

With the TCMS software replacing the circuits on a train that conventionally realize vehicle control logic, the number of wires and components used in the train is reduced, reducing the train weight. To obtain this benefit, the vehicle control logic is being incorporated into the TCMS. If PLC tools capable of creating logic highly compatible with and equivalent to the vehicle control logic are used, the TCMS software specifications must be disclosed.

The use of PLC tools allows railway operators to easily change the failure detection logic as well.

2.3 Train operation assistance using ground-to-train networks

The combined use of the TCMS and WMDS will enable more advanced train operation assistance functions in the future. These include a virtual cab function to reproduce the cab display in a wayside facility; a remote setting function to set parameters for a vehicle from a wayside facility; and an energy-saving operation assistance function to evaluate the actual running curve against the design running curve based on the per-vehicle energy information database, thereby creating a new design running curve (Fig. 4).

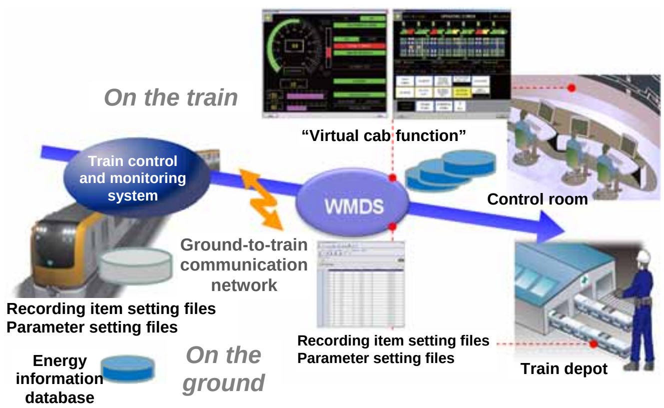


Fig. 4 Train operation assistance functions using a WMDS

Table 1 Comparison between the international standard and Mitsubishi Electric's TCN specifications

Layer	IEC 61375 Standard: Between trains with fixed car composition	IEC 61375 Standard: In a train with fixed car composition	Mitsubishi Electric: Between trains with fixed car composition	Mitsubishi Electric: In a train with fixed car composition
Application	At the railway operator's discretion		Applications considering availability for users	
Application profile	To be specified in IEC61375-2-4	Not specified		
Communication profile	IEC61375-2-3		IEC 61375-2-3 compliant TRDP	
OSI model layers 7–5: Application layer, presentation layer, and session layer				
OSI model layer 4: Transport layer	IEC 61375-2-5 ETB	IEC 61375-3-4 ECN	IEC 61375-2-5 compliant ETB	IEC61375-3-4 compliant ECN
OSI model layer 3: Network layer				
OSI model layer 2: Data link layer				
OSI model layer 1: Physical layer				

3. Integrated Control Using a TCMS-Based Network

By fully using our strength as a one-stop supplier of major electric equipment (for a TCMS, propulsion control, braking, protection system, etc.) to be installed on railway vehicles, we use consolidated information from individual equipment to a TCMS via a network under integrated management for train equipment control, offering the following added values.

(1) Energy conservation

(i) Higher operating efficiency of the motor and improved regenerative braking through the communication between the TCMS and the propulsion control and braking units.

(ii) Assistance for the driver in energy-saving operation using the expertise in automatic operation systems, propulsion control units, and traction motors. The TCMS displays energy-saving running curves and target speeds on the cab screen according to the traveling position on the route.

(iii) Improved efficiency of auxiliary power supply operation by a control method to stop auxiliary power supplies when they are operated in parallel and in a synchronized manner under light-load conditions made up based on their inherent characteristics.

(2) Improved maintainability

(i) Maintenance time shortened by simultaneously performing on-board testing on multiple equipment from the TCMS.

(ii) Failure prevention functions that involve accumulating long-term equipment condition information (leakage current, number of contactor activation times and blower activation times, etc.) in the TCMS and displaying replacement warnings for individual equipment based on the information.

4. Future Prospects

As the amount of equipment operation data that can be collected and stored increases, we anticipate an increasing need for more advanced equipment condition analysis and failure analysis for railway vehicle maintenance assistance systems in pursuit of more energy-saving and efficient railway vehicle maintenance.

4. 1 CBM through dynamic monitoring

The faster data transmission mentioned in Section 1.4 has allowed dynamic monitoring involving constant surveillance of the operating conditions of individual equipment. The TBM, which is currently prevailing, uniformly sets an inspection cycle for all equipment in operation to inspect and replace them accordingly. On the other hand, the CBM carries out replacement at the right time for each equipment (Fig. 5). We consider that this minimizes downtime due to failure, while maximizing the life of each equipment.

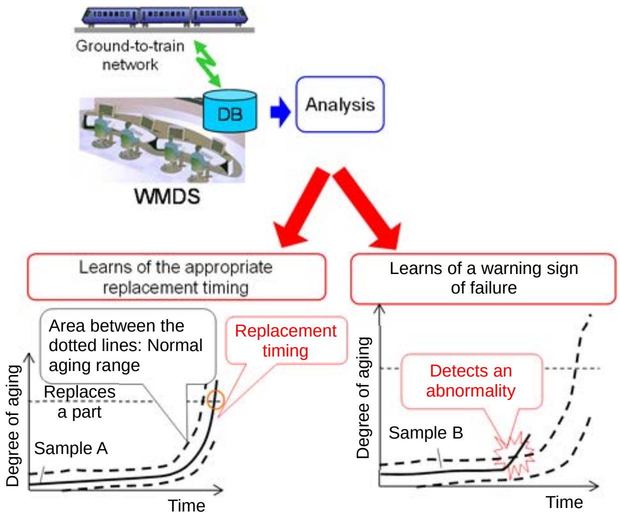


Fig. 5 Concept of the CBM

In the future, we will improve the statistical analysis of information on on-board equipment operation collected by a WMDS to learn of failure characteristics and failure signs in order to complete the CBM.

4. 2 Labor saving in inspections

The use of dynamic monitoring in TBM as well as CBM can save labor in periodic inspection work. We are considering a method that involves extracting data on equipment with similar load conditions or operating environments from the data accumulated through dynamic monitoring of individual equipment when conducting a periodic inspection, confirming the soundness of the extracted data, and using the data as the results of the periodic inspection.

5. Conclusion

We have described the latest technologies and future prospects of railway vehicle maintenance assistance systems using TCMSs and WMDSs, together with the progress of the ground-to-train communication technology behind the development.

We believe that the CBM will allow the optimum management of vehicle maintenance and vehicle life cycles, contributing to the provision of safer transportation and improved transportation services. As a one-stop supplier of systems for running, stopping, and controlling trains, we will develop technologies for the entire railway vehicle system including propulsion equipment and braking control equipment toward practical use of the CBM.

MITSUBISHI ELECTRIC CORPORATION