The 100-Year History and Future Perspective of Mitsubishi Transportation Systems

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1. Introduction

Mitsubishi Electric Corporation started transportation business in 1921 when the company was founded, and thus has a history of 100 years. Currently, the company provides a wide range of products for whole railway systems, from equipment for railway vehicles (equipment of the train system for running, stopping, and control) to ground equipment with power electronics, control, radio, and video technologies as the core (Fig. 1).[(1)] In the 1960s, the company expanded its railway business to overseas, and has now supplied products for more than 60,000 railway vehicles in 36 countries around the world.

Railway transportation is an eco-friendly high-speed mass transit system; it is a social infrastructure that supports economic growth. It is also regarded as an important means of mitigating various social issues such as overcrowded cities and environmental problems, thus helping to achieve the SDGs[*1] to create a sustainable society.

This paper looks at changes in the railway business and our core technologies cultivated in the last 100 years. It also introduces our technologies and product development that will pave the way for future activities to create new values towards achieving the SDGs.

2. Social Issues in the Railway Business in Japan and Overseas

Railway transportation is a safe and highly-reliable social infrastructure that is essential for societies today, such as for metropolitan railways, inter-city railways, and freight transportation.

In some industrial countries such as Japan and Germany, the population has started to fall. In Japan, in particular, the birthrate and labor force have been rapidly decreasing and the population has been dramatically aging. The Japanese railway business has been growing based mainly on passenger transportation as well as freight transportation. However, the population has been decreasing as society matures, and the industrial structure has been changing as it shifts toward the

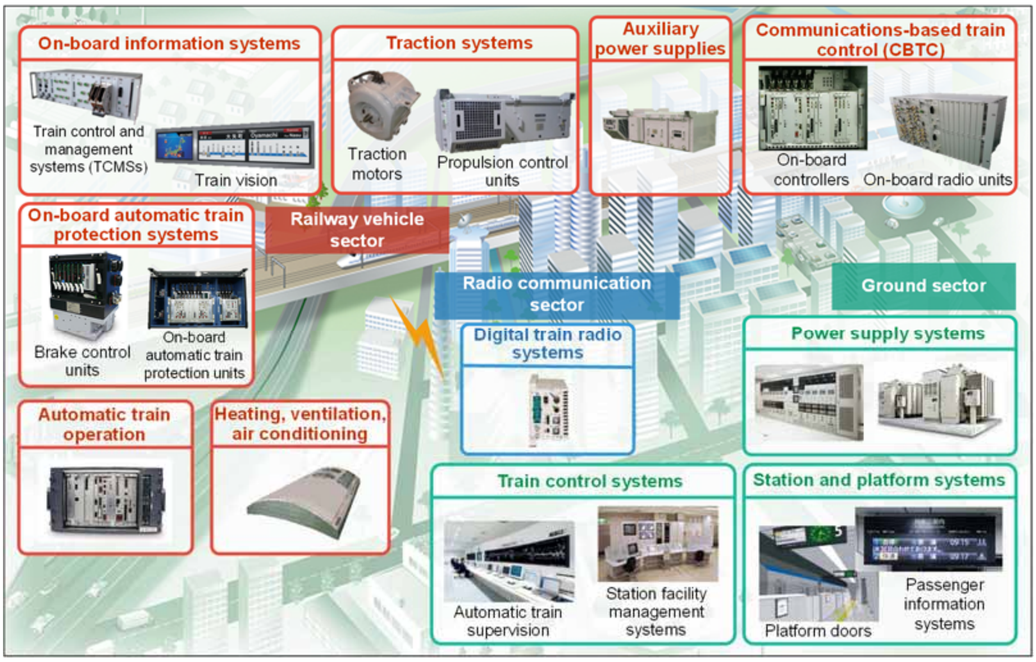

Fig. 1 Mitsubishi Electric's products and systems in the transportation business

*1 SDGs: Sustainable Development Goals

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tertiary industry; this may cause a structural decrease in railway transportation volume. In addition, demand for transportation may decrease due to changes in working style, such as the expansion of digitization and teleworking and a sharp decrease in passenger demand due to the recent COVID-19 pandemic, driven by the growth of the Internet community and infection prevention measures.

In response to such changes in the social environment, there is a pressing need in the railway business to improve business efficiency by promoting digitization and reducing operating costs. In addition to measures against the aforementioned energy and environmental problems, social issues related to railway transportation are becoming greater in scale and complexity. Examples of such issues are antiterrorism measures for the security of society, infrastructure maintenance and management, and preparation for large-scale disasters caused by global warming and global-scale climate change.

Overseas, in Europe, which is the center of railway technologies, regulations and systems, EU directives have been issued indicating a policy of separating railway operation (upper side) from infrastructure (lower side), and business efficiency has been improved based on the principle of competition since the 1990s. Policies for the railway sector are in line with economic policies such as the European Green Deal and Green Recovery. In addition, in emerging countries mainly in Asia where the focus has been on developing urban areas, metropolitan railways have been rapidly constructed and developed since the 2000s to solve urban problems, such as population concentration, traffic congestion, and atmospheric pollution. As new lines have been constructed, technologies such as CBTC[*2] and autonomous driving have been adopted and new maintenance systems and concepts such as CBM[*3] and asset management have been introduced.

In view of the changing railway business environment in Japan and overseas, social issues may be solved by applying new technologies in order to help achieve the SDGs, too.

3. Technology Bases in the 100 Years Since the Foundation of Mitsubishi Electric Corporation

It is considered that railway services started with railway transportation by Stephenson's steam locomotive between Stockton and Darlington in the U.K. in 1825. Electric railway services started with passenger transportation by Siemens & Halske AG in a suburb of Berlin, Germany in 1881.(2)

In Japan, railway services began between Shimbashi and Yokohama in 1872, while electric railway services began in Kyoto City in 1895—approximately ten years after that in Berlin—and thus have a history of more than 120 years.

Mitsubishi Electric entered the transportation business in 1921 when the company was established. It engaged in the electric railway business in Japan as a leading maker of technologies that revolutionized the field, such as AC electrification, technologies for Shinkansen, and induction motor drive, and the company has grown in line with the history of electric railways in Japan. This section looks at the history of railway technologies and Mitsubishi Electric's transportation business in each era.

3.1 From the foundation of Mitsubishi Electric (1921) to before the war: Technical cooperation with overseas companies

The 1920s, when Mitsubishi Electric was established, saw rapid industrialization in Japan. The company delivered electric components for railway applications from its founding year, such as transformers to the Ofuna Substation of the Japanese Ministry of Railways (1921), standard type traction motors for electric trains of the Japanese Ministry of Railways (1936), and Abt-system electric locomotives, and built up a strong track record. In addition, Mitsubishi Electric formed a technical tie-up with Westinghouse Corporation in the U.S. in 1923 and Westinghouse Air Brake Technologies Corporation in 1924; it learned new designs, drawing methods, engineering technologies, and factory management methods, which helped it modernize the company and enhance the technical level of its railway products.(3)

3.2 From after the war to the 1950s: Start of AC electrification and improvement in equipment performance

During Japan was recovering from the war, Japan National Railways (JNR) decided to promote AC electrification to increase the transportation capacity. Mitsubishi Electric delivered transformer units for AC electrification to JNR (1956) and developed and delivered prototype electric components with mercury rectifiers for AC electric locomotives (1956). AC electrification technologies led to technologies for locomotives for overseas markets and the Tokaido Shinkansen in the 1960s. During this period, performance was improved by development of the WN drive, reducing the weight of the traction motors and improving the acceleration and deceleration performance. We developed and delivered the first HVAC[*4] system for JNR sleeping cars (1950) and the

*2 CBTC: Communications-Based Train Control
*3 CBM: Condition Based Maintenance
*4 HVAC: Heating, Ventilation, and Air Conditioning

first electric components for DD50 diesel locomotives (1953).

3.3 1960s: Revenue Service of the Tokaido Shinkansen, pioneering radio and train control, and the start of overseas business

Japan rebuilt itself after the war during the period of high economic growth, and hosted the Tokyo Olympics. In the event of the Tokaido Shinkansen project, we were in charge of designing the main electric components for railway vehicles, and delivered them in 1963. In addition, the use of information and control systems, such as train radio (1960) and ATC*5 systems (1961), began. As our first business overseas, we exported ignition-rectifier AC electric locomotives for Indian Railways (1960) and then electric components for DC electric locomotives for Spanish National Railways (1966) (Fig. 2, Fig. 3).

3.4 1970s: Energy saving, computer control, power electronics, and choppers

In this era, computer control, power electronics, and energy-saving technologies advanced. We developed chopper systems for chopper-controlled railway vehicles (1970) and for the world's first chopper-controlled railway vehicles with regenerative brakes with thyristors, which were put into service from 1971.(4) Various technologies, such as reverse conductive thyristors, automatic variable field choppers, ebullient cooling, and four-quadrant choppers, were developed and chopper systems were adopted mainly for subways in cities in Japan. Mitsubishi Electric made its mark in this era as a manufacturer of chopper-controlled systems for urban traffic and exported chopper systems to overseas markets such as Mexico (we have received many orders, totaling 1,521 vehicles since 1979).

As ground equipment, Mitsubishi Electric developed thyristor inverter systems for electric power regeneration for the first time (1976). In 1981, Japan's first new transportation system with unattended operation using ATO*6 entered operation.

3.5 1980s to 2000s: Advancement of power devices, development of inverter-induction motor drive systems, and further expansion overseas

The Japanese economy recovered from the oil shocks and exports from Japan increased. In 1980, we held the Mitsubishi Transportation System Exhibition to promote our new inverter technologies to customers in Japan and overseas and accelerated development. In 1982, we supplied the first traction inverter systems for trams. Then, we worked for the high-voltage GTO thyristors (rated voltage of 4,500 V) and developed 1,500-V VVVF inverters for the first time (1984). Today, railway vehicles with inverters are standard for subway trains, electric trains for urban and inter-city lines, electric locomotives, and Shinkansen high-speed trains.

As various other countries developed their urban traffic transportation systems, we set up manufacturing bases for local production in Mexico, Australia, the U.S., and China and supplied products. We also rapidly increased exports to Spain, Singapore, Hong Kong, South Korea, Taiwan, Turkey, and India.

3.6 2010s to present: Promotion of SiC*7 inverters, ground-vehicle cooperation, railway LMS*8, and localization, and increase in the number of overseas customers

As power electronics technologies advanced, we commercialized SiC inverters for railway vehicles ahead of other companies (2012) and introduced the world's first SiC auxiliary power supplies (2013), realizing energy saving and smaller and lighter equipment. We also developed and commercialized CBTC systems that used information transmission technologies. In addition, we developed and introduced technologies to monitor the operation status of equipment through ground-vehicle cooperation and autonomous driving. Furthermore, as services to reduce maintenance work using IoT platforms, CBM, and asset management, we started providing LMS for railways (2019). Moreover, we have

Fig. 2 AC electric locomotive in India (in 1960)

Fig. 3 DC electric locomotive in Spain (in 1966)

*5 ATC: Automatic Train Control
*6 ATO: Automatic Train Operation

*7 SiC: Silicon Carbide
*8 LMS: Lifecycle Management Solution

developed a measuring vehicle MMSD[*9] that measures devices along railway lines and tunnels in detail. We have been continuing to develop technologies that help make the railway business more efficient.

Overseas, we established new production sites in Italy and India and promoted localization in Poland and Finland in cooperation with local companies. We increased customers in South America, such as Brazil, Chile, and Argentina as well as in Western Europe, such as the U.K., Germany, Italy, and the Netherlands.

This section looked at the trend of railway-related technologies for the 100 years since Mitsubishi Electric was founded in 1921. In all the eras, we promoted the railway business through strong cooperation with customers and applied the latest technologies in each era, such as power electronics, radio communications, and power transmission and distribution technologies, to railway infrastructure. We will keep advancing in the next 100 years by applying the latest technologies, such as AI[*10], sensors, and quasi-zenith satellites.

4. The Future of Mitsubishi Electric's Transportation System Technologies

Mitsubishi Electric handles all the functions of "running, stopping, and control" as a single company and proposes various types of products and technologies to satisfy diverse customer needs as a general electric machinery manufacturer. Our development and proposal activities are geared toward achieving the SDGs, which the entire staff have been actively working toward. The four solutions that will form the next-generation railway transportation system (Fig. 4) are: Eco-friendly and Environment; Maintenance and Asset Management; Safety, Security, Reliability, and Stability; and Autonomous Driving.

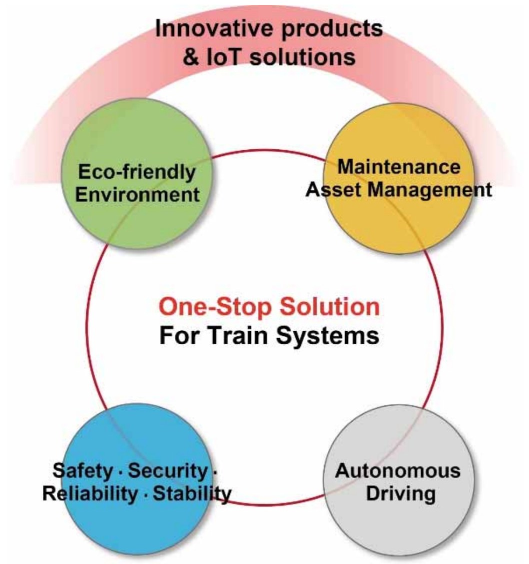

Fig. 4 Concept of the next-generation transportation system

4.1 Eco-friendly and Environment

A key target of our transportation business is to create a sustainable society and so we have focused on developing environmental and energy-saving technologies.

(1) The use of self-cooling (cooling method using traveling air and air convection) in propulsion control systems for railway vehicles reduces noise and enhances reliability, thus increasing maintenance efficiency and saving energy. Self-cooled converters, inverters, traction transformers, and traction motors are efficient, smaller, and lighter.

(2) One of our strengths is that we can propose optimum solutions for replacement projects and functional improvement and satisfy customer needs appropriately. We supplied traction transformers for French railways (SNCF) in a replacement project and IGBT inverter systems as replacements for chopper systems, achieving energy saving, lower noise, and reduced life cycle costs.

(3) For HVAC for railway vehicles in Europe, we have been developing low-GWP[*11] HVAC systems using a low-GWP refrigerant or a natural refrigerant (CO_2) to satisfy GWP regulations and help mitigate global warming.

(4) Our power semiconductor research/development and production sections cooperate on product development. We have developed SiC power modules ahead of other companies in the world, achieving higher efficiency, smaller size and weight, and energy savings of equipment for railway and electric sectors.

4.2 Maintenance and Asset Management

We have been promoting the LMS Platform, a total life cycle management solution for railway vehicles. The core of the LMS Platform is a TCMS[*12] that monitors the states of on-board equipment and manages them. In the LMS Platform, in addition to the TCMS, a WMDS[*13] for ground-vehicle cooperation, propulsion control unit, and other sub-systems are integrated. We will improve the efficiency of life cycle management in the railway business by providing various applications, and will propose optimum systems that realize customers' ideas, while also considering compatibility with existing systems.

In addition, in Japan, we provide railway vehicle maintenance solutions that help improve the business efficiency of railway operators and ensure safe and

*9 MMSD: Mitsubishi Mobile Monitoring System for Diagnosis
*10 AI: Artificial Intelligence
*11 GWP: Global Warming Potential
*12 TCMS: Train Control and Management System
*13 WMDS: Wayside Monitoring and Diagnostic System

stable train operation by using our proprietary IoT platform, which features Maisart*14, Mitsubishi Electric Corporation's AI technology.

4.3 Safety, Security, Reliability and Stability

We have been proposing flexible solutions that include cooperation between units on board and units on the ground to satisfy customers' diverse needs, providing safe, secure, stable, and reliable services. Video analysis that detects passenger attributes (e.g., a wheelchair) and suspicious substances enables prompt response. The PIS*15 with high-resolution screens notifies passengers of information accurately through universal design. In addition, we provide safe, prompt and stable services, such as estimation of load factors through cooperation between train operation management and PIS and information provision to contribute to the security of passengers and train crews.

4.4 Autonomous Driving

In the railway sector, research and development of autonomous driving has accelerated, and autonomous driving has been spreading in Europe in particular. We have been developing autonomous driving systems for the next-generation railway transportation system by leveraging our knowledge on the design and production of train protection and control units such as CBTC and ATO. We will also contribute to enhancing the performance of train control, for example, for more comfortable rides, higher stopping accuracy, and energy-saving operation, in addition to safe train operation.

5. Conclusion

This paper looked at the technical progress of transportation systems in the 100 years since Mitsubishi Electric was founded, and at future plans for its transportation systems. These activities allow us to adapt to recent social and environmental changes in the transportation business, while helping to attain the SDGs including recent countermeasures against infectious diseases.

In order to create the next-generation railway transportation system for a sustainable society, it is crucial to use Mitsubishi Electric's technical synergies and to apply new technologies through research and development. It is also important to cooperate with stakeholders and customers. We will establish a new eco-system together with railway operators, the railway industry, government and municipal offices, universities, and research institutions in Japan and overseas by using IoT platforms. We will work hard toward the next 100 years based on our achievements in the past 100 years.

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*14 Maisart: Mitsubishi Electric's AI creates state-of-the-art technology

*15 PIS: Passenger Information System