Development of Cutting-edge Railway Systems that Satisfy Social Needs

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HOW TO IMPROVE SAFETY, SECURITY, AND ATTRACTIVENESS OF RAILWAYS

RAILWAY infrastructure suffered significant damage during the Great East Japan Earthquake in March 2011, particularly the railway lines along the nation's east coast. Despite this severe and widespread damage, the disrupted railway network has largely been restored thanks to the efforts by the affected railway companies, except for lines identified as in need of further investigation for reasons such as their role in local recovery plans. There have even been stories of residents along restored railway lines turning out to show their support by welcoming the return of the trains. Not only are we greatly encouraged in our role as staff involved in railway systems development, we can also feel that people have high expectations of us.

It also reconfirms the importance of developments that make railways more attractive, not only to make railway systems safer and more secure, but also so that more people choose to travel by train.

Hitachi is engaged in continuous development, extending from signalling and control technologies that help achieve safety and security to rolling stock technologies that address the problem of global warming, power supply system technologies, transportation control systems that support reliable transportation services, and information systems that operate in conjunction with these transportation control systems to provide railway users with accurate information.

While the forms taken by railway systems tend to be different depending on the areas they serve, there are growing demands for technology to comply with global standards and the extent of this compliance is becoming an important consideration.

OVERVIEW OF TECHNOLOGY DEVELOPMENT AND KEY FIELDS

As a total railway systems integrator, Hitachi is developing cutting-edge technologies that underpin advances in systems needed to satisfy changing social requirements. Hitachi is globally deploying such technologies as reducing the weight of rolling stock so that it will be more energy efficient, making improvements to comfort, and encouraging the reuse of parts and materials to improve environmental performance. Hitachi is also seeking to make electrical components more energy efficient and is working continuously on developments such as technology for smaller size. For signalling systems, it is aiming to make wayside systems lighter and is developing and implementing wireless signalling systems that are less vulnerable to disasters, less work to maintain, and able to cope with high railway traffic density. In the field of electrical conversion systems, Hitachi is commercializing systems that utilize regenerative electric power.

For transportation control systems, Hitachi is making improvements to fault-tolerant technology and developing technology for interoperation between different systems to satisfy the demands of railway operators and make continuous improvements to railway services. Hitachi has also commercialized maintenance technologies for railway systems and made progress on improving the associated inspection techniques. In response to the need that has arisen in recent years to predict various railway system performance characteristics, Hitachi is improving the functions and performance of existing evaluation systems and developing technologies that can perform precise assessments, including of the energy efficiency and headway[a] of railway systems (see Fig. 1).

(a) Headway
The headway between consecutive trains on a railway line. While the headway between trains is kept above a minimum time for safety reasons, it is also possible to shorten the interval within this constraint by various means, including varying the train speed. Shortening this minimum headway allows trains to run closer together and increases the volume of passengers or goods carried per unit of time.

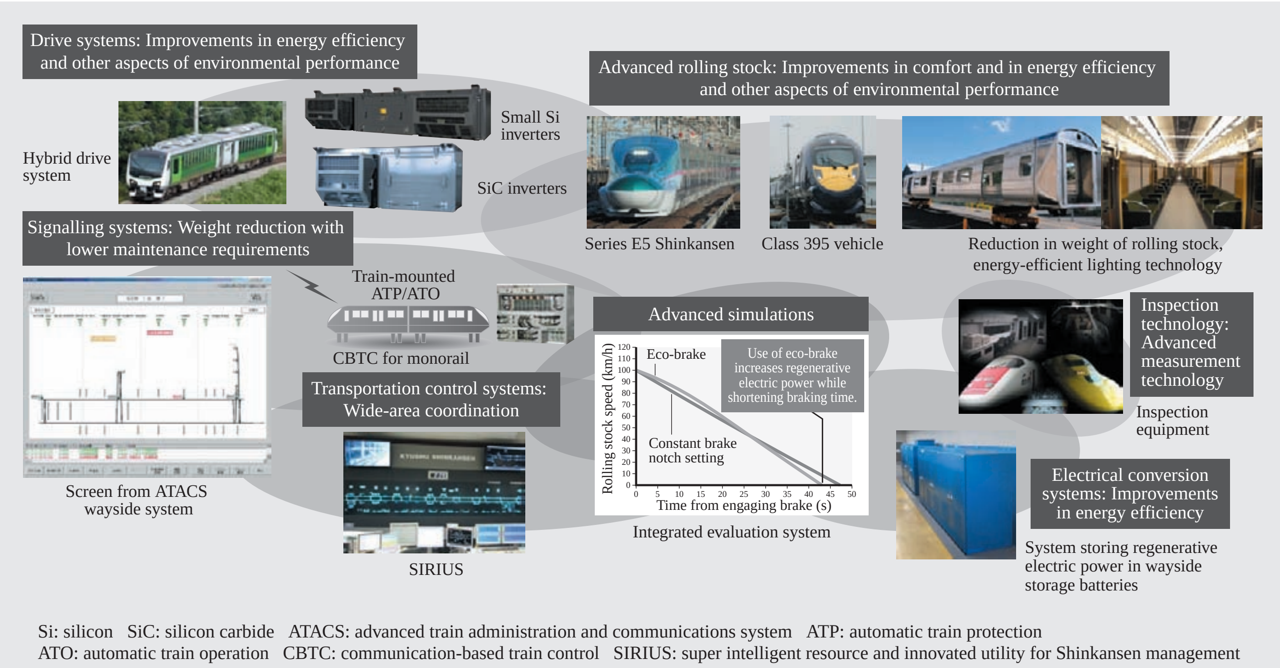


Fig. 1—Latest Railway Systems that Satisfy Social Needs.
As a total railway systems integrator, Hitachi is responding to the changing requirements of society by developing and implementing technologies that underpin advances ranging from rolling stock systems to wayside control and information systems.

TECHNOLOGY DEVELOPMENT AND GLOBAL DEPLOYMENT OF ROLLING STOCK SYSTEMS

Hitachi is working continuously on the development of technology for Shinkansen and conventional trains. Hitachi has been devoting considerable effort for some time to developing technology for its A-train[(b)] conventional rolling stock, and uses friction stir welding (FSW)[(c)] in both its conventional and Shinkansen trains to achieve an attractive and smooth carbody finish. Progress is also being made in areas such as modular designs to reduce the weight of rolling stock while also facilitating the reuse of parts and materials. To improve energy efficiency, Hitachi has adopted light-emitting diode (LED) lighting in recent years. This has gone beyond merely replacing the light fittings, and has included the development of technology for delivering the required light levels with consideration of safety,

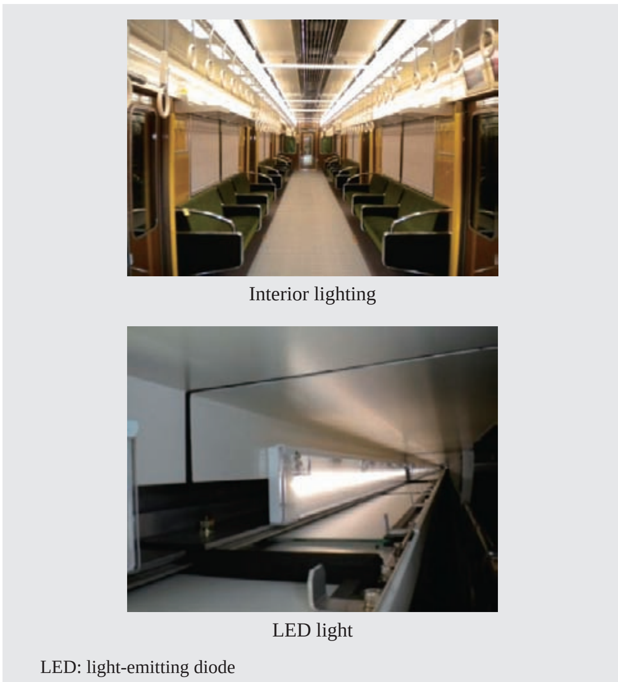
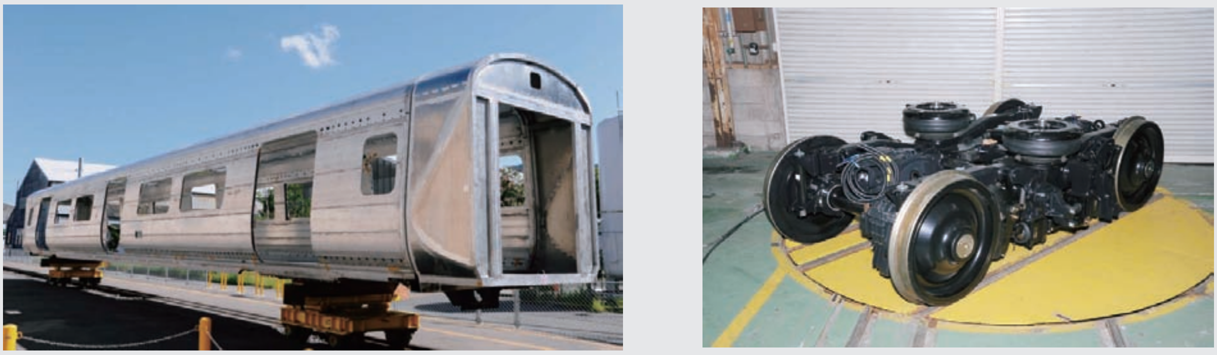


Fig. 2—Indirect LED Lighting in the Series 9000 Trains Supplied to Hankyu Corporation (New Vehicles).
Hitachi was the first supplier to offer full LED interior lighting in December 2010.

(b) A-train
A rolling stock system developed by Hitachi that features a modular production system and use of an aluminum double-skin body structure. "A-train" stands for "advance," "amenity," "ability," and "aluminum." In addition to dividing rolling stock up into separate modules based on function, adopting the A-train aluminum double-skin body structure, which does not require a frame, results in a rolling stock system that is simple and light while maintaining high quality. It also has excellent recycling characteristics and is achieving increasing success in Japan and elsewhere as a form of rolling stock that places only a light burden on the environment.

(c) FSW
Abbreviation of "friction stir welding." A welding technique that works by moving a rotating cylindrical tool along the materials to be joined to generate heat through friction. As the material being welded does not actually melt, FSW results in less strain and distortion in the weld than occurs with melt welding. Other advantages include high weld strength, fewer bubbles, cracks, or other defects, and that the weld surface and rear surface remain flat.



(a) Body structure (b) Lightweight inner frame bogie

Fig. 3—Key Components of Global A-train.
Hitachi intends to achieve further cost and weight reductions in the global market.

lower power consumption, and ease of maintenance. Key developments have included expanding the spread of light emitted by LED lights from 120° to 170° or more, and the design of lights with a life of 100,000 hours by devising circuit and board designs that are resistant to influence by heat (see Fig. 2).

In the shift to global markets, Class 395 rolling stock based on A-train technology has already been supplied to the UK and these trains have been in commercial operation since 2009. To contribute to advances in railway systems around the world, Hitachi is also working on achieving local certification, lighter weight, better energy efficiency, and easier maintenance. With the aim of maximizing both the flexibility and standardization of rolling stock operating at speeds from 160 km/h to 225 km/h, Hitachi is seeking to reduce costs through local production and is developing lightweight inner frame bogies (see Fig. 3).

Hitachi has also commercialized equipment for track inspection cars. This has included products for measuring rail displacement and wear in overhead wiring, for example. The Doctor Yellow (unofficial name) product for the Shinkansen incorporates inspection equipment able to perform measurements at the operating speed of 270 km/h. To meet the need for continuous monitoring of equipment, Hitachi is working on the commercialization of small measurement instruments able to be fitted in operating trains.

EFFICIENCY IMPROVEMENT FOR TRACTION SYSTEMS

Hitachi has developed traction systems that can make effective use of regenerative electric power both on electrified and non-electrified railway lines, and was the first in the world to commercialize a hybrid drive system for diesel passenger trains. This system uses a series hybrid drive[d] developed in collaboration with the East Japan Railway Company. Hitachi has confirmed this system can achieve energy savings of 15% or more (depending on the nature of the railway line on which the train is traveling) by conducting simulations for a wide range of conditions. Another

(a) (b)

Fig. 4—Train-mounted Parts of Control System for Expanding High-speed Operating Range of Regenerative Braking.
The train-mounted equipment includes 16 lithium-ion battery modules (a), a chopper [(b)-front], and a main smoothing reactor (MSL) [(b)-rear].

(d) Series hybrid drive
Hybrid drive systems combine two different power sources, such as an engine and electric motor. In series hybrid drive systems, these power sources are mounted in series. The engine drives a generator to produce electric power, which is stored temporarily in a secondary battery. The electric power is then used to turn an electric motor, which drives the train. During braking, the regenerative electric power produced by the drive motor is also used to charge the secondary battery.

Fig. 5—Inverter for Additional Series E233-3000 Units.
Both the external dimensions and mass have been reduced by 20% or more compared to the previous units.

benefit of using series hybrid drive is that it simplifies the mechanical design and reduces the amount of maintenance work required. Since installing the drive system in the Series Kiha E200 trains used on the Koumi Line of the East Japan Railway Company in 2007, it has also been used on the Series HB-E300 resort trains, which entered commercial operation in 2010.

A system that Hitachi has commercialized for electric trains returns regenerative electric power produced during braking to the overhead lines so that it can be used to drive other trains. However, problems such as regenerative braking becoming non-operational can occur if no trains able to use the generated power are nearby. To allow regenerative electric power to be utilized even under low-load conditions, Hitachi has developed a system where secondary batteries are installed on the train to store regenerative electric power for subsequent use. Also, because the extent of regenerative braking is restricted at high speeds due to the motor output characteristics, Hitachi is developing a system that extends the operating range of regenerative braking to higher speeds by installing secondary batteries in the train and increasing the direct current voltage of the inverter. Fig. 4 shows photographs of the batteries and other equipment. Field testing has confirmed that higher voltages result in a higher level of regenerative electric power.

Hitachi is engaged in ongoing development aiming at making the electrical components of drive systems smaller and more efficient. In the case of additional rolling stock for the Series E233-3000 trains supplied to the East Japan Railway Company, both the external dimensions and weight of the new units were more than 20% less than earlier units (see Fig. 5). Meanwhile, the development of highly efficient totally enclosed induction motors that do not require internal cleaning and are 30 dB quieter than previous motors has increased the efficiency of the traction motors to 95%. Hitachi has also developed 3.3-kV silicon carbide (SiC) hybrid modules[(e)] and built power units with a simple two-level design that are able to operate with 1,500-V overhead lines, reducing inverter losses by 35% (see Fig. 6).

For markets outside Japan, Hitachi has developed a high-output drive system for use in high-speed trains in China in which four 615-kW electric motors are controlled in parallel by combining rolling stock, motors, a main converter, and other components based on European technology. This system is currently undergoing operational trials. Hitachi intends to continue working on improvements in energy consumption and efficiency, taking account of both environmental considerations and the demands of the global market.

ENHANCEMENTS TO WAYSIDE CONTROL SYSTEMS AND ENERGY EFFICIENCY OF ELECTRIC POWER SYSTEMS

The major wayside control systems developed and implemented by Hitachi include transportation control systems, systems for supplying trains with electric power, and signalling systems.

Fig. 6—Inverter Built Using SiC Hybrid Modules.
The losses of the inverter power unit were reduced by 35%.

(e) SiC hybrid module
Power modules for rolling stock inverters that combine 3.3-kV SiC Schottky barrier diodes (SBD) and silicon (Si) insulated-gate bipolar transistors (IGBTs). Interest in SiC as a material has come about because SiC circuit elements have a lower resistance than those made using Si, which means that power modules can be made smaller with simpler cooling systems.

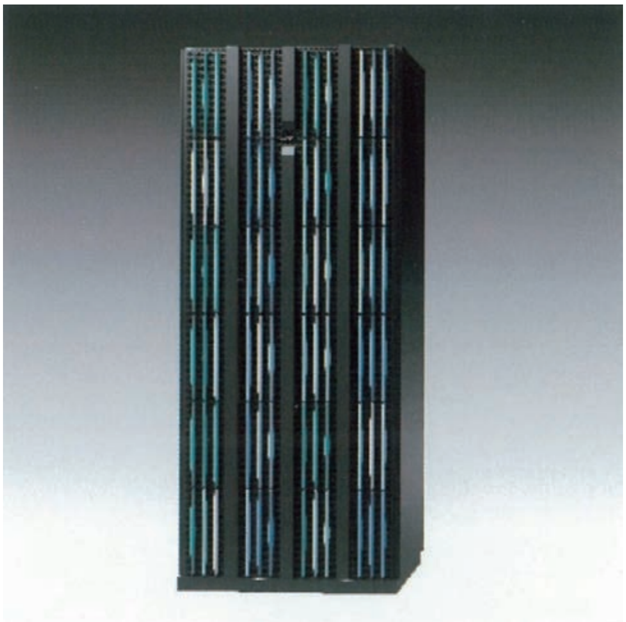


Fig. 7—CF-1000/FT Fault-tolerant Model of Realtime Server.
A loosely coupled architecture with four-fold redundancy is used to achieve high availability and data reliability.

In addition to having developed and installed a wide range of transportation control systems for a variety of different railway lines in Japan, Hitachi also undertook development work aiming at system interoperation between Kyushu Shinkansen and Sanyo Shinkansen services to coincide with the introduction of through trains. The main objective of this development work was to coordinate operation through the exchange of various types of information, including operational functions such as primary and modified timetables and train movement records. The newly developed fault-tolerant models adopted for this work use a loosely coupled(f) architecture with four-fold redundancy. The system is operating successfully, providing high availability and a high level of data reliability (see Fig. 7).

In the field of signalling systems, Hitachi was the first company in Japan to implement an automatic train control (ATC) system that works by transmitting digital data along the rails. Hitachi is also engaged in ongoing development of systems that use space-wave radio transmission and has implemented a wayside control system for an advanced train administration and communications system (ATACS) supplied to the East Japan Railway Company. For ATACS, Hitachi was the first to implement a moving block control system (system for preventing collisions between trains) based on positioning data acquired on the trains. This included developing four ground controllers and equipment for controlling field terminals on approximately 18 km of railway line, and also equipment for tracking the locations of trains on the line. The system entered service on October 10, 2011, and continues to operate successfully (see Fig. 8).

Fig. 8—Fail-safe Ground Unit for ATACS.
The ground controller (left) is used for train interval control and the train existence supervision server (right) is used to manage the position of trains on a railway line.

(f) Loosely coupled
In the context of systems that involve the interoperation of multiple processors, application software programs, and other components, "loosely coupled" means that the individual components have a high degree of autonomy. This allows the creation of systems with high availability because the limited degree of mutual interdependence means that problems in particular components do not influence other parts of the system. In contrast, systems in which the components have a high degree of interoperation are called "tightly coupled."

Fig. 9—System Storing Regenerative Electric Power in Wayside Storage Batteries on Seoul Metro9 Subway.
The system is expected to deliver greater energy savings than initially predicted and has demonstrated its ability to cut peak electric power demand.

In the field of wireless signalling systems for use outside Japan, Hitachi has developed and installed a total communication-based train control (CBTC) system for a monorail in Chongqing, China. The scope extends from wayside equipment to vehicle-mounted equipment and wireless systems. Because the system includes a moving block control system that acquires positioning information from the monorail vehicles, its features include the establishment of predetermined block sections in case wireless communications are interrupted as well as measures for making wireless communications more robust. The system is contributing to public transportation in Chongqing, with a configuration that supports both driverless operation and intervals of as short as 120 seconds between monorail vehicles.

To supply trains with electric power, Hitachi has developed the system storing regenerative electric power in wayside storage batteries. The system was installed at the Itayado substation on the Seishin-Yamate Line of the Kobe City Subway in 2007. The systems supplied to two substations on Seoul Metro9 subway in South Korea also commenced operation in 2011 (see Fig. 9). While total annual energy savings for one of the substations was predicted to be 510 MWh, the actual savings reached 94 MWh in the first month alone, indicating that the system may prove even more effective than initially estimated. The energy savings provided by the system continue to be assessed, and it has also demonstrated its ability to cut peak demand by reducing rush-hour energy consumption.

There is growing demand for the ability to predict factors such as energy consumption and transportation capacity in order to achieve energy efficiency across entire railway systems. Hitachi has developed simulators in the past for estimating power consumption that it has used in engineering, and it has now developed integrated evaluation systems with enhanced functions and performance to meet these needs. In addition to estimating power consumption based on planned timetables, these systems have been enhanced to predict factors such as transportation capacity and power consumption as well as to evaluate optimum run curves for achieving energy efficiency (see Fig. 10). Hitachi has also developed submodules in response to demands such as for operational support functions that assess run curves to achieve more energy-efficient operation. These modules can be combined as required to perform the desired assessments. Hitachi intends to continue enhancing simulation functions so that it can respond accurately to demand for the evaluation of different types of railway systems.

DEVELOPMENT OF TECHNOLOGY TO RESPOND ACCURATELY TO NEEDS

In addition to their use for underground, monorail, and other urban transportation services, railways are also valuable for being a means of medium- to long-distance transportation with an extremely low impact on the environment. For the future, it is also important to satisfy the expectations of society by making further progress and developing technologies for improving railways' attractiveness to users so that they can remain a vital form of urban and intercity transportation, and by achieving an appropriate division of roles with other modes of transportation such as automobiles, buses, aircraft, and shipping.

Countries in the world are engaging in a variety of technology developments with the aim of achieving sustainable societies. Rather than just seeking to improve energy efficiency, this involves considering, from a wide range of perspectives, the question of what sort of future societies people should be aiming for at the level of regions and entire societies.

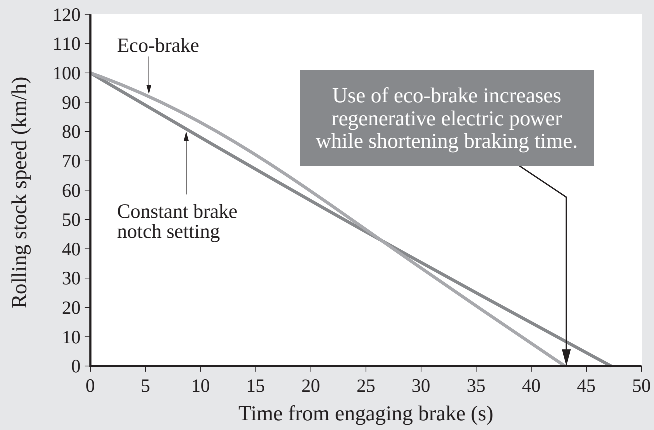


Fig. 10—Example of Brake Notch Optimization during Deceleration.
These results show how use of the brake notch settings can affect braking time and the amount of regenerative electric power.

Hitachi intends to obtain an accurate grasp of these trends in the progress of societies, and to continue engaging vigorously in technology development to respond accurately to the demands placed on railways by combining technologies from throughout Hitachi.

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