May 2024 Technical Information

Innovation for Advancing with Customers: Green Energy & Mobility

Research & Development

#Carbon Neutral #Innovation Creation #Co-creation and Open Innovation #Sustainability #Generative AI #IoT/Data Utilization #Research & Development

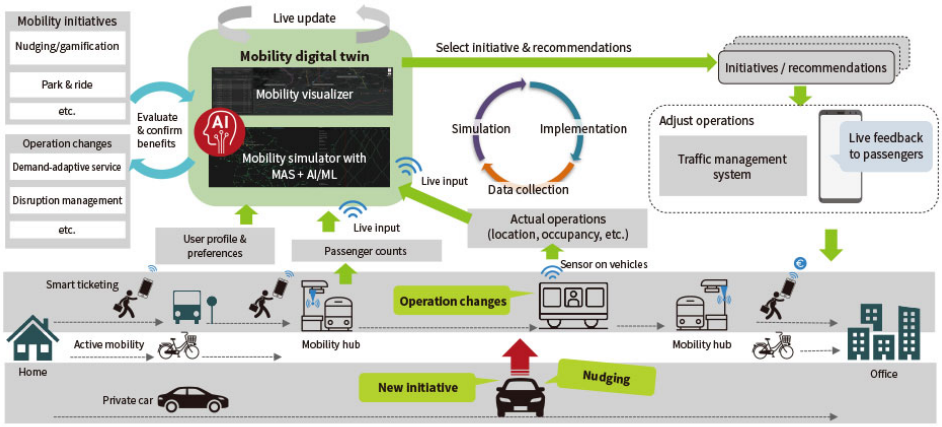
1. Digital Twin for Green Mobility—People and Traffic Flows Simulation

While European society is moving towards green mobility, there is a need for mobility digital twins that can monitor the current situation and predict in near real-time the operational aspects of public transport as well as people's journeys, enabling better transport services and encouraging a modal shift to a more sustainable travel mode.

Hitachi has developed a mobility digital twin that combines a Multi-Agent Simulation (MAS) technique with Artificial Intelligence(AI)/Machine Learning(ML) and visualization. The digital twin monitors and updates itself dynamically every 10 to 20 minutes for better prediction of the flows of both people and traffic, based on a new dataset obtained periodically from sensors installed on public transport vehicles. Hitachi's simulator can work in near real-time to predict travel demands, the location and occupancies of public transport vehicles in an entire city. In addition, the digital twin has a flexible framework and can incorporate passengers' individual behavioral aspects, such as preferences, and hence is an enabler for any green mobility initiatives.

(Hitachi Europe Ltd.)

[01] Conceptual framework of the system of mobility digital twin to support green mobility



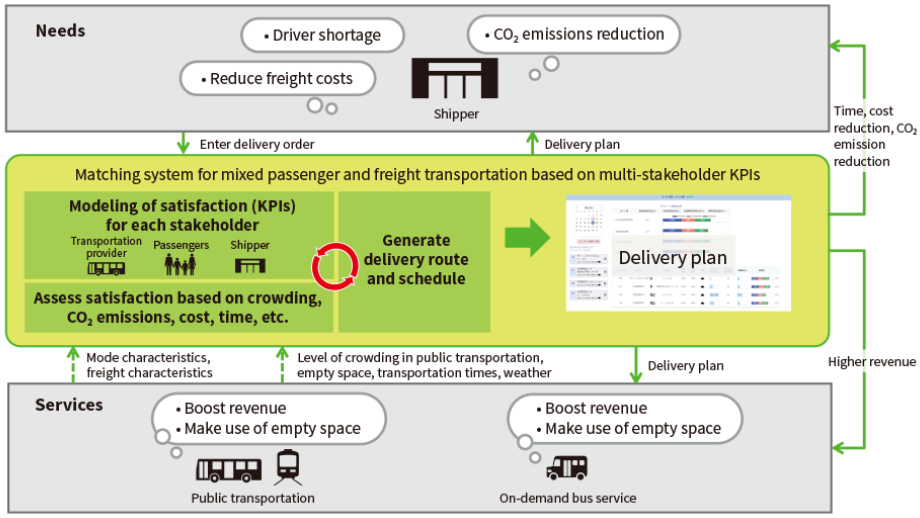
2. Matching System Based on Multi-stakeholder KPIs for Multi-modal Transportation of Both Passengers and Freight

The distribution industry is facing challenges that include ongoing increases in freight volume and a shortage of drivers due to Japan's "2024 problem" (restrictions on driver working hours). On the other hand, public transportation such as buses and trains are finding profitability harder to maintain as changing working styles lead to more people working from home. These developments have attracted interest in mixed passenger-freight transportation services that match passenger transportation providers with opportunities to carry freight. A potential downside of doing this, however, is that it will increase passenger discomfort during peak times and lead to fewer people using transportation services.

What is needed, then, are operational plans that increase the overall level of satisfaction without compromising the satisfaction of any particular stakeholder group. Accordingly, Hitachi has developed a matching system for mixed passenger and freight transportation that models key performance indicators (KPIs) for passengers, shippers, and transportation providers to identify the optimal means of transportation for items of freight.

In the future, Hitachi intends to address the driver shortage facing freight businesses and to contribute to decarbonization by further developing the technology with a view to its commercial deployment.

［02］Block diagram of matching system for mixed passenger and freight transportation based on multi-stakeholder KPIs



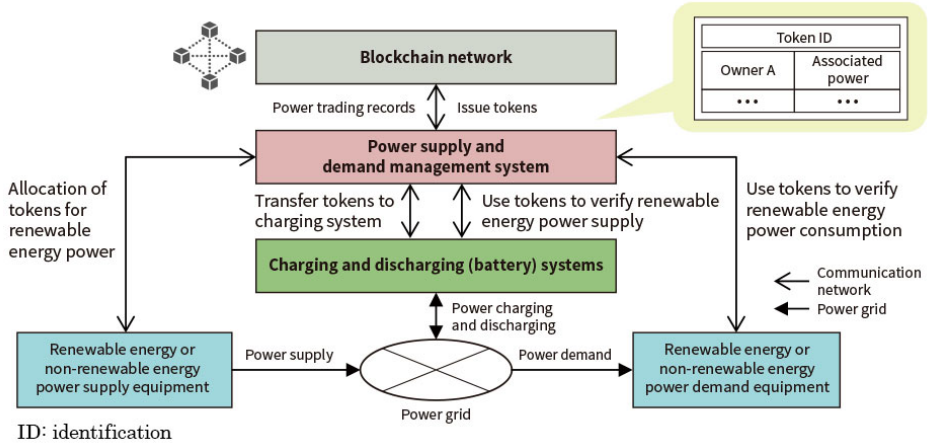
3. Power Supply and Demand Management Service for 24/7 Carbon-free Energy

As part of efforts to reduce greenhouse gas emissions, practices are being adopted for the 24-hour/365-day time-increment management of the use of power generated from photovoltaic, wind, and other renewable energy sources. This requires the efficient use of renewable energy power through power trading by market participants in fine-grained increments as well as identifying when renewable energy power is being used.

To achieve this, Hitachi is working on the research and development of a traceability technique that uses blockchain and allocates tokens for renewable energy use to track when supplied power was generated from renewable energy sources. To reduce the risks associated with handling differences between planned and actual power supply that are inherent in fine-grained power trading, a technique is also being developed to assess power supply reliability for each time increment.

In the future, Hitachi plans to further develop the technology with a view to its commercial deployment and to offer high-level services for power supply and demand management for retailers, users, and suppliers.

［03］Traceability technique for renewable energy power trading



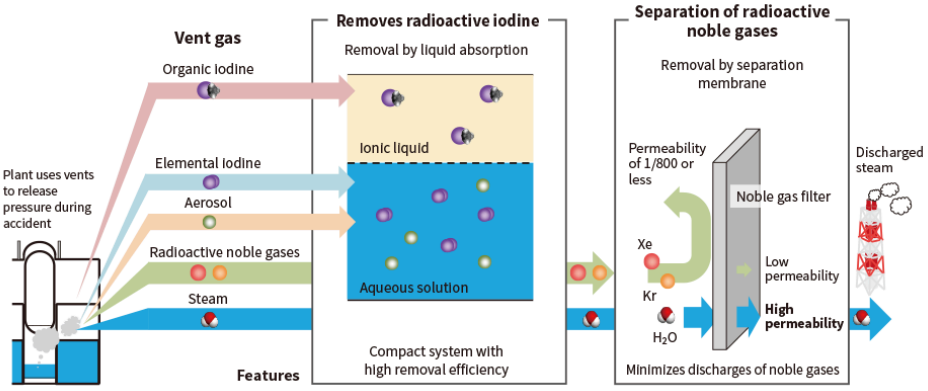
4. System for Filtering All Radioactive Substances to Significantly Reduce Exposure of Neighboring Residents during an Accident

Achieving carbon neutrality calls for the stable supply of energy from nuclear power, a low-carbon power source. To make the most of nuclear power, it is essential to provide for more of the neighboring residents from a safety perspective by drawing on the lessons of the Fukushima Daiichi Nuclear Power plant accident to make power plants even safer.

To this end, Hitachi is developing a system for filtering out all radioactive substances* that works by removing them from gases that could potentially be released in the event of an accident. This is done using a liquid absorbent (ionic liquid) and a separation membrane (noble gas filter). While radioactive noble gases were difficult to remove in the past, this is accomplished here by the noble gas filter. Similarly, the ionic liquid absorbs radioactive organic iodine with high efficiency. This helps to enhance the safety of the nuclear power plant, reduce the concerns of neighboring residents, and minimize evacuation requirements. As compact size is one of the features of the system, it is also suitable for retrofitting in existing plants with limited space availability.

* Excluding tritium

[04] System for filtering all radioactive substances

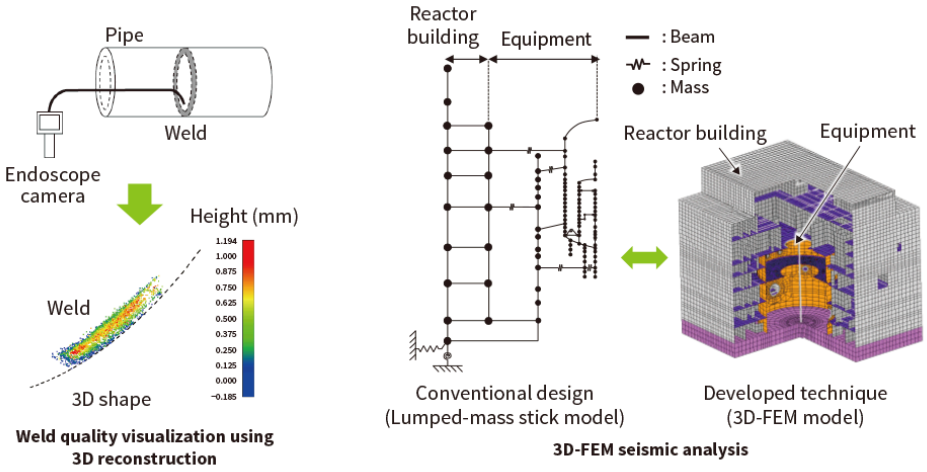


5. Weld Quality Visualization and Seismic Analysis Techniques for Improving Reliability of Nuclear Power Plants

Growing use is being made of the Internet of Things (IoT) and advanced analysis to improve the reliability of nuclear power plants. While weld shape is one of the criteria for weld quality, conventional weld quality assessment cannot perform such checks on locations that are not visible to workers because they are inside pipes or in a confined space. In response, Hitachi has developed a technique for reconstructing three-dimensional (3D) shapes from endoscope camera images that is suitable for use in pipes or other confined spaces. The system can also assess and monitor the weld quality based on the differences between the reconstructed 3D shape and the ideal weld shape. Use of the technique in a welder training system also helps welders to upskill and gain experience.

Meanwhile, one of the issues with the seismic design over recent years has been how to consider 3D behavior during an earthquake in existing designs that use 2D seismic models. To address this, Hitachi has developed a modeling technique that can simulate the 3D transmission of forces from the building to equipment by reconciling the geometric connections between a 3D finite element method (3D-FEM) model of the reactor building and beam and mass models of equipment. By doing so, Hitachi is helping to improve seismic safety by enabling seismic design to take account of 3D behavior during an earthquake in a way that considers coupled vibration of the building and equipment.

[05] 3D-FEM seismic analysis and weld quality visualization using 3D reconstruction



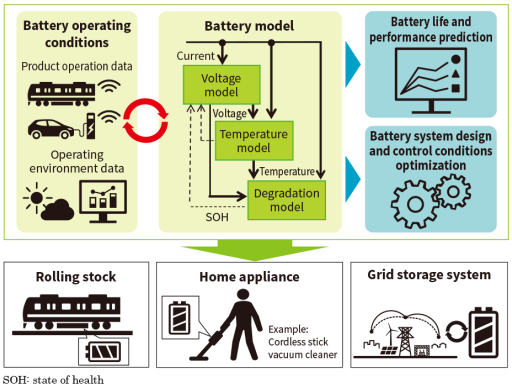
6. Digital Twins for Improving Battery Life Cycle Cost

To keep costs down, battery-equipped products such as low-emission vehicles, portable devices, and distributed grid-linked power supplies need to reduce the quantity of batteries required and the frequency of replacement. Leveraging its knowledge of battery reaction mechanisms and battery test data acquired over many years, Hitachi has been developing digital twins for the highly accurate prediction of battery life and charge/discharge performance.

This uses a coupled calculation that includes battery voltage and temperature along with a degradation model. By obtaining detailed information about the actual operating conditions experienced by the battery-equipped product and making use of this in the calculation, the developed technique can reduce the life cycle cost of battery systems from design to maintenance. It is being used in the product development of a wide variety of battery-equipped Hitachi products such as rolling stock, home appliances, and grid storage systems to help make products smaller and lighter and to reduce costs.

In the future, Hitachi intends to offer battery solution services that expand use of digital twins to resolve customer challenges, including the use of battery data collected from the field to extend the life of battery-equipped products and by making them more efficient to operate and maintain.

[06] Use of digital twins of battery-equipped products



SOH: state of health

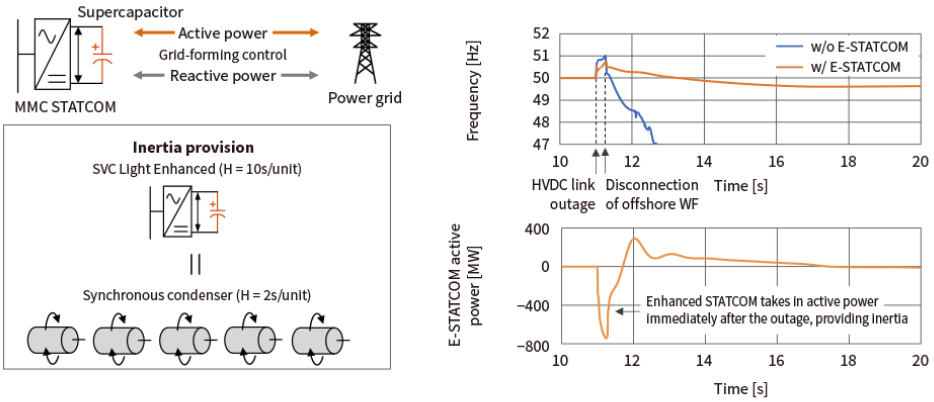
7. Inertia and Voltage Support Using Enhanced STATCOM

The power system today is facing stability and reliability issues due to the decrease of fossil-fuel generators and their associated inertia and voltage support. Enhanced STATCOM (SVC Light Enhanced), developed by Hitachi Energy, is a system stabilization device that adds active power capability and grid forming function to a conventional STATCOM to contribute to frequency and voltage stability.

Conventional synchronous machines store a large amount of kinetic energy in its rotating mass but can only extract a portion of this energy to stay synchronized with the grid. For a frequency deviation of 1 Hz, only 4% of the total kinetic energy can be used for inertia provision. SVC Light Enhanced can extract a high portion of its energy using a fully flexible direct-current (DC) link and therefore provides a larger inertia constant compared with a synchronous machine of the same rating. In case of an outage of a high-voltage DC (HVDC) link or generator, SVC Light Enhanced can supply the necessary inertia at 1/5 the capacity of synchronous condensers to ensure grid resilience.

(Hitachi Energy, Ltd.)

[07] Inertia provision using SVC Light Enhanced



MMC: modular multilevel converter
E-STATCOM: enhanced STATCOM

8. AI-equipped Grid Stabilization System for Grids with Expanding Renewable Generation

To cope with the long-distance transmission of large amounts of electric power from the Joetsu Thermal Power Station, the power grid for the Nagano region operated by Chubu Electric Power Grid Co., Inc. uses voltage and reactive power control in the Integrated Stability Control (ISC) system for Nagano area to maintain voltage control. As greater use of renewable generation exacerbates voltage fluctuations, however, this raises concerns about the increased incidence of voltage deviations and more frequent switching by transformer tap changers and phase modifying equipment.

In response, Hitachi has used AI to develop a voltage and reactive power control technique that keeps the voltage in the appropriate range while also minimizing the frequency of switchgear operation. The technique performs offline AI training based on targets for equipment states that will stay within operational constraints. During online operation, this is achieved by using the target equipment states output by the AI as a basis for determining which equipment to operate. In a simulation performed to verify operation, the technique reduced switchgear operation by about 50% compared to previous practice.

［08］ISC system for Nagano region

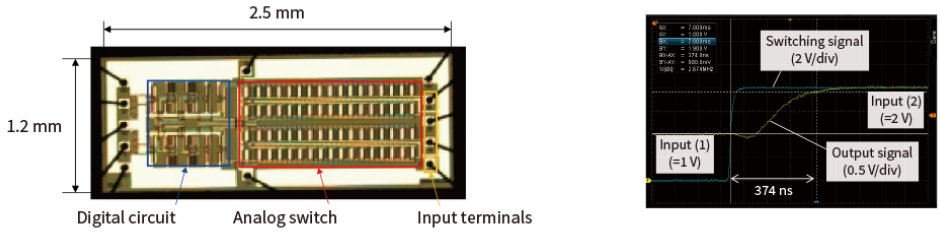
The Nagano ISC system equipped with this technique has commenced operation. In recognition of its novelty, it achieved the 79th IEEJ Technical Development Award of the Institute of Electrical Engineers of Japan (IEEJ).

9. Radiation-hardened Devices for More Sophisticated and Reliable Plant Operation

Nuclear power plants require instrumentation with a strong tolerance for radiation. Accordingly, Hitachi has developed complementary metal-oxide semiconductor (CMOS) technology that can withstand harsh radiation environments by using silicon carbide (SiC) semiconductors that have a higher environmental tolerance that the silicon (Si) devices used in the past. The technology has been used to develop a radiation-hardened multiplexer that can selectively connect data from multiple sensors to an output line.

The left side of the figure shows a photograph of the new multiplexer. The multiplexer is a mixed-signal circuit made up of an analog switch and the digital circuit that controls it, both of which are implemented on the same chip. The chip is able to switch four data inputs. The right side of the figure shows a test waveform exposed to gamma radiation. This shows that, even when exposed to 500 kGy of radiation, enough to make operation difficult for an off-the-shelf device, the new multiplexer was able to switch the output without any problems. In the future, Hitachi intends to further enhance plant operation monitoring by increasing the number of multiplexer inputs.

［09］Radiation-hardened multiplexer currently under development (left) and test waveform after exposure to radiation (right)



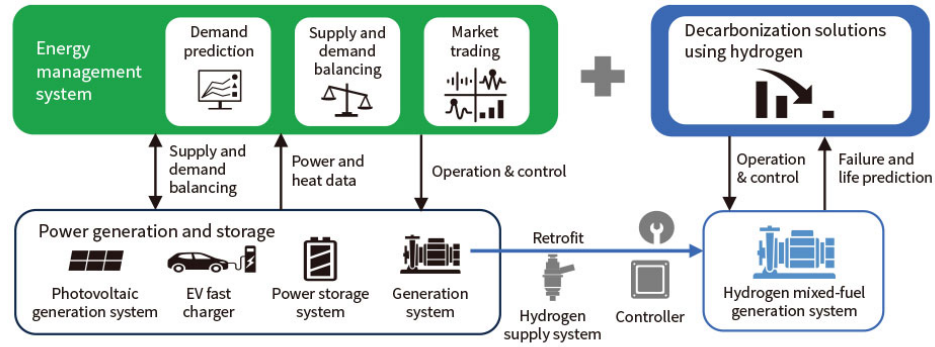
10. Hydrogen Mixed-fuel Generator to Expedite Transition to Carbon Neutrality

Progress is being made on electrification and on turning renewable energy into a major source of electric power to help achieve carbon neutrality. However, growing use of renewable wind and photovoltaic power generation with highly variable output increases the potential for energy supply and demand to get out of balance, creating a greater role for distributed generation systems.

In this environment, distributed generation systems powered by hydrogen or synthetic fuel can balance power supply and demand in terms of both timing and quantity by manufacturing fuel from excess renewable electricity, storing it, and then generating power as and where needed.

To do so, Hitachi has developed a hydrogen supply system and controller that can be retrofitted to existing engine generators enabling mixed-fuel operation on conventional fuels and hydrogen. This has included the development of a technique for the control of hydrogen flow rate based on the real-time detection of potential anomalies and combustion conditions using combustion analysis from the automotive industry. Its use has increased the proportion of hydrogen able to be used in mixed-fuel operation to 50%, an industry-leading figure for a commercially available system. In the future, Hitachi intends to continue its work on decarbonization solutions that support the diverse energy mixes used by customers, including through advances in interoperation with energy management systems.

［10］Overview of decarbonization solutions using hydrogen



EV: electric vehicle

11. Maintenance Workload Reduction Technology for Rolling Stock Using Remotely Acquired Real-time Data

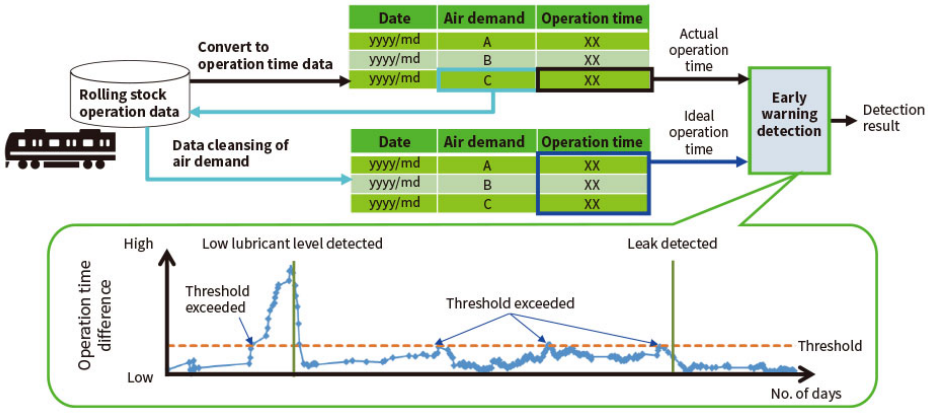
To help railway operators cut operating costs by reducing maintenance workloads, Hitachi has developed an early warning technique for detecting problems in onboard air compressors.

On-board compressors operate with on/off control depending on the pressure in the compressed air tank and store compressed air in the compressed air tank. They also supply compressed air to equipment such as air brakes and air springs.

Hitachi looked at how breakdowns such as leaks and low lubricant levels increase the compressor's operating time. It was found that the operating time varies depending on the demand for compressed air, so it is difficult to judge whether or not there is an abnormality only by increasing the operating time. Therefore, Hitachi has developed a technology that applies the collected compressed air demand data to a data cleansing process and calculates the operating time for each compressed air demand condition. After analyzing time series data on the difference between actual and ideal operating times, it found that setting thresholds can warn of compressor failures before anomalies occur.

In the future, Hitachi intends to offer this technology to its customers for practical deployment while also helping railway operators to reduce their maintenance workloads by also developing early warning techniques for other types of equipment.

［11］Use of rolling stock operation data for early warning of air compressor faults

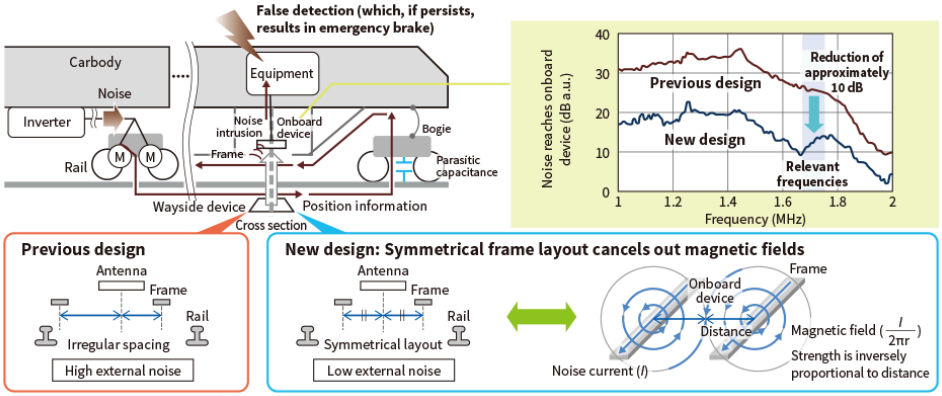


12. Reduction of Electromagnetic Interference in Protection Devices to Underpin Shinkansen Safety and Punctuality

To ensure the reliable operation of the new N700S Shinkansen, Hitachi has developed a technique for reducing the influence of electromagnetic noise on onboard position detection devices (antennas). A problem with the Shinkansen is that electromagnetic noise generated by the traction inverters can interfere with protection devices causing unnecessary application of the emergency brake. This results in delays. Given the length and complexity of trains, past practices have not been able to correctly identify the mechanisms by which the electromagnetic noise generated from a moving train interferes with equipment.

In response, Hitachi has developed techniques for the continuous measurement of electromagnetic noise in a moving train and for experimental verification of the mechanisms by which this noise interferes with equipment. The mechanism by which unnecessary brake application occurs was determined by developing a way to use the results of this testing to simulate electromagnetic noise propagation pathways. Hitachi then went on to use this knowledge of the mechanism to develop a rolling stock design that cancels out this noise, achieving a 10-dB reduction. Implementing this on actual trains helped to minimize unnecessary application of the emergency brake. The design is used in the new N700S Shinkansen, which has demonstrated reliable operation with no instances to date of delays due to electromagnetic noise.

［12］Design technique for reducing electromagnetic interference



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