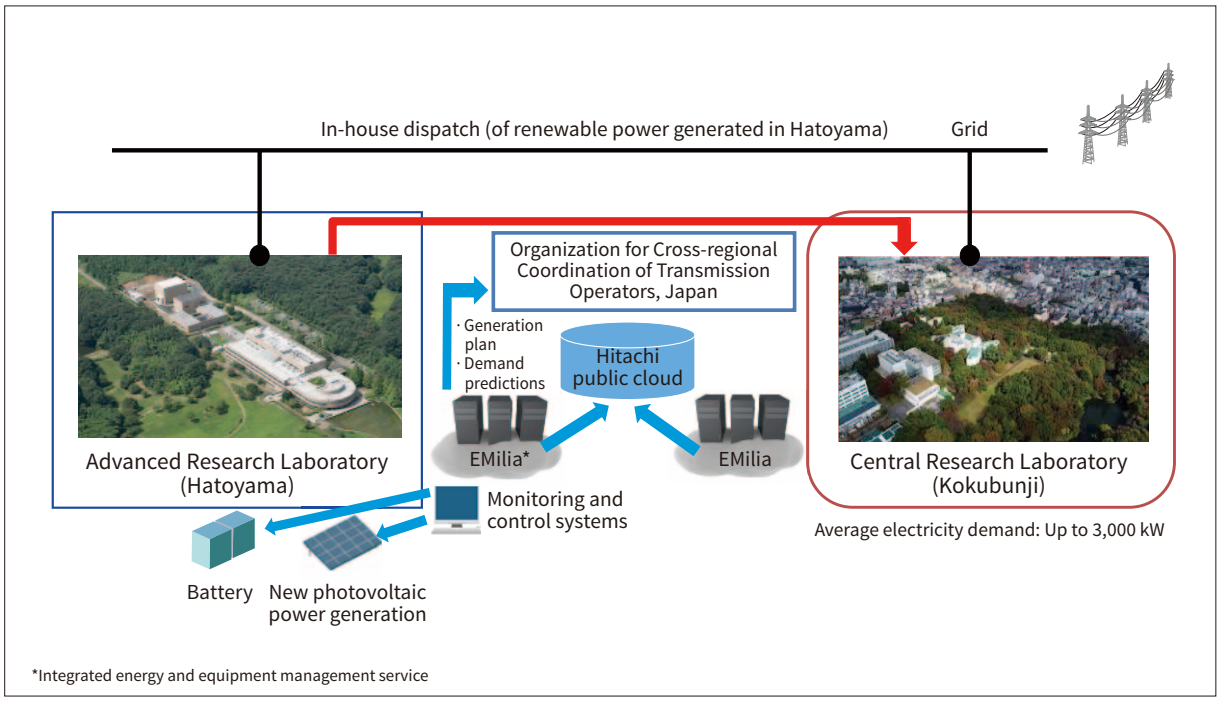
Innovation for Advancing with Customers
Green Energy & Mobility



1 Demonstration system for dispatching of power between Hatoyama and Kokubunji

1 System for In-house Dispatching of PV Power across Multiple Sites

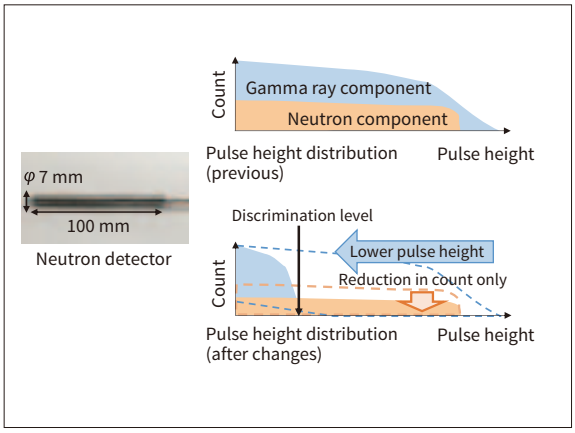
Hitachi has developed a technique for estimating electricity generation in real time using a mathematical model of photovoltaic (PV) generation that is intended to encourage wider adoption of in-house electric power dispatching systems for the low-cost and reliable procurement of green electricity. Factors such as the weather make the output of PV generation highly variable, meaning that the contracted level of power supply usually needs to be set lower than the actual generation capacity. It is estimated that the new technique will be able to increase contracted power by 30% compared to past practice by estimating actual PV generation (available power) in one-minute intervals and coordinating operation with battery control.

To demonstrate the operation of the system, PV generation has been installed at the Advanced Research Laboratory in Hatoyama-machi, Saitama Prefecture and work started on implementing a system for the in-house dispatch of this electric power to the Central Research Laboratory in Kokubunji City, Tokyo. Along with using this demonstration to trial the reliable and highly efficient dispatch of PV electric power in the MW range, there are also plans to expand the system into one for the in-house dispatch of PV power across multiple sites. By doing so, it will deliver both economic and environmental value by minimizing volatility and making full use of PV generation across many sites where the process of electrification is ongoing.

2 Sensing Technique for High-radiation Environments

This article describes two techniques for sensing in high-radiation environments, a requirement in the nuclear power industry.

Hitachi has developed a neutron detector that can function in the high-radiation environment at Fukushima Daiichi Nuclear Power Station. Previous neutron detectors have been unable to distinguish between gamma rays and neutrons because the simultaneous detection of multiple gamma rays in contaminated water results in a pulse height similar to that for neutrons. Noting that



2 Neutron detector for conducting surveys of Fukushima Daiichi Nuclear Power Station

sensitivity and pulse height are correlated for gamma rays but not for neutrons, Hitachi has addressed this problem by shrinking the metal electrode that influences sensitivity, thereby eliminating the gamma rays that interfere with neutron detection. Surveys conducted using a submersible remotely operated vehicle (ROV) equipped with this new detector were able to detect neutrons for the first time since the earthquake*.

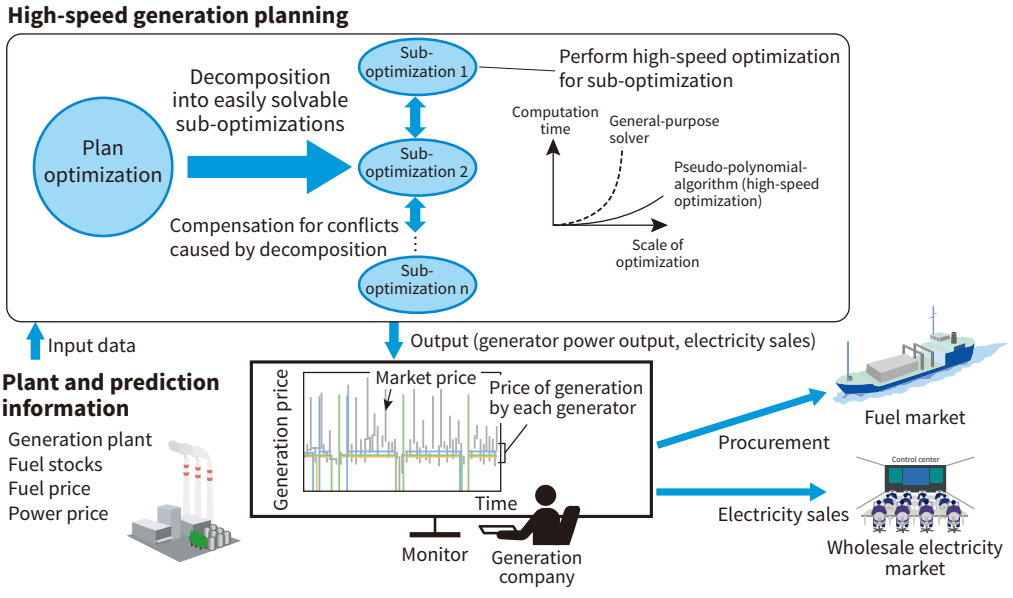
Hitachi has also developed an amplifier that uses silicon carbide (SiC) material in order to make the instrumentation at nuclear power plants more tolerant of radiation. As SiC is a wide-band-gap semiconductor, devices that use it are less prone to gamma-ray-induced defects than conventional silicon devices. By using complementary metal-oxide semiconductor (CMOS) components that take advantage of this superior property of SiC, the radiation tolerance of the new amplifier has been improved by a factor of 6,000 compared to previous amplifiers.

* The work described here was undertaken by Hitachi-GE Nuclear Energy, Ltd. in its role as a member of the project entitled, "Development of Technology for Detailed Investigation inside Primary Containment Vessel (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)" run by the International Research Institute for Nuclear Decommissioning.

3 Optimization Solution to Support Economical Electricity Supply and Demand Operation in Increasingly Volatile Electricity Markets

Generation companies predict future conditions such as volatile fuel and electricity market prices and optimize their operation plan for their plants in a way that makes economic sense. To maintain the economic sustainability of their operations in the face of changes in these future conditions, Hitachi is developing a solution for optimizing the supply and demand operations based on prediction techniques that compensate for prediction errors dynamically and planning techniques that can rapidly evaluate the impact of future changes and provide advance assessments of the consequences of specific actions to mitigate the impact.

In the operation planning, future changes such as fuel and electricity market prices during operation are simulated by several dozen scenarios and operation plans are



3 Diagram of high-speed planning technique

created to consider these scenarios and reduce risk of losses and constraint violations by taking countermeasures in advance. However, it can take several hours of computing to optimize the plan for just one of these scenarios. Accordingly, Hitachi has developed a high-speed planning technique that is able to complete even large-scale plan optimization in around half an hour by decomposing the plan optimization process and using parallel processing to concurrently execute high-speed pseudo-polynomial algorithms for each of these decomposed optimization processes.

This enables economic operation by increasing the number of scenarios that can be considered and by more accurately estimating the effects of potential actions or the changes in future conditions.

4 Use of Reinforcement Learning to Prevent Power Outages Based on Anticipation of Risks

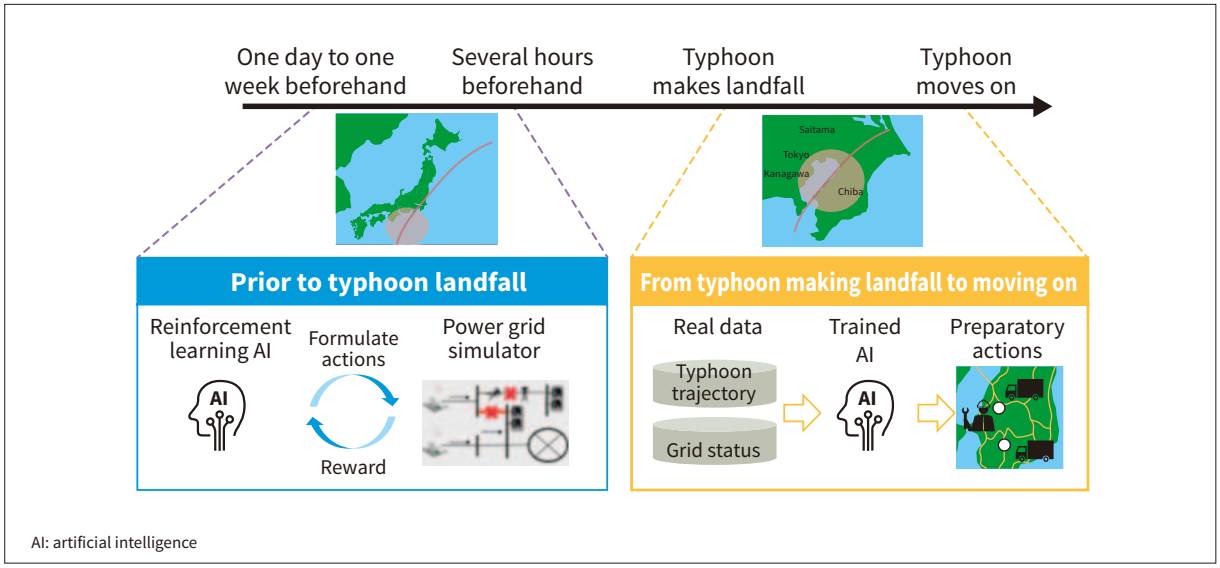
More attention is being paid to disaster preparedness measures that minimize the time and geographical spread of power outages caused by typhoons or other low-frequency/high-impact natural disasters. Conventional operational planning methods based on mathematical optimization have found it difficult to calculate timely operational plans for typhoons due to the way their path continuously changes over time, resulting in a massive increase in the number of fault scenarios that need to be considered. Hitachi has developed a technique for preventing power outages based on the anticipation of risks utilizing reinforcement learning.

This involves using a large number of transmission-line-fault scenarios generated from the typhoon predictions to train a machine learning model in advance on what actions are appropriate, taking account of the tradeoffs between the extent of outages and the costs of action. When a typhoon approaches, the trained model is then used to rapidly identify a set of actions that will be efficient given the actual damage. Simulations have verified that the technique can reduce power outages, taking less than an hour to produce plans for power plant output and the pre-deployment of mobile generators.

In the future, Hitachi intends to contribute to making the electricity system more resilient by continually testing the technique in practical use.

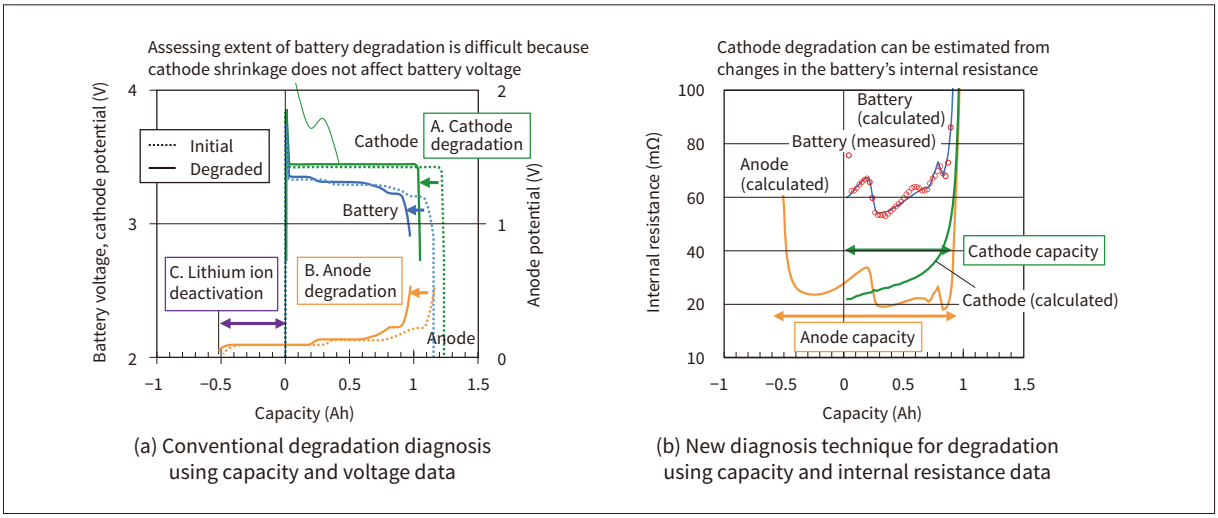
5 Accurate Diagnosis of Lithium-ion Battery Degradation through Discharge Curve Analysis

Lithium-ion batteries are experiencing rising demand for use as a power source in stationary electric power systems and electric vehicles. Ensuring high reliability in the control of these battery systems calls for accurate and non-destructive means of assessing battery degradation. For highly reliable control of the lithium nickel manganese cobalt oxide batteries that currently predominate, past practice at Hitachi has been to assess degradation using the relationship between battery voltage and capacity (discharge curve analysis). Recent years have seen growing use of lithium iron phosphate batteries, however, and this method does not work well on these batteries due to their characteristic of maintaining a constant voltage. In response, Hitachi



AI: artificial intelligence

4 Flowchart for use of reinforcement learning to formulate actions in advance



(a) Conventional degradation diagnosis using capacity and voltage data

(b) New diagnosis technique for degradation using capacity and internal resistance data

5 Non-destructive diagnosis of causes of degradation in lithium iron phosphate batteries

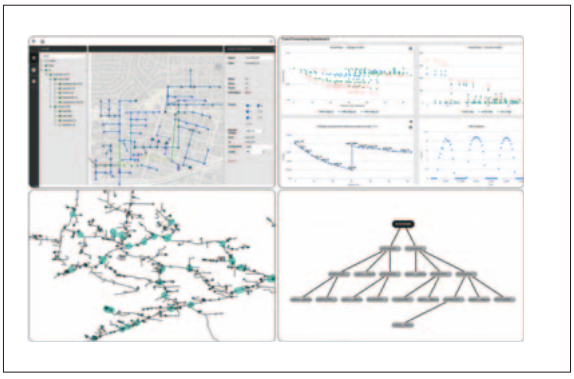
has developed a new diagnostic technique for degradation using data on capacity and internal resistance that has demonstrated high reliability on all types of lithium-ion battery, including lithium iron phosphate.

To commercialize this kind of battery diagnostic technique, Hitachi has developed a service for remotely diagnosing degradation in on-board automotive lithium-ion batteries in partnership with Hitachi High-Tech Corporation (detailed in a Hitachi High-Tech news release dated July 25, 2022). The service provides highly accurate remote diagnosis by combining the use of discharge curve analysis to collect basic battery data with a technique for assessing the extent of battery degradation from both this basic battery data and operational information from the vehicle.

6 Distribution Planning Method and Modeling Platform for DER Integration

The rise of self-generating communities is requiring advanced control of the grid and creating opportunities for innovation. Hitachi has developed an open-source power distribution planning method and modeling platform, G Platform, to bridge the gap and enable intuitive resource planning, which lowers the barriers for engineers to analyze the grid to manage and mitigate the impacts of distributed energy resources (DER).

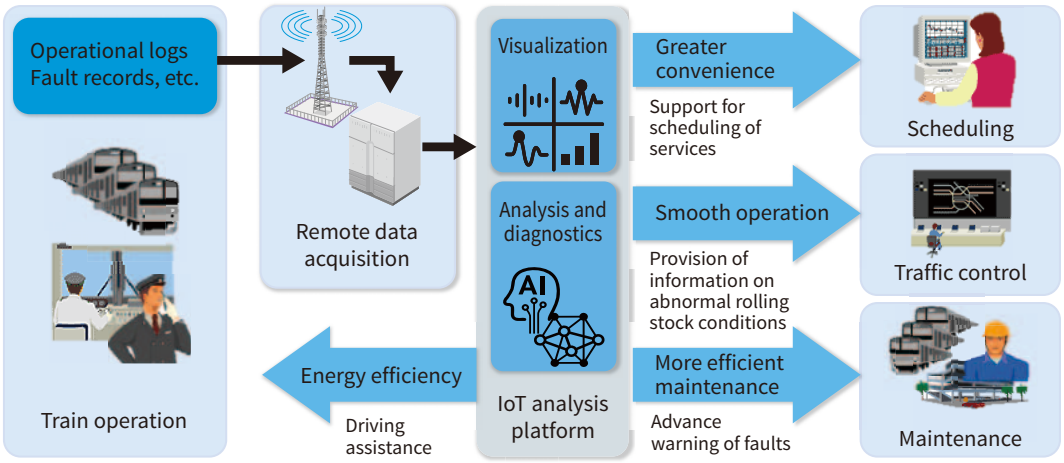
G Platform allows integration of third-party solvers for complex distribution grid modeling scenarios. Use cases include hosting capacity analysis, grid resilience, and electrification evaluation for buildings and electric vehicles. G Platform visualizes complex information, supports flexible architecture, and provides scalability for big data simulation. Additionally, a post-processing tool is integrated in the platform to facilitate data analysis and result realization. Deployment on both workstations and cloud computing are supported. G Platform promotes the adoption of green energy by reducing both the time and cost of the DER integration process. G Platform is supported with funding from the California Energy Commission under grant EPC-17-043.



6 G Platform

7 Added Value from Use of IoT for Rolling Stock Data

The comprehensive and quantitative monitoring of operations is essential to improving convenience and reducing operating costs for rolling stock. In response, Hitachi supplies solutions for resolving wide-ranging operational challenges such as energy and maintenance efficiency through the remote acquisition and analysis of rolling stock data. Underpinning these solutions, development is also progressing on techniques for the reliable and remote collection of data from rolling stock and on an analysis platform that utilizes the Internet of Things (IoT) for the visualization and analysis of big data archives.



7 Flowchart of how value is added through visualization and analysis of rolling stock data

One example of a solution that Hitachi has implemented to use these technologies is a driver support system that facilitates energy-efficient operation by showing the variability in train driving practices and identifying which practices use less energy.

In the future, Hitachi intends to extend this work to include support for driving practices that save energy and the scheduling of services to help improve convenience for passengers, the provision of information on abnormal rolling stock conditions to help ensure that those services run smoothly, and diagnostics for advance warning of faults to help make maintenance more efficient.

8 Development of Rolling Stock with Low Environmental Impact for HS2 in UK

The new High Speed 2 (HS2*) railway line in the UK is scheduled to enter service in 2029. Hitachi is currently developing a new generation of quiet and energy-efficient rolling stock for use on the line that feature low environmental impact and a top speed of 360 km/h. As aerodynamic drag accounts for the bulk of energy used by a high-speed train, streamlining the design plays a crucial role in energy efficiency. By leveraging expertise in the use of computational flow dynamics for large-scale simulations acquired from the past development of rolling stock for Europe, Hitachi is able to work rapidly through a large number of design iterations. By doing so, it has succeeded in creating a low-drag design.

Likewise for quiet operation, Hitachi has used operational trials on existing rolling stock to highlight and quantify the sources of noise in parts such as the pantograph and bogies, augmenting this with simulations to allow for actual conditions on the new line, including the infrastructure of the track and sound-insulating walls. Together, these practices have enabled the design of rolling stock that is quiet enough to satisfy the regulations and specifications.

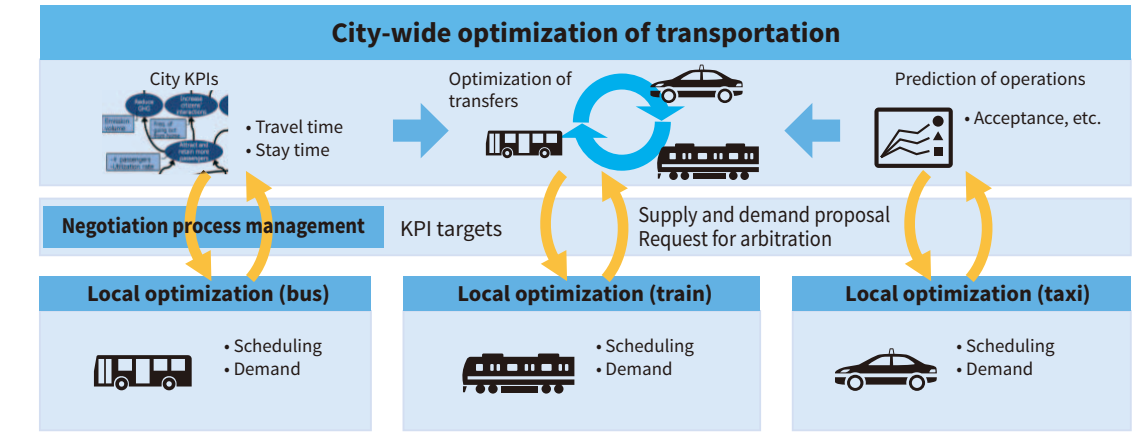
8 Artist's impression of HS rolling stock (top) and visualization of noise (bottom)

In the future, Hitachi intends to continue using simulation and measurement techniques to develop sustainable rolling stock with a low impact on the environment.

* See the list of "Trademarks."

9 Coordination of Mobility Providers to Improve Operations

COVID-19 has significantly impacted people's movement in terms of quality and quantity, raising expectations



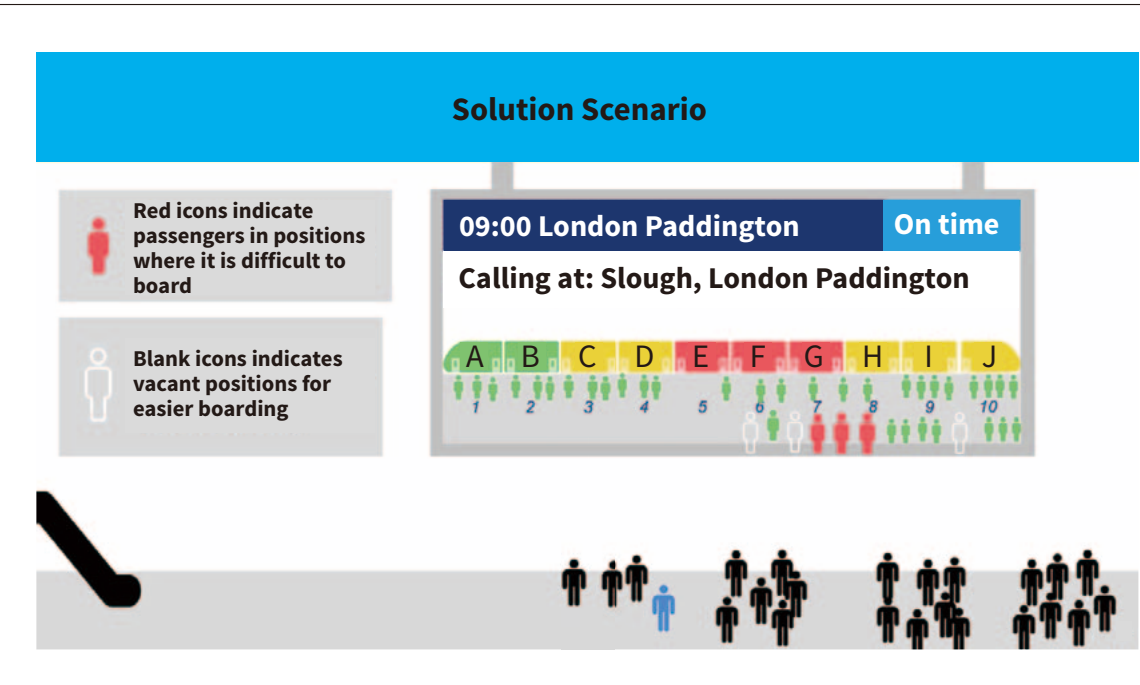
9 Coordination of mobility operations

for safety and comfort. The need for carbon neutrality also drives a modal shift toward public transportation, such as trains and buses with low carbon dioxide (CO_2) emissions. However, the different modes of urban mobility, including trains, buses, and taxis, are operated by various providers. Hitachi has developed a technology to facilitate operational improvements of mobility services provided by multiple entities and modes by coordinating these different mobility providers.

This technology looks at how each provider operates their services regarding their circumstance and then seeks to coordinate the public transportation and related services from the perspective of the city-wide transportation network by optimizing transfers between the various services. Hitachi aims to improve the convenience and sustainability of mobility services across entire cities by reducing overcrowdedness and ensuring seamless operation between different providers.

10 Easy Boarding—Optimising Passenger Boarding

The "Easy Boarding" solution reduces boarding times at busy stations by taking passenger boarding and disembarking data in real-time and visualising the optimal



10 Easy Boarding solution scenario

waiting positions for passengers on the platform. The goal is to reduce delays, improve passenger experience, and avoid accidents. Value was proven with Network Rail in the "First-of-a-Kind 2021" project funded by UK Research and Innovation.

Through collaboration with transport operators, the solution used historical passenger flow data from station sensors to simulate optimal passenger positioning with the potential to reduce boarding times by up to 50%. The solution was enhanced to comply with data protection regulations using the "privacy first" camera-as-a-sensor prototype; replacing real faces with synthetic faces using generative adversarial network technology.

Passengers were interviewed to understand their motivations behind where they choose to wait along the platform, reflecting their needs into several interface designs, and usability testing each to identify the best option.

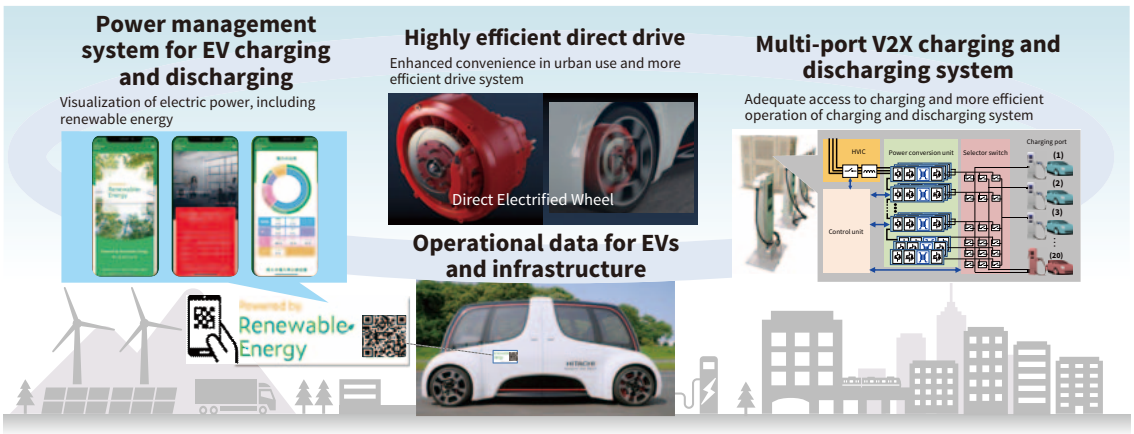
Hitachi Europe exhibited the solution at Innotrans 2022, alongside Hitachi Rail, leading to discussions and workshops with multiple transport operators across Europe.

11 Technology for Electric Mobility Infrastructure for Electrification of Society

In response to the growing adoption of electric vehicles (EVs), Hitachi has developed a solution for EV charging and discharging to help establish infrastructure for electric mobility that operates efficiently not only for drivers and EV owners, but also for the infrastructure of the cities and other areas served by EVs. Overcoming the issues facing drivers and EV owners will require the delivery of renewable and other forms of energy while also ensuring sufficient access to vehicle charging to assuage concerns about its availability and making the EVs themselves more efficient to improve range. With existing charging systems, however, each charging port is tied to a specific parking space, meaning that the next vehicle cannot start charging until the previous one moves away. The result is less efficient use of the chargers and considerably fewer charging opportunities.

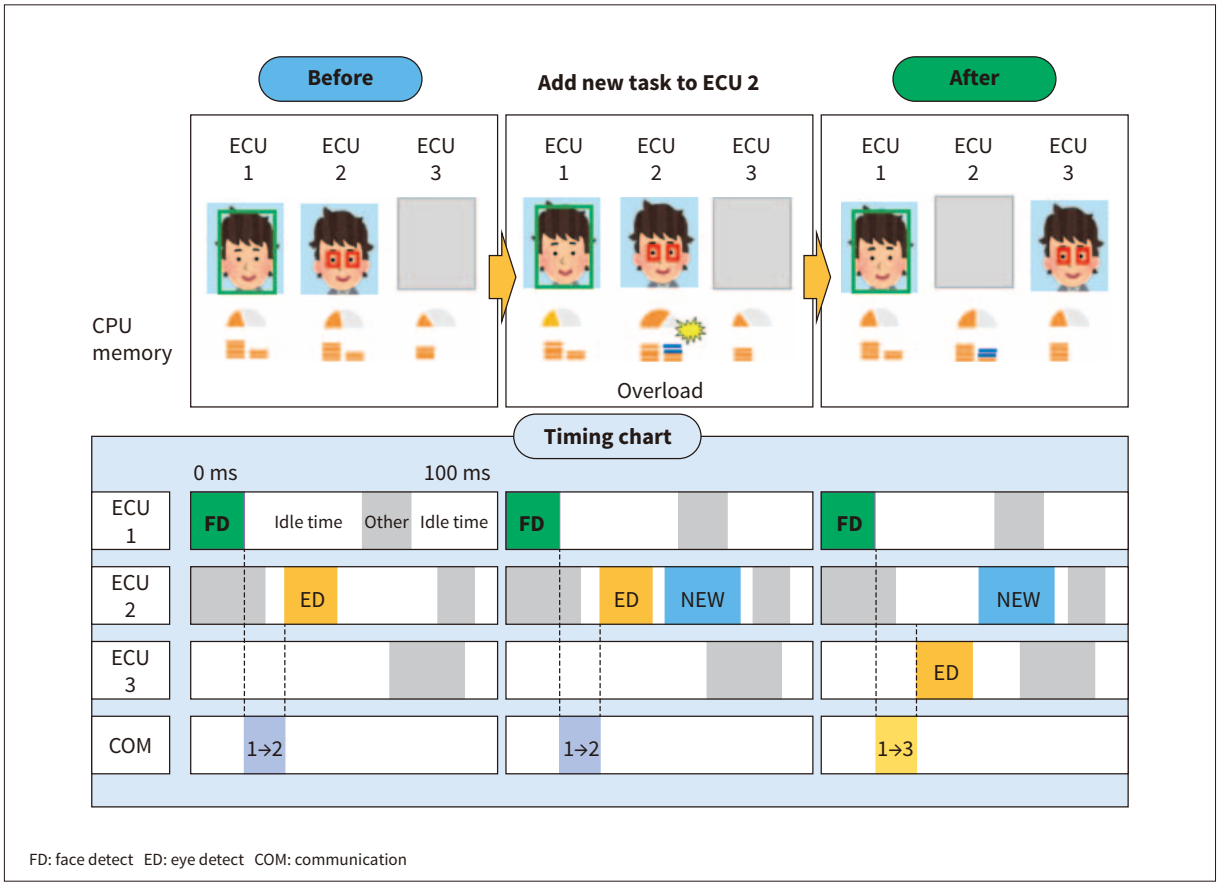
The new system ensures adequate access to charging by using a split configuration in which the output from multiple charging and discharging systems can be connected in parallel and switched on the basis of the number of EVs to be charged and when they will complete charging. This allows it to charge all of the EVs connected to the multiple charging ports provided, and to do so in an efficient manner without any gaps between one vehicle and the next. The system also uses digital grid technology to manage electric power for charging that is derived from renewable sources, thereby ensuring that this power is put to good use. This includes the analysis of operational data for drivers and EV owners and the areas where charging and discharging systems are located. Making vehicles more efficient and spacious is another important factor when they are used for transportation and delivery in urban areas. Hitachi has made improvements in these areas compared to previous EVs through the supply of direct-drive systems that provide higher efficiency and carrying capacity.

(Hitachi Industrial Products, Ltd. and Hitachi Astemo, Ltd.)



V2X: vehicle to x HVIC: high-voltage input circuit

11 Electric mobility infrastructure for electrification of society



12 Looking for idle time to spread processing workload

12 Software Design for Advanced Automobiles

Hitachi has developed software design techniques for creating the advanced cars of the future in which "connected, autonomous, shared and services, and electric" (CASE) are key features.

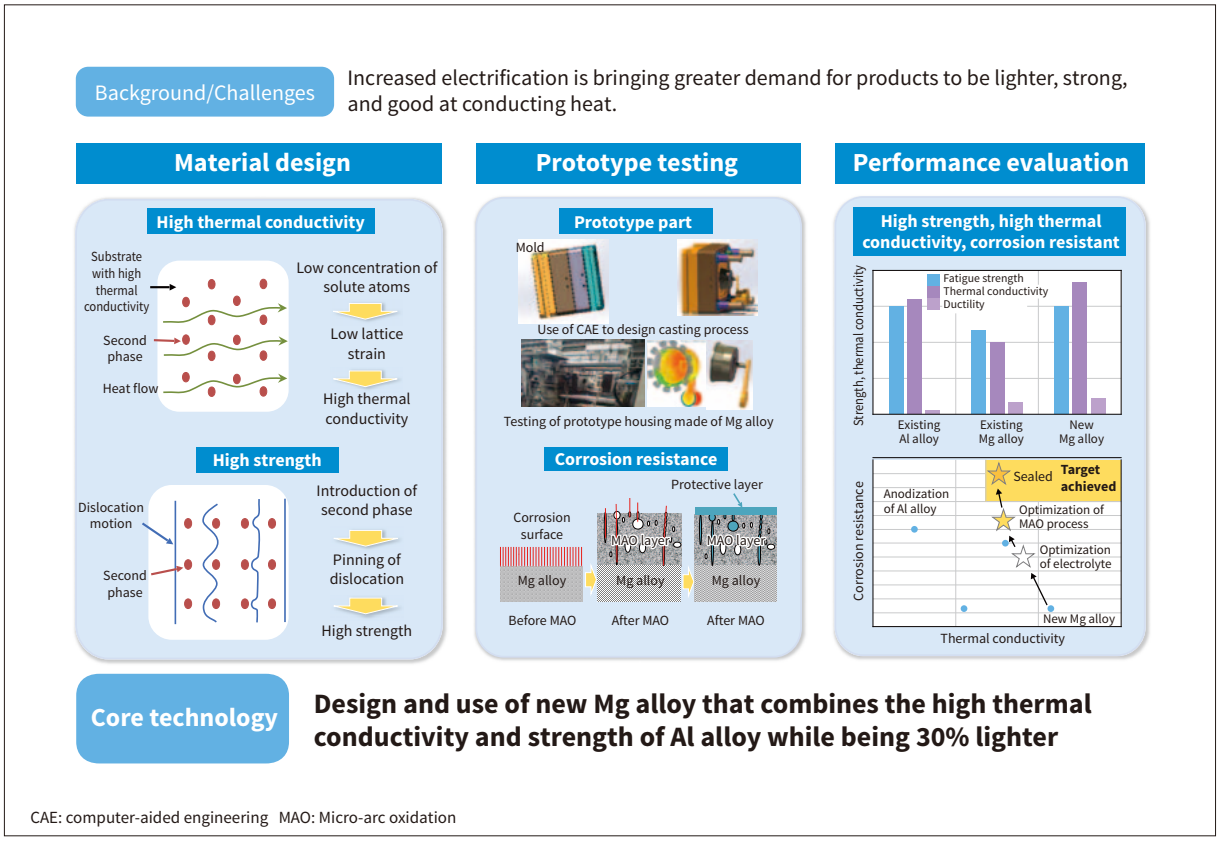
When using over-the-air (OTA) updating of software, it is necessary to ensure not only that the software being updated will operate as intended, but also that it will not interfere in unexpected ways with the output of the other existing control software. This new technique works by fixing the execution timing of each task (unit of software processing) and each communication between electronic control units (ECU) and then determining what idle times occur under these constraints. The task allocation and other configuration details are then adjusted to make room for the additional tasks and balance the processing workload for the new functions being added. This makes design and verification more efficient by keeping the same task execution sequencing, enabling software updates to be completed quickly and at low cost.

In the future, Hitachi intends to fulfill the expectations of its customers by supplying next-generation ECUs that combine performance and low cost, utilizing this new technique for autonomous driving and advanced driver assistance system (ADAS) ECUs that are updated by OTA as well as for the consolidation of multiple existing ECUs into a single device.

13 Light, High-strength, and High-thermal-conductivity Mg Alloy for Electric Mobility

The use of EVs has grown rapidly over recent years as part of efforts to make mobility greener. As reducing the amount of energy consumed by these vehicles requires that they be made significantly lighter and more efficient in their use of energy, this has also been accompanied by rising demand for automotive parts to be lighter, strong, and good at conducting heat. There is currently intense competition among automotive manufacturers to make their vehicles lighter and more energy efficient with longer range.

In pursuit of these goals of lighter weight, higher strength, and higher thermal conductivity in parts, development efforts in the field have focused on optimizing the design of material composition and microstructure. By using a base material with a low density of solute



13 Development of Mg alloy for electric mobility

atoms together with introduction of a second phase that is effective at pinning dislocations, Hitachi has successfully developed a new magnesium (Mg) alloy that combines the high thermal conductivity and strength of existing aluminum (Al) alloys while being 30% lighter. The ability of parts made from this Mg alloy to satisfy performance requirements has also been verified using a prototype housing. This prototype made from the new Mg alloy is intended to provide a high level of functionality, including improved corrosion resistance. Future plans include investigations into the use of the technology by Hitachi's business units.