Energy

1 Work to Update Second GT to be Completed at Toa Oil's Mizue Thermal Power Plant

Hitachi has signed a work agreement to update the second gas turbine (GT) at the Mizue Thermal Power Plant of oil and power producer Toa Oil Co., Ltd. The plant is the facility that drives Toa's activities in the power sector. It is also one of a number of key facilities that generate electricity using fuel in the form of byproduct gases generated by the oil refineries behind Toa's activities in the oil sector. The GT update will involve replacing the GT with a new model*1. It will provide benefits to the customer by improving cost-effectiveness*2 and facility reliability. Hitachi will be working on completing the work by December 2019 while coordinating periodic inspection work*3.

Hitachi will continue bringing its engineering expertise to bear on a wide range of renovation and replacement projects such as GT updating.

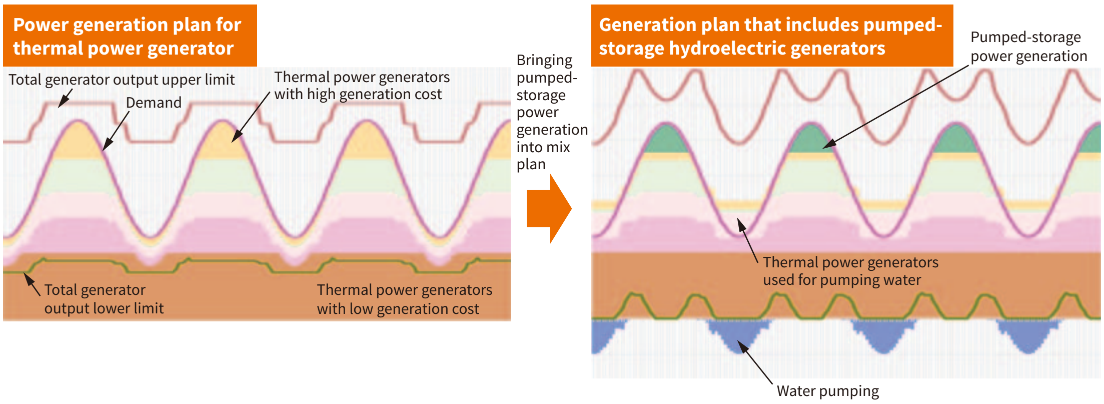
*1 The General Electric Company model 6F.03-1 GT is being updated to model 6F.03, and the Mark V control system to Mark VIe.
*2 Relative to before the update, the output at air temperature of 15°C will be improved by 6.6%, and the thermal efficiency by 2.6%.
*3 As of October 2019.

2 Power Generation Planning/Control Verification Solution Enabling Repeated Estimation by Power Generation and Ancillary Services for Multiple Scenario Evaluation Leveraging High-speed Calculation Engine

Drastic output variations needed to maintain the balance of power supply and demand have recently become a challenge due to the increasing mass-installation of solar and wind power facilities with drastic output that varies due to fluctuation depending on weather conditions and the like. To overcome this challenge, Hitachi has been working on ensuring power supply stability by developing a tool that rapidly creates operation plans that ensure the required control by absorbing output fluctuations using the planning tools of thermal power generators and pumped-storage hydroelectric generators, which can deal with the above output fluctuations through rapid simulation capabilities and enable power system stability.

The tool operates with a simple configuration consisting of just one PC, but the developed computation

1 The gas turbine facility (during the replacement process)



Shows the planning result for power generation in response to demand with 30-minute granularity and a sine-wave curve (each fuel and generator type is displayed in a different color).
When pumped-storage hydroelectric generators are included in the plan, pumped-storage hydroelectric generation is used to generate power in time slots with high thermal power generator cost, and water is pumped up in time slots when the thermal cost is low.

2 Example of developed tool's output results

engine can calculate 5-minute-increment annual plans for 80 full-scale thermal power generators in just 10 minutes. The tool also makes it possible to evaluate multiple power generation plans with the high speed of this computing engine, simplifying trial verification for various power generation plans. For example, multiple annual plans can be used during the annual plan creation phase to verify multiple scenarios, which consider the risk of an excess or shortfall in the forecasted demand share to be provided by the thermal power generators. To enable verification of control maintenance against the base generation plan scenario, the tool can also calculate the amount of replacement reserve-for feed-in-tariff (RR-FIT) that could be activated through the electricity balancing market that is planned to open in Japan in 2021.

Hitachi will continue to develop advanced functionality based on this high-speed computing engine into solutions, such as power generation planning systems that consider total optimization from fuel procurement to generation planning.

3 Delivery of Southern System of Hydropower Operation Center for Tohoku Electric Power

Hitachi has delivered a wide-area distributed monitoring and control system for Tohoku Electric Power Co., Inc. (Tohoku EPCO). The system has functions for monitoring and controlling the hydroelectric power stations and dams in Fukushima and Niigata prefectures that account for about half of the 205 mainland hydroelectric facilities governed by Tohoku EPCO. The system's main characteristics are as follows:

(1) Hitachi has shortened the develop time by using a development method that adds functions needed for operating the Hydropower Operation Center, such as functions for monitoring imbalances and for coordinating with the Energy Supply and Demand Operation Center, while utilizing a wide-area distributed control station system architecture and functions needed to monitor and control hydroelectric power stations and dams.

(2) The system has a triple configuration of monitoring and control servers that includes one monitoring and control server located at a backup base. This system configuration enables continuous monitoring and control of hydroelectric power stations and dams even when the Hydropower Operation Center is incapacitated by a disaster.

3 Large screen display and monitoring/control panels for Tohoku EPCO's Hydropower Operation Center Southern System

(3) Operating data is sent in real time to information-providing terminals connected to a companywide network. This feature enables information to be rapidly shared with the Power Engineering Center (maintenance bases for hydroelectric power stations and dams), and reduces operator workload.

The system should be able to help make Tohoku EPCO's hydroelectric power stations and dam operation more efficient and advanced.

4 Upgrade to JR East's Integrated Hydroelectric Monitoring and Control System

Located in the Shinano River basin in Niigata prefecture, the Shinanogawa Power Station of the East Japan Railway Company (JR East) supplies power to the Greater Tokyo Metropolitan Area rail network, to Joetsu line, and to Shinkansen lines and other rail transport facilities. It has a total maximum output of 449,000 kW, supplying one-fifth of the power consumed by JR East.

The integrated hydroelectric monitoring and control system of this power plant monitors and controls hydropower facilities. It is designed to automate the work processes that are done more reliably by machinery and equipment, and to reliably execute operation work.

Since the existing system has exceeded the standard 10-year maintenance period, Hitachi has recently added new functions tailored to today's needs while keeping the existing functions in place, and has delivered the system, which is simple and easy-to-use, with outstanding maintainability and expandability.

4 Integrated hydroelectric monitoring and control system after start of operation

The new functions provided to the system enable rapid and flexible equipment operations by operators. The primary examples are as follows:

(1) Training functions: Let operators train for a series of generator operations, using a utility such as fault simulation and water flow condition change reproductions.

(2) Switching order generation: Switching plan with operation steps can be generated and executed.

(3) Coordination of notification and reporting: Enables the system to sound dam discharge alarms and announce to the relevant parties about discharges.

(4) Gate operation sequence guidance: Can assist operators with operations by using gate opening aperture states and provisions such as dam operation regulations to provide guidance on gate operation sequences.

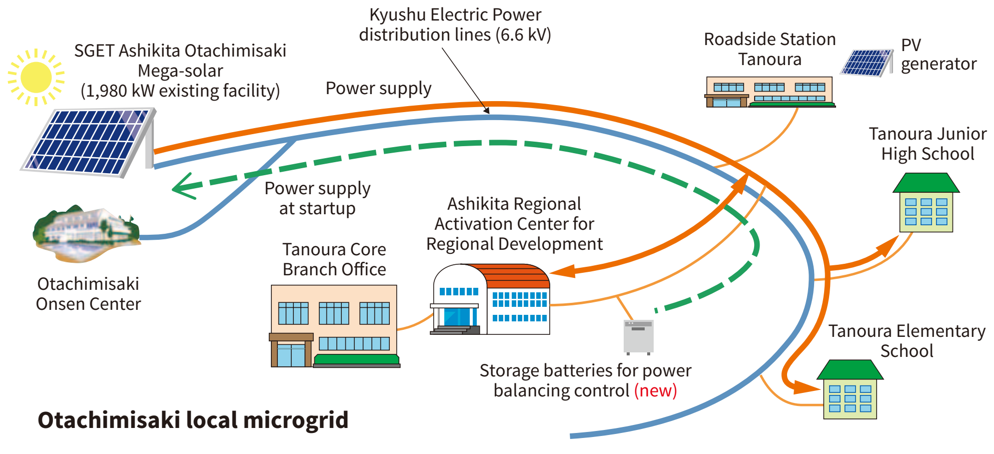
The system should be able to improve power plant operation safety, creating an environment that lets operators concentrate on work that calls for expert judgement.

5 Construction of Local Megasolar-powered Microgrid

Major impacts on the lives of local residents as a result of wide-area power outages caused by natural disasters have recently been on the rise. Researchers are responding to this issue by looking into methods of using local renewable energy plants to ensure supply of electricity during power outages. For example, there is a demand for building a microgrid battery storage management system and development of control technology to underpin the system.

Hitachi is researching a building method for a microgrid that is driven by one solar power plant in Ashikita town, Kumamoto Prefecture. The project is being run by solar power plant owner, SGET Ashikita Otachimisaki Megasolar LLC. In this project, to reduce the initial cost, the existing distribution lines owned by the electric power company are used to supply power to the outage area.

But the use of the power company's distribution lines by a local government requires a review of existing regulations such as the Electricity Business Act, along with greater safety measures than previously used. Since the project is based on a new model that combines supply and demand, and also requires ensuring its business feasibility, further research will be necessary



PV: photovoltaic

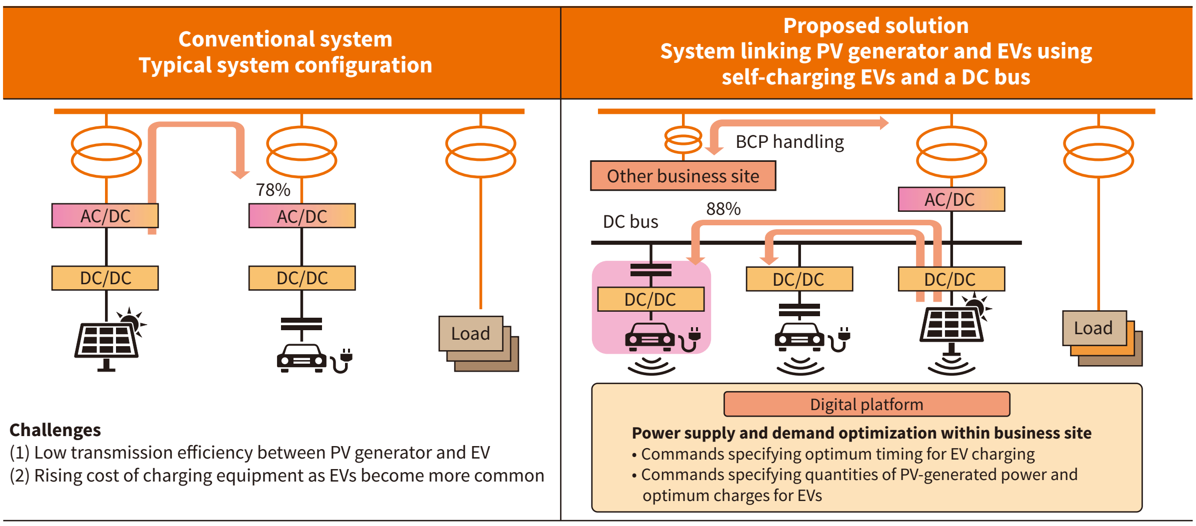
5 Overview of local microgrid configuration

on which storage batteries and other equipment can be used during non-outage routine operation. The project has received a subsidy and is being assisted by a local government (the town of Ashikita) and general power transmitter/distributor (Kyushu Electric Power Co., Inc.). The master plan for the project is currently being researched.

6 Solution Linking Self-consumption PV Generation and Self-charging EV Systems

Technology for solar power generation (PV generation) has been making continual advances since the start of Japan's feed-in tariff (FIT) system, creating expectations for the rise of self-consumption power generation. In a related vein, Japan's Ministry of the Environment is planning for a reduction in CO_2 emissions as its research shows the share of next-generation vehicles rising to 90% in just under 30 years. Hitachi has recently proposed a system that enables PV-based electric vehicle (EV) charging with little loss in generated power while providing more charging opportunities.

Today's EVs are charged through alternating current (AC) power distribution lines, requiring a transformer, AC/direct current (DC) converter, and DC/DC converter. The proposed method eliminates the need for this equipment. Instead, the EV itself is given a function enabling it to control the charging process. This function enables the vehicle drive inverter in the EV to also be used for charging, so that only a small



BCP: business continuity plan

6 Comparison of conventional system and proposed system linking PV and EVs transformer and switch box need to be added. The EV can also be charged from a conventional stationary charger.

Since the solution promotes a link between EVs and PV generation, it should become a launching point for greater use of renewable energy. It should also help to create momentum for the renewable energy (RE) 100 and EV 100 initiatives (commitments to 100% renewable energy and 100% electric vehicles), and promote vehicle-to-grid (V2G) systems.

reactive power. The power grid information and battery control system is linked to a power trading system created by German partner EWE AG. It enables a power supply with balancing control through the use of power trading contracts.

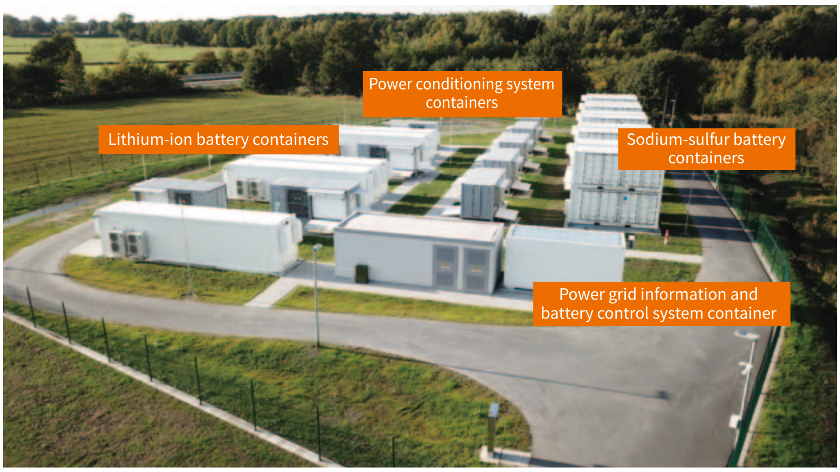
The operation demonstration project began on November 1, 2018 and has been adapting to changes in actual power grid conditions and regulations in Europe since then. It will run through February 2020.
(Hitachi Power Solutions Co., Ltd.)

7 Large-scale Power Storage System in Lower Saxony, Germany

Hitachi Power Solutions Co., Ltd. is working on an operation demonstration project for a large-scale hybrid power storage system designed to help improve the stability of power grids that have incorporated large amounts of renewable energy. Located in the German state of Lower Saxony, the project is a collaborative effort with the New Energy and Industrial Technology Development Organization (NEDO), Hitachi Chemical Company, Ltd., and NGK Insulators Ltd. The demonstrated system is a hybrid charge/discharge system of lithium-ion batteries enabling high-output charging/discharging and sodium-sulfur batteries enabling high-capacity charging/discharging. Hitachi Power Solutions is managing the operation of both battery types using its power grid information and battery control system. Operating the system enables balancing control functioning as an alternative to conventional thermal power generation, along with functions for reducing imbalances in balancing groups and supplying

8 DC Gas-insulated Switchgear for Chubu Electric Power's Hida Converter Station

Hitachi has developed a DC gas-insulated switchgear (DC200 kV and DC10 kV for the Hida Conversion Station being constructed for Chubu Electric Power Company, Incorporated. Before creating the design technology for the DC gas insulated equipment, Hitachi carried out demonstration testing on an actual-size busbar configuration. This testing was done to incorporate a number of components into the equipment design—insulation performance evaluations dependent on resistivity unique to DC, the behavior of metallic particles (of prime importance to DC insulation), and charging phenomenon on the insulator. Hitachi also developed and demonstrated a DC lightning arrester (DCLA; a key component of a DC system), and demonstrated the application of the DC current transformer (DCCT) and DC potential transformer (DCPT). A highly reliable DC gas-insulated switchgear with completely gas-insulated component devices was created. After type-testing the main components



7 Large-scale hybrid power storage system demonstrating operation (photo courtesy of NEDO and EWE AG)

8 DC gas-insulated switchgear (DC200 kV)

of the DC gas-insulated switchgear (the disconnectors, earthing switches, DC bushings, DCLA, DCCT, and DCPT), the equipment was installed at the site in stages beginning in May 2019. Once preparations such as grid-linked testing are complete, Hitachi is planning to start operating the equipment as Hitachi's first DC gas-insulated switchgear in April 2021.

9 HVDC Control and Protection Equipment for Hida-Shinano Frequency Conversion Facility

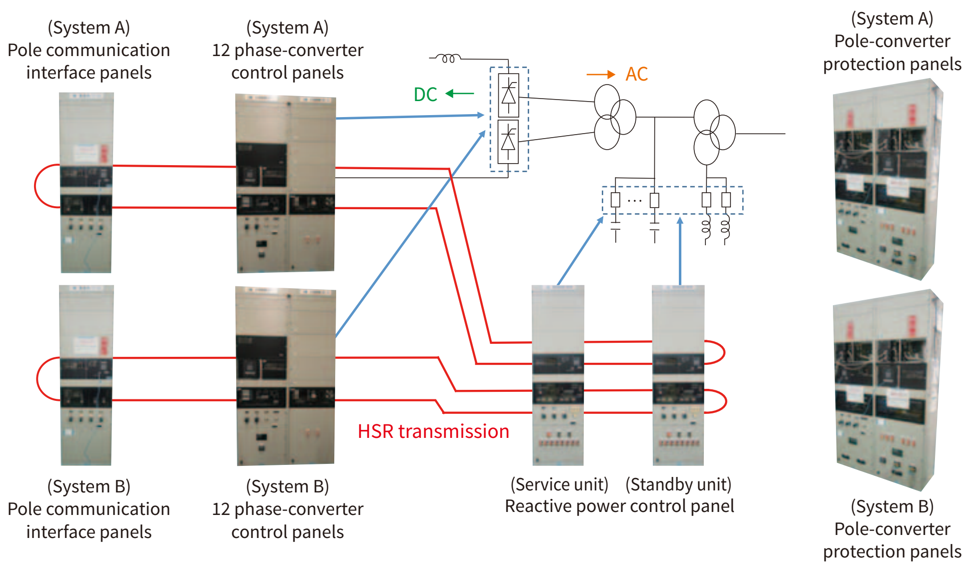
The 900 MW Hida-Shinano frequency conversion facility was planned as a way to improve the connection between Japan's 50 Hz and 60 Hz zones in the wake of the 2011 Great East Japan Earthquake. After winning the order for the Hida conversion station in the 60 Hz zone, Hitachi developed and delivered a high voltage direct current (HVDC) system that makes use of the latest third-generation digital control and protection panels. The project was Hitachi's first new facility project since a domestic HVDC facility that began operating in 2000. On-site combinatorial testing is currently underway.

Converter control involves sharing command values with the other end, outputting control pulses to the converter, and performing reactive power control to compensate for the reactive power consumed by the converter. For this project, Hitachi applied the High-availability Seamless Redundancy (HSR) transmission protocol (a redundant communication technology defined by IEC 62439-3) to the interface between the multiple devices in use as a way to improve communication reliability with an optical ring configuration while reducing interface hardware parts.

Hitachi is also planning to apply HSR technology when replacing the line commutated converter control and protection panels that it delivered in the 1990s.

10 Busbar Protection System for Retrofitted Updating

The first-generation digital protection systems Hitachi delivered in the 1990s are aging, meaning that a lot of them are now due for updating. But, since the resistance-grounded bus protection system involved in this project had many power transmission lines to be



9 HVDC control and protection system

Before unit replacement (first-generation equipment)

(1) With processes through on-site model wiring done

(2) Focusing on connecting connectors and fastening terminals at the site

After unit replacement (Veuxbus series)

10 Protection system before and after unit replacement

protected, each of the transmission lines required main circuit shutdown work when updating them with new panels. The updating work would take longer than work for other protection systems, and finding staff to do the power company work would be difficult.

A unit replacement method was therefore proposed by Hitachi to the power company for this project. This method involved re-using the terminal blocks and hardware components that form the interface with the control cables, and replacing only the central processing units (CPUs) and other degraded parts. Hitachi used actual equipment to demonstrate that this method would not require main circuit shutdown and could update equipment rapidly. As one way to minimize the time needed for updating, model wiring and cables were prepared on-site in advance to simplify the route installation/attachment work.

Using this unit replacement method to update the equipment enabled major reductions in the on-site workload and the update planning work required by the power company for updating the new panel. This method should make future updating projects more efficient.

When updating new panels in busbar protection systems, the unit replacement method used in this project enabled updating with 5 days of on-site work instead of the years usually required. Hitachi plans to use the unit replacement method for future equipment updates in existing equipment replacement projects.

11 Power Transmission Line Protection Relay Equipment Using Optical Wavelength-division Multiplexing Transmission

Protection equipment for power transmission lines of 66 kV and above usually uses current differential relays with pulse-code modulation (PCM). Adopting these relays requires installation of optical fibers and multiplexers as the communication line between electrical substations, but the evolution of power transmission lines into multi-terminal types has made it difficult to allocate optical fiber communication lines.

Hitachi has recently developed and delivered protection relay equipment for power transmission lines that uses the Parallel Redundancy Protocol (PRP; a redundant communication technology) Ethernet technology along with optical wavelength-division multiplexing

11 Power transmission line protection relay equipment using optical wavelength-division multiplexing transmission

modules to halve the number of optical fiber core wires occupied. The equipment has the following features:
(1) More compact design made possible by hardware packaging of PRP communication functions (functions concentrated into single unit)
(2) Use of sampling synchronization protocol defined by IEEE 1588, and use of data format defined for use with general-purpose communication
(3) Mounting of new master/slave station switching process that uses IEEE 1588 best master clock (BMC) algorithm
(4) Using small form-factor pluggable (SFP) general-purpose communication modules enables optical wavelength-division multiplexing method.

12 Digital Protection Relay Equipment for Phase Modifiers

In recent years, the main objectives of phase modifiers installed in Japan and overseas have been to control tidal currents in loop grids to increase the loop grid's overall transmission capacity, improve reliability, and reduce loss.

Hitachi has recently released a phase modifier protection relay designed for use in phase modifiers installed in series on power transmission lines. Its aims are to eliminate major tidal currents in transmission lines and ensure grid and transmission line operation flexibility.

The relay was recently used at an electrical substation where abnormal currents were analyzed by simulating phase modifiers, the presence/absence of back impedance, and internal/external accidents. Elements with the features below were combined, and a method incorporating forward/reverse-phase ratio-differential relays was used.

12 Digital protection relay equipment for phase modifiers

(1) Use of ratio-differential relays (protection of windings connected in series and regulating windings)
(2) Use of ratio-differential relays (protection of excitation windings)
(3) Use of forward-phase ratio-differential relays/reverse-phase ratio-differential relays (protection of tap windings, stabilizing windings and eddy current windings)

13 High-power Density SiC Power Module (3.3 kV/1,000 A) Using Sintered-copper Die-attach Technology

Hitachi Power Semiconductor Device, Ltd. has developed a 3.3 kV, 1,000 A full-silicon carbide (SiC) power module with a 25% higher current rating than previous models. The new power module is for use in inverter equipment used in applications such as rolling stock.

The 800 A current rating achieved by the company's previous full-SiC modules was already one of the world's highest. It was made possible by a new low-inductance package and a diode-free configuration that eliminated free-wheeling diodes and used only transistor chips. The new model has replaced the soldering previously used to join the chips and substrate with an original sintered-copper die-attach method developed in-house. The maximum allowable junction temperature has been increased from 150 to 175°C, and the current rating further boosted to 1,000 A. The high power density of 47 kVA/cm^2 achieved as a result is one of the highest in the world.

This compact, high-capacity module can be used to reduce heat generation while tolerating high-temperature operation. This benefit enables higher-capacity or more compact inverter equipment with longer life and simplified cooling equipment that can help save energy and space.

(Hitachi Power Semiconductor Device, Ltd.)

13 Full-SiC power module (3.3 kV/1,000 A)