2. Energy Systems

2.1 Demonstration Operation of Prototype C2One™ CO_2 Electrolyzer and Improvement of Durability of CO_2 Electrolysis Stack

Overall view of test stand equipped with C2One™ prototype

Toshiba Energy Systems & Solutions Corporation plans to commercialize the C2One™ electrolyzer in 2026, which is designed to efficiently convert carbon dioxide (CO_2) to produce 150 tons of carbon monoxide (CO).

Following the procurement of equipment and piping components and the manufacturing of a CO_2 electrolysis stack, we completed the prototype C2One™ in July 2024 and installed it on a test stand for demonstration operation. After turning it on and checking the operation of individual electrical and control devices, we verified and tuned the control functions in the non-electrolyzing state. The demonstration operation of the C2One™ then began.

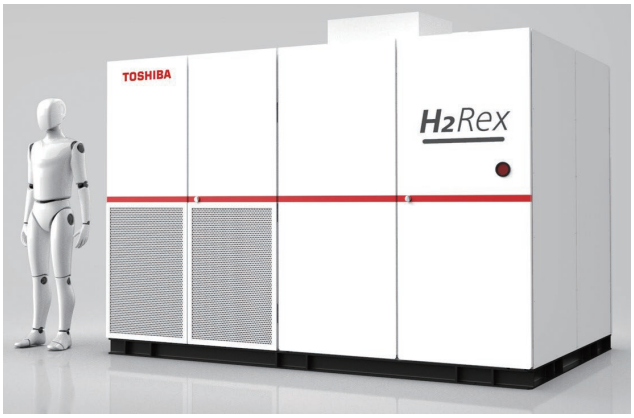
Presently, we are verifying smooth and safe startup and shutdown, the quantity and composition of the electrolytic gas under stable conditions, the dynamic response of the electrolyzer to rapid load changes, and so on. We are also evaluating the usability of the C2One™ by actually walking through the inspection, maintenance, and parts replacement processes while acquiring knowledge for safety management.

To achieve practical deployment of the C2One™, it is essential to further improve the durability of the CO_2 electrolysis stack. With this in mind, we selected highly durable materials and improved operational control methods to suppress degradation. The resulting durability of the CO_2 electrolysis stack was verified using both small-size and full-scale cells.

Finally, we determined the design specifications for the CO_2 electrolysis stack and manufactured a 10-cell short stack accordingly. We are currently verifying the durability of this short stack, including long-term continuous operation and repetitive startup/shutdown cycling.

Part of the results were obtained through the Project for the Establishment of a Circular Carbon Economy Model Through Carbon Dioxide Recycling commissioned by the Ministry of the Environment (MOE) of Japan.

2.2 Cold-Climate Model of H2Rex™ Stationary Fuel Cell System



Third-generation H2Rex™ stationary pure-hydrogen fuel cell system model with standard specifications

Cold-climate H2Rex™ installed at Fukushima Renewable Energy Laboratory

To achieve carbon neutrality, it is crucial to leverage fuel cell systems that efficiently generate electricity from hydrogen. With this in mind, Toshiba Energy Systems & Solutions Corporation developed the H2Rex™ 100 kW stationary fuel cell system and shipped the first unit of its first-generation model in 2016 and the first unit of the third-generation model in 2023.

The third-generation model is compact, cost-effective, quiet, and efficient. Thanks to a high-power-density fuel cell stack and an optimized system configuration, the third-generation model has achieved 95% LHV(*1) efficiency and world-class durability(*2). The standard package size of the third-generation model is 2.8 m wide, 2.0 m deep, and 1.9 m high, making it one of the smallest stationary fuel cell systems in the world(*2). It has a weight of approximately 4.5 tons and a volume of 0.1 m³ per kW of power output. The required maintenance space is only 1.5 m at the front and rear. Without the need for lateral maintenance space, the third-generation model requires less space at the installation site.

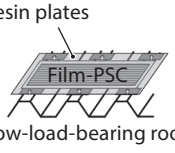
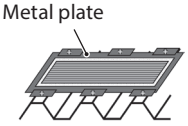
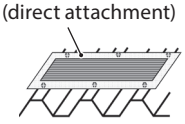
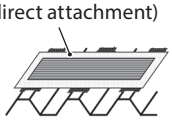
In February 2024, we delivered the cold-climate version of the H2Rex™ to the Fukushima Renewable Energy Laboratory of the National Institute of Advanced Industrial Science and Technology (AIST) in Koriyama, Japan. While the minimum ambient temperature of the standard model of the H2Rex™ is -5ºC, the cold-climate version can generate power at as low as -30ºC. At 3.2 m wide and 5.5 tons in weight, the cold-climate model is larger and heavier than the standard model. However, to simplify the installation of the entire package, the cold-climate model integrates a preheater, a unit to warm the fuel cell by taking in outside air. The preheater operates using part of the fuel cell power. The heater output is adjusted according to the ambient temperature to optimize fuel cell operation. Additionally, the filter location has been optimized to prevent the formation of icicles at the air intake, which is located higher than the possible snow depth.

In the future, we will expand sales of the cold-climate version of the H2Rex™ to cold regions such as Hokkaido, where the introduction of green hydrogen, or hydrogen produced via water electrolysis using renewable energy, is expected to increase.

(∗1) LHV: lower heating value. When power generation efficiency is calculated as a ratio of the amount of electricity generated to the amount of heat generated, the latent heat of condensation of water vapor is excluded from the amount of heat generated.

(∗2) As of April 2025 (according to Toshiba Energy Systems & Solutions Corporation research)

2.3 New Method to Install Film-Type Perovskite Solar Cells Satisfying Weight, Maintainability, and Safety Requirements

Evaluation criterion	Mechanical securing with transparent resin plates	Mechanical securing with metal plates (including metal frames)	Mechanical securing with eyelets (direct attachment of Film-PSCs)	Adhesive securing (direct attachment of Film-PSCs)
Manufacturer	Toshiba Energy Systems & Solutions Corporation	Others	Others	Others
Workability	◎	○	○	△
Weight	○	×	○	◎
Maintainability (maintenance and replacement)	◎	◎	○	×
Safety (resistance to wind pressure and snow load)	○ (anticipated)	◎	△	△
Installation image	Mount for transparent resin plates  Low-load-bearing roof	Metal plate 	Film-PSC (direct attachment) 	Film-PSC (direct attachment) 

◎ : Excellent ○ : Good △ : Fair × : Poor

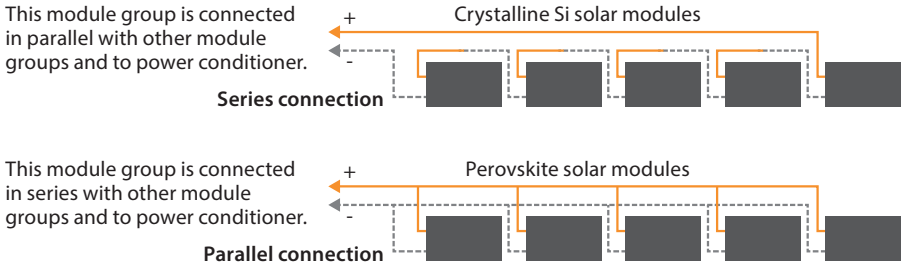
: Issues needing improvement

Comparison of installation methods for film-based perovskite solar cells (Film-PSCs)

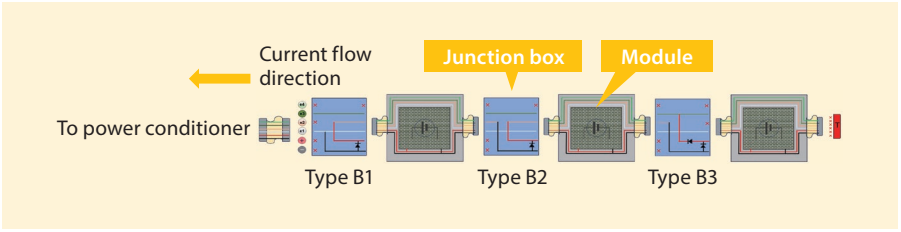
Enterprises aiming to achieve the RE100 (Renewable Energy 100%) goal are expected to install light and flexible film-type perovskite solar cells on low-load-bearing roofs. Manufacturers have been exploring three installation methods: (1) mechanical securing with metal plates, (2) mechanical securing with eyelets, and (3) adhesive securing (using adhesive materials such as glue and double-sided tape). However, with these methods, it is difficult to satisfy all the weight, maintainability, and safety requirements simultaneously.

Toshiba Energy Systems & Solutions Corporation is developing a new method using light, transparent resin plates to secure perovskite solar cells mechanically. It attaches perovskite solar cells to the back of a transparent resin plate. The mounting structure that supports the solar cells is secured to the low-load-bearing roof using brackets, and the entire solar cell is anchored mechanically. With this method, we aim for a more than 30% weight reduction compared to mechanical securing with metal plates without compromising maintainability and safety.

2.4 Simplifying Cable Connections between Perovskite Solar Modules



Comparison of crystal Si and perovskite solar module connection methods



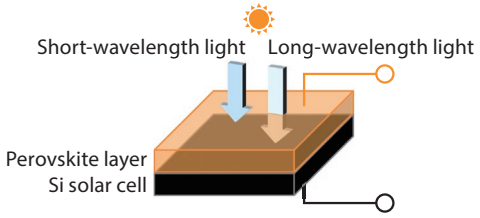
Development of new connecting technology

Light and flexible perovskite solar modules are expected to be installed on low-load-bearing roofs and building walls, whereas conventional silicon (Si) solar cells have not been installable before. However, to install perovskite solar modules on roofs and building walls, it is necessary to simplify inter-module cable connections. Crystalline Si solar modules are often connected in series because a single module provides high current—for example, 10 A. In contrast, perovskite solar modules are connected in parallel because they generate less than 1 A per module. Therefore, perovskite solar modules require several to several tens of times more cable connections than crystalline Si solar modules, necessitating branch cables customized for each installation site. This makes installation work complicated and results in increased total weight and cost.

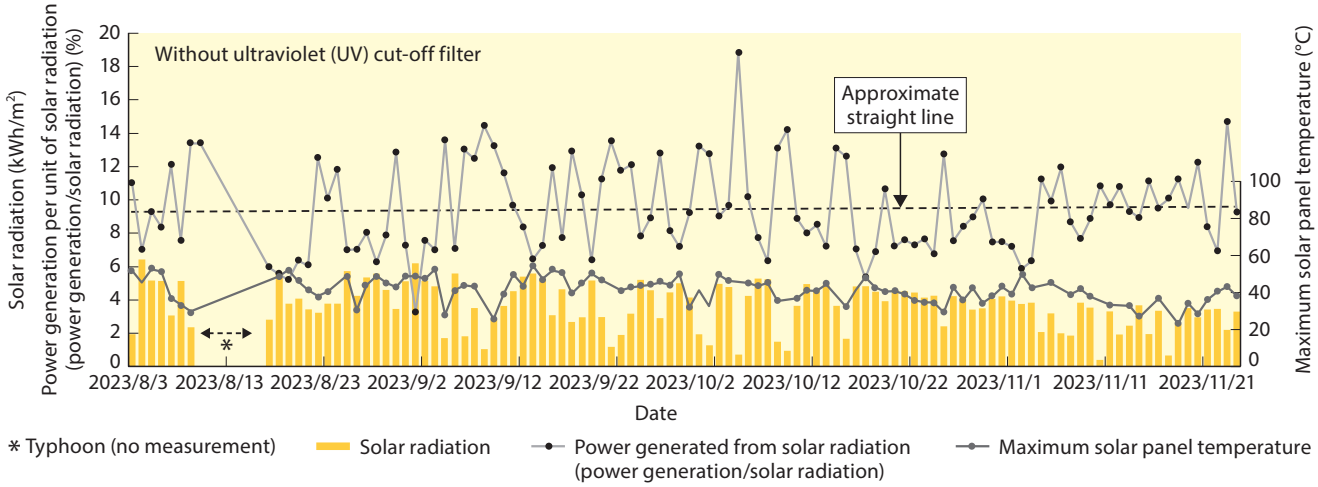
To solve this issue, Toshiba Energy Systems & Solutions Corporation has developed new perovskite solar modules and junction boxes which make it possible to create arbitrary configurations simply by connecting adjacent modules. Our verification using prototypes confirmed proper functioning of the solar modules. The new method reduces the effort required to customize branch cables and allows perovskite solar modules to be installed in a linear layout as long as the installation space with a width of the module is available.

We are currently working to reduce the space requirements and improve the dust- and waterproof performance of perovskite solar modules and junction boxes.

2.5 Realization of Long-Term Stability for Perovskite/Si Tandem Solar Cells



Basic principle of two-terminal perovskite/Si tandem solar cells



Outdoor test of transparent perovskite solar cell for perovskite/Si tandem solar cells

Expectations for renewable energy solutions such as solar cells are growing as part of efforts to achieve a carbon-neutral society. Toshiba Energy Systems & Solutions Corporation is developing next-generation solar cells called two-terminal perovskite/Si tandem solar cells, which are designed with multiple materials to absorb a broader range of wavelengths of sunlight and increase the total power conversion efficiency (PCE). High-PCE tandem solar cells are expected to replace conventional solar cells and help increase Japan's power generation capacity. In 2023, we reported a perovskite/Si tandem solar cell with an improved PCE of 27.5%.

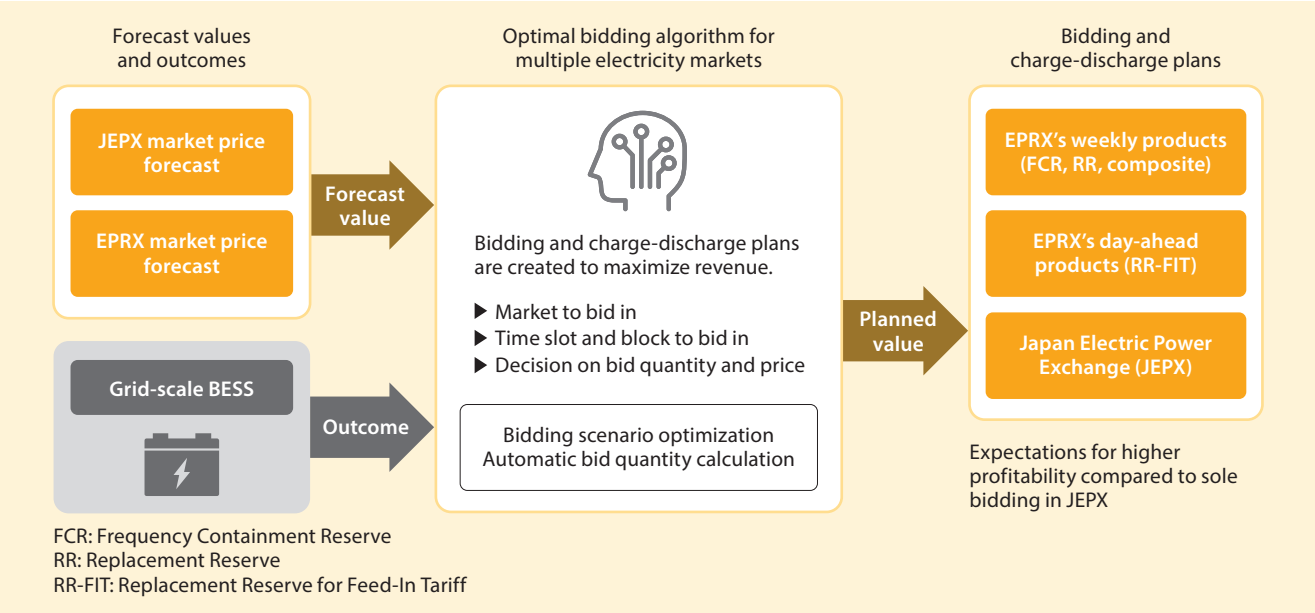
However, to achieve practical use of perovskite/Si tandem solar cells, it is necessary to increase their product service life to about 25 years, which is equivalent to the lifetime of Si solar cells. For perovskite/Si tandem solar cells, sputtering of transparent electrodes damages the perovskite layer, reducing their lifespan. To solve this issue, we explored sputter deposition conditions that are less damaging for the perovskite layer. In 2023, we performed a 1 000-hour light-soaking test, achieving light stability with a less than 10% degradation rate.

In 2024, to resolve the bottleneck of the top subcell, we fabricated a see-through perovskite solar cell with a top subcell possessing transparent positive and negative electrodes on a glass substrate and tested it outdoors for four months over the summer season. The daily solar radi-

ation during the test period ranged from 0.39 to 6.44 kWh/m^2, while the module temperature on clear days reached a maximum of 59°C. We calculated the energy conversion efficiency as the amount of power generated from daily per unit cell area and approximated the relationship between the solar radiation and the energy conversion efficiency over the test period, confirming that the energy conversion efficiency of the new cell did not degrade significantly.

In September 2024, we were selected for a project commissioned by MOE of Japan in recognition of this achievement in an outdoor environment. We will continue to develop long-life, high-efficiency solar cells for practical application and contribute to the growth of renewable energy.

2.6 Functions to Support Optimal Bidding in Multiple Electricity Markets for Grid-Scale Battery Energy Storage Systems



Overview of support functions for optimal bidding in multiple electricity markets

In recent years, renewable energy sources have seen widespread adoption to achieve carbon neutrality, driving the need to maintain a balance between electricity supply and demand. Supply-demand balancing is required to address unexpected changes in electricity supply due to weather events and sudden fluctuations in power generation output. Although supply-demand balancing currently relies primarily on thermal power plants, there are concerns about future balancing capabilities. With this in mind, grid-scale battery energy storage systems (BESS) are becoming increasingly important as an alternative means of supply and demand management.

For grid-scale BESS, it is important to sell the stored battery energy in the most profitable electricity market among the Japan Electric Power Exchange (JEPX), the Electric Power Reserve eXchange (EPRX), and so on. Toshiba Energy Systems & Solutions Corporation has developed an algorithm to support the creation of bidding plans for each market, taking into account the available battery capacities.

This algorithm forecasts electricity prices in the JEPX and the EPRX based on our own weather prediction and market performance data. It then selects the products with higher expected returns based on the price forecasts to create bidding plans. Additionally, the new algorithm is characterized by its ability to create different plans, depending on the traded products.

In the case of the EPRX's weekly products, the new algorithm compares the expected returns from each product within the upper and lower bid price limits set by the operator to determine the optimal bid price. If a limit price is set, it can create the optimal bidding plan, considering

factors such as the contracting probability. In the case of the EPRX's day-ahead products and JEPX bids, the new algorithm creates the optimal bidding plans for each market to maximize expected returns based on the available capacity at a given time, considering the capacity of the batteries used for weekly products. This algorithm could enable businesses with a grid-scale BESS to shorten their investment recovery period.

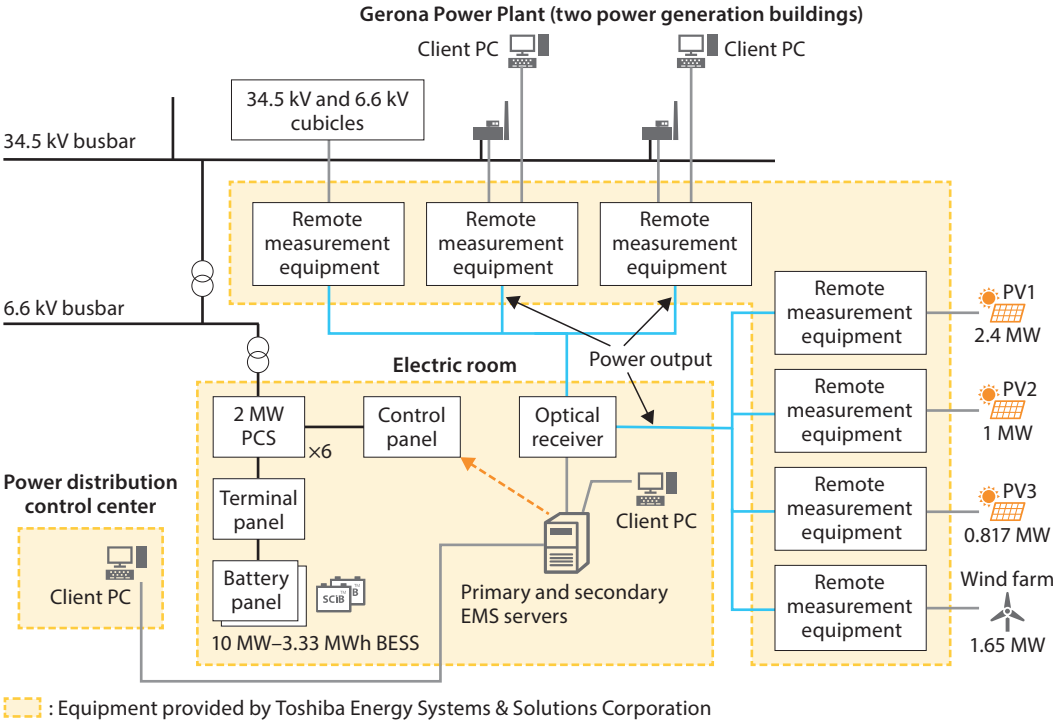
We have integrated the new algorithm into our virtual power plant (VPP) service on the cloud. This makes it easy to modify to adapt to future changes such as regulatory revisions.

2.7 JICA Cuba Project: Commencement of Operation of Grid Stabilization System for Isle of Youth, Cuba

As part of the Project for the Improvement of Power Supply in the Isle of Youth of the Japan International Cooperation Agency (JICA), Toshiba Energy Systems & Solutions Corporation delivered a grid stabilization system consisting of an energy management system (EMS) and a BESS to the Gerona Power Plant on the Isle of Youth managed by Unión Eléctrica de Cuba (UNE), a Cuban electricity company. Following the handover to UNE in April 2024, the grid stabilization system has begun operation.

The EMS provides functions for remote BESS monitoring and operation, photovoltaic (PV) and wind power output monitoring, PV output prediction, frequency fluctuation (ΔF) control, and generator backup. The BESS is composed of a 2 MVA power conditioning system (PCS) and a group of Toshiba Corporation's SCiB™ lithium-ion rechargeable batteries with a rated capacity of 10 MW–3.33 MWh. The BESS provides a power fluctuation (ΔP) control function to smooth out grid power fluctuations caused by sudden fluctuations in renewable energy output.

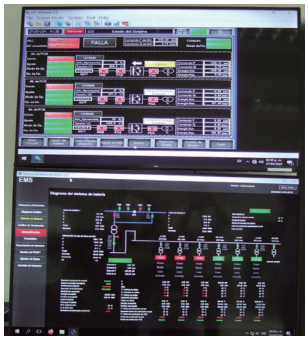
This grid stabilization system is the first of its kind for UNE and will help Cuba meet its goal of increasing the proportion of renewable energy in the energy mix of the Isle of Youth from 5% to 30% by 2030.



Overview of EMS and BESS at UNE power plant on Isle of Youth, Cuba

Electrical room and battery container

Battery control panel (front) and EMS server (back) in electric room



Screenshots of battery control panel in power distribution center (top) and EMS monitoring and operation function (bottom)

External view

2.8 Field Demonstration for Commercialization of Battery Degradation Diagnostic Service for EV and Stationary Battery Applications

Electric vehicles (EVs) and stationary BESS are becoming increasingly prevalent as part of efforts to achieve carbon neutrality by 2050. However, there are growing concerns over the deteriorating state of health (SoH) of mainstream lithium-ion batteries caused by aging as well as potential hazards such as fires. Demand is therefore on the rise for battery degradation and safety diagnoses.

With this in mind, the Toshiba Group has developed battery degradation diagnostic technology known as charging curve analysis, which is a nondestructive method that estimates the internal state of lithium-ion batteries. The new technology can evaluate the SoH and the state of safety (SoS) of lithium-ion batteries in detail based only on basic data such as voltage and current during the charging process, without the need for any special measuring instruments.

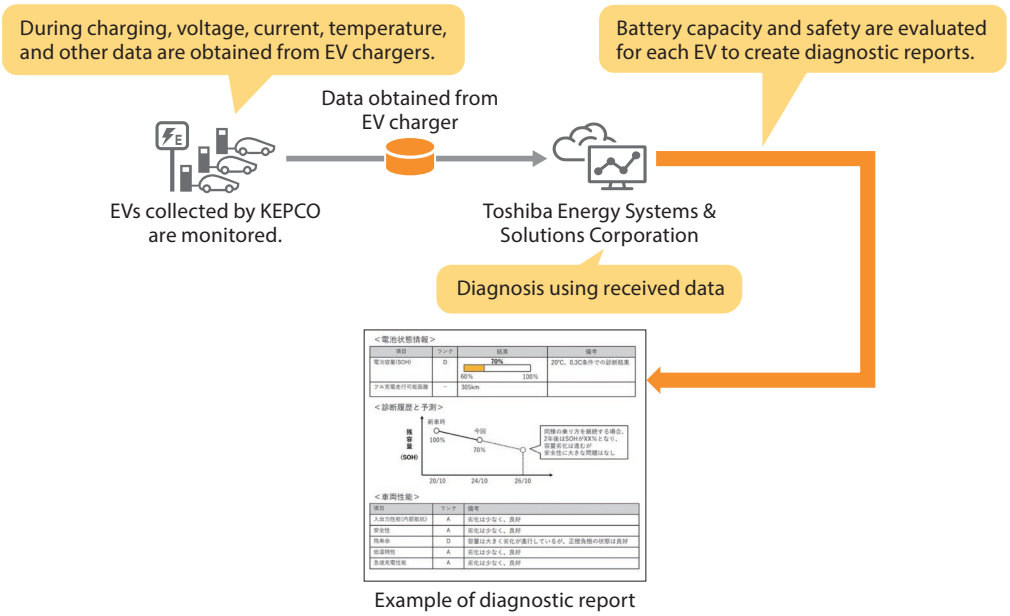
With the aim of commercializing battery degradation diagnostic services using charging curve analysis, Toshiba Energy Systems & Solutions Corporation is conducting field demonstrations for both EVs and BESS in collaboration with The Kansai Electric Power Co., Inc. (KEPCO).

In the EV demonstration, we performed a battery degradation diagnosis based on charging data obtained from the EVs collected by KEPCO and created diagnostic reports for each vehicle. The EVs that have been evaluated since August 2023 include major models from domestic and overseas automakers. Demonstration experiments have identified the usefulness and issues of the new technology.

In the BESS demonstration, we performed a battery degradation diagnosis based on charging data obtained from KEPCO's BESS using second-life EV batteries and Tokyu Construction Co., Ltd.'s grid-connected BESS using new batteries. Periodic evaluations of the BESS make it possible to identify degradation trends associated with normal operation. Additionally, the state of battery degradation can be evaluated in detail by obtaining charging data at the system, rack, and module levels.

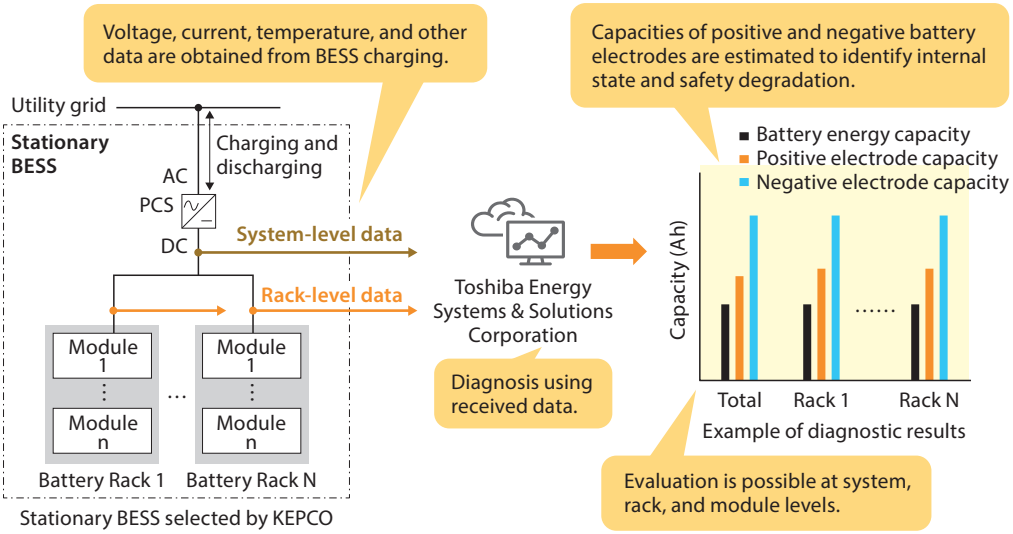
We will leverage the insights acquired from the demonstrations to develop new technologies for achieving early commercialization of battery degradation diagnostic services and thereby contribute to improving the safety of lithium-ion batteries.

What is verified in joint demonstration:
- Versatility of diagnostic technology using only basic data obtained from chargers for various EV models (Toshiba Energy Systems & Solutions Corporation)
- Value proposition for EV business owners through diagnostic reports, including advice on extending battery life, decisions on vehicle replacement, and residual battery value (KEPCO)



Overview of joint demonstration of battery degradation diagnosis for EV

What is verified in joint demonstration:
- Detailed diagnosis and visualization of SoH and SoS during BESS operation (Toshiba Energy Systems & Solutions Corporation)
- Value proposition for BESS owners through asset management and maintenance support services based on diagnostic results (KEPCO)



Overview of joint demonstration of battery degradation diagnosis for stationary BESS

2.9 Restarting Operation of Tohoku Electric Power Co., Inc. Onagawa Nuclear Power Plant Unit 2

Panoramic view of Onagawa Nuclear Power Plant

All photos are courtesy of Tohoku Electric Power Co., Inc.

Loading nuclear fuel into reactor

Reactor startup from main control room

Following the Great East Japan Earthquake, Toshiba Energy Systems & Solutions Corporation modified the main facilities at Onagawa Nuclear Power Plant Unit 2 (825 000 kW) to comply with revised safety regulations. Following this, the Unit 2 boiling water reactor (BWR) restarted operation on October 29, 2024 and began power generation on November 15, 2024, marking the first restart of this type of reactor in 13 and a half years since the earthquake.

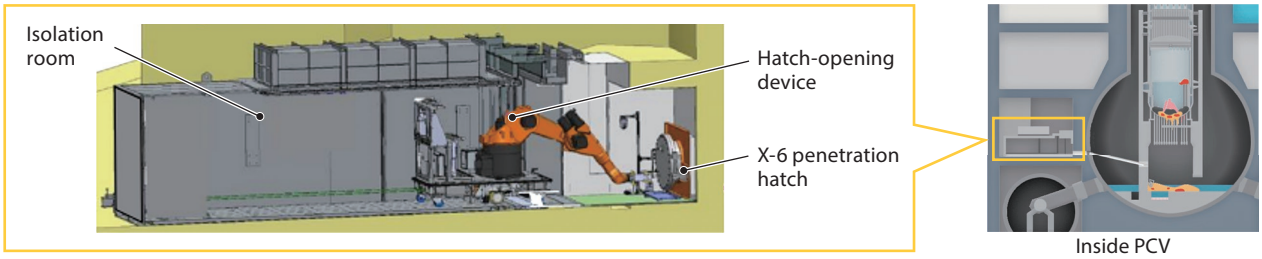
In preparation, we collected information about issues that had occurred at the power plant in the past, evaluated the impact of the 13-year shutdown on equipment, and assessed the influence of the new equipment required by the new regulatory standards on existing equipment. We anticipated and evaluated potential events that could occur during the restart process, incorporating the knowledge of Tohoku Electric Power Co., Inc., and implemented preventive measures to reduce risks.

We organized a support team consisting of 450 experts from various fields and deployed them on-site to prepare for unexpected problems related to the design, construction, and test aspects of major events (e.g., fuel loading, reactor hydrostatic test, containment vessel leakage test, reactor startup, turbine startup and generator synchronization, and response during a power run-up). We also organized a support team consisting of knowledgeable design engineers and procurement personnel at our headquarters, factories, and partner companies. After the reactor startup, experienced personnel responsible for Toshiba Operation Plant Services (TOPS) were stationed in the main control room around the clock to provide operational support.

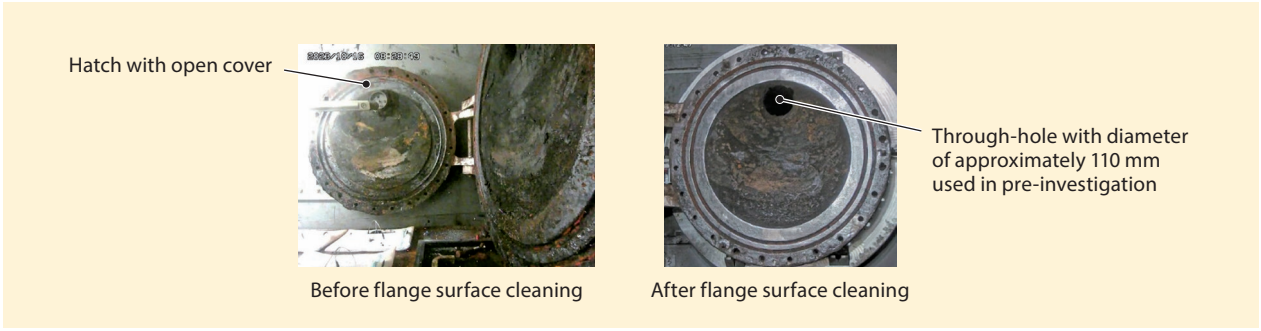
During the plant startup, we collected data from equipment such as output control devices, measuring instruments, turbines, and generators and compared the collected data with standard values and past data to evaluate equipment health and performance in a timely manner. We dealt with issues that occurred every day with Tohoku Electric Power Co., Inc. to meet major milestones, commencing commercial operation on December 26, 2024 as initially planned.

We will continue to handle maintenance at Onagawa Nuclear Power Plant Unit 2 to ensure stable operation while offering construction and support services to restart other BWRs.

2.10 Opening of X-6 Penetration Hatch for Test Retrieval of Fuel Debris From Fukushima Daiichi Nuclear Power Station Unit 2



Opening X-6 penetration hatch using hatch-opening device for test removal of fuel debris from Fukushima Daiichi Nuclear Power Station Unit 2



X-6 penetration hatch with open cover (before and after flange surface cleaning)

Toshiba Energy Systems & Solutions Corporation has developed the equipment necessary to open the X-6 penetration hatch of Fukushima Daiichi Nuclear Power Station Unit 2, which has an inner diameter of approximately 600 mm to provide an access route to the inside of the primary containment vessel (PCV) for detailed investigation. We have completed on-site installation of the equipment and the opening of the X-6 penetration hatch.

The requirements for this equipment included preventing radioactive materials inside the PCV from leaking through the X-6 penetration hatch and eliminating the need for workers to approach the highly radioactive hatch. In response, we developed (1) an isolation room that provides a shield from the X-6 penetration hatch and (2) a remote hatch-opening device designed to remove all 24 pairs of bolts and nuts from the hatch, open the approximately 200 kg hatch, and clean the flange surface in the isolation room.

The hatch-opening device has a manipulator mounted on a self-propelled dolly. The tool at the tip of the manipulator can be replaced to move the hatch or perform multiple operations remotely from outside the isolation room.

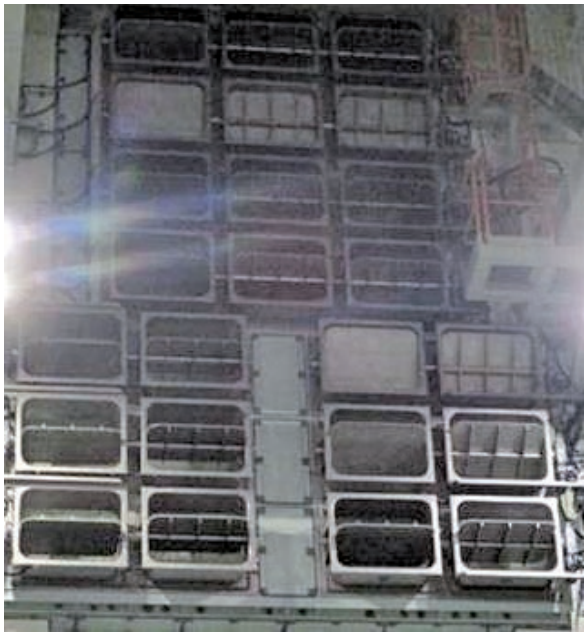
On-site, the nuts were cut to remove the bolts, assuming that thread galling could occur when loosening the bolts and nuts. However, several bolts were found to be unremovable simply by cutting the paired nuts due to the effects of the earthquake and aging. Therefore, we developed a new drill to cut the galled threads to remove the bolts.

We also prepared laser cleaning and buffing tools to clean the flange surface, anticipating adhesion of foreign matter. However, the foreign matter was firmly stuck to the surface and could not be completely removed, so we also employed a chisel to chip it off, achieving the required flange surface properties.

We will use the experience acquired through this project for future surveys and fuel debris retrieval to contribute to the decommissioning of the Fukushima Daiichi Nuclear Power Station.

Part of this work was subsidized by the Ministry of Economy, Trade and Industry (METI) under the Decommissioning and Contaminated Water Management project and implemented by the International Research Institute for Nuclear Decommissioning (IRID).

2.11 Completion of Blowout Panel Re-closing Device at Shimane Nuclear Power Plant Unit 2



Blowout panel re-closing device installed at Shimane Nuclear Power Plant Unit 2

In Japan, restarting nuclear power plants is subject to strict regulations which mandate the installation of a device to quickly re-close the reactor building blowout panel in the event of an accident to reduce operators' risk of exposure to radiation.

Toshiba Energy Systems & Solutions Corporation completed installation of a blowout panel re-closing device at The Chugoku Electric Power Co., Inc. Shimane Nuclear Power Plant Unit 2 in August 2023.

Because its design requirements included the use of foreign-made dampers purchased by The Chugoku Electric Power Co., Inc., we needed to interact with and provide support for their vendors who were unfamiliar with the Japanese regulations, encompassing earthquake resistance verification, construction plan approval, and functional requirement identification processes. Cableway construction was also complicated because it was necessary to communicate with multiple vendors, including those overseas, to adjust connections between their devices. Furthermore, because we were not involved in the construction of the Shimane Nuclear Power Plant, we needed to cooperate with all concerned parties, including The Chugoku Electric Power Co., Inc., to overcome various challenges to complete the installation of a blowout panel re-closing device within the required period of time, such as learning the construction management rules, identifying interfering devices from other vendors, including their operating ranges, managing on-site companies, and securing the necessary workforce.

We plan to leverage this experience to contribute to promoting restarting and new construction of nuclear power plants in Japan.

2.12 Commercial Operation of Four Units at Barakah Nuclear Power Plant, UAE

Overview of Barakah Nuclear Power Plant, UAE

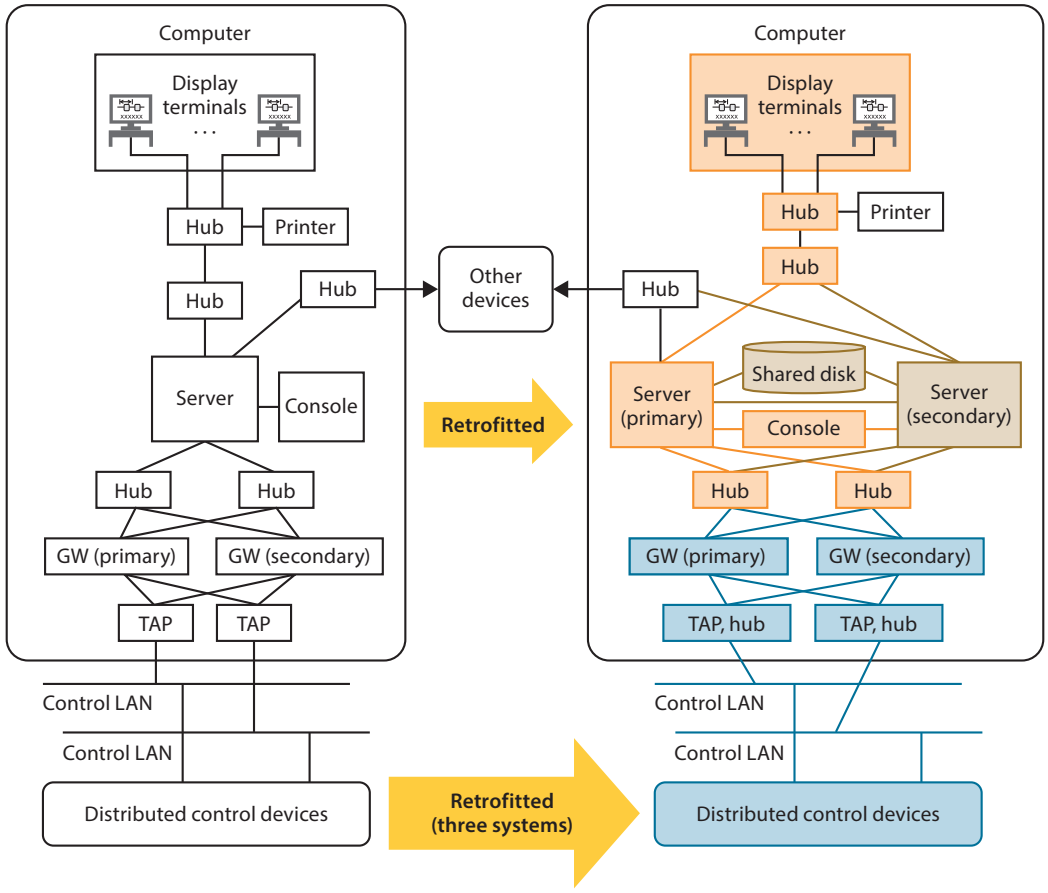
In September 2024, Unit 4 of the Barakah Nuclear Power Plant of Emirates Nuclear Energy Company (ENEC) in the United Arab Emirates (UAE) commenced commercial operation. Toshiba Energy Systems & Solutions Corporation and Doosan Enerbility Co., Ltd. were responsible for the design and manufacturing of its steam turbine, generator, and auxiliary equipment.

The Barakah Nuclear Power Plant was constructed by ENEC with KEPCO acting as the prime engineering, procurement, and construction (EPC) contractor. The plant consists of four APR1400 pressurized water reactors (PWRs), each with a capacity of up to 10 TWh (T: tera = 10^{12}) per year. We and Doosan Enerbility Co. Ltd. supplied turbines and generators (with a 52-inch last-stage low-pressure blade) for all units.

Since Unit 4 began commercial operation, all four units of the Barakah Nuclear Power Plant have been operating approximately for one year, supplying approximately 25% of the electricity demand in the UAE and thus significantly contributing to its energy security and decarbonization as a core power source.

We will continue to supply equipment to overseas nuclear power plants, thereby contributing to achieving a safe and stable electricity supply while reducing environmental load.

2.13 Retrofitting Process Control Computers to Improve Reliability of Nuclear Reprocessing Plant



Configurations of previous and retrofitted process control computers at Rokkasho Reprocessing Plant

The Japan Nuclear Fuel Ltd. (JNFL) Rokkasho Reprocessing Plant is equipped with ten process control computers. However, since the plant was constructed, its process control computers have not had any redundancy except for some server systems. During operations, however, the importance of process control computer redundancy became increasingly apparent. From 2017 to 2024, Toshiba Energy Systems & Solutions Corporation duplicated all the system servers at the Rokkasho Reprocessing Plant to increase availability and reliability.

We adopted hot-standby redundancy using shared disks (disk array devices) so that various data generated during operation can be transferred accurately from an active system to a standby system in the event of a failure. Additionally, we optimized the monitoring cycle and parallel processing to reduce the time required to resume process data transmission to about 10 seconds (compared to a few minutes with the existing installations).

The process control computers now provide a new function (called Priority mode), which allows operating data to be transmitted to other devices even in the event of a failure or when the shared disk is turned off for periodic inspections. Also, to minimize missing transmissions and thus avoid the risk of information loss, the process data transmission function is designed to keep the missed measurement period within 30 seconds. We also enhanced data management accuracy by reducing the transmission cycle for collecting process data from distributed control devices to one second (compared to two seconds required by the existing installations).

2.14 Shipment of Superconducting Detector Solenoid Magnet for J-PARC COMET Experiment

COMET detector solenoid superconducting magnet

The Coherent Muon to Electron Transition (COMET) experiment is a collaborative international experiment aimed at discovering new physical laws using muons. The Japan Proton Accelerator Research Complex (J-PARC) accelerator is used to accelerate a pulsed muon beam, and a superconducting detector solenoid magnet at the exit of the beamline acts as a spectrometer to measure the momentum of electrons by applying a magnetic field of one tesla.

Toshiba Energy Systems & Solutions Corporation had been manufacturing this superconducting detector solenoid magnet since 2015 and completed shipping it in September 2024. The superconducting detector solenoid magnet consists of 14 coils with a vacuum bore diameter of 1.8 m and a length of 3.3 m. It is the world's largest direct-cooling superconducting magnet using small refrigerators without liquid helium(*).

We will continue to contribute to the progress of particle physics through the development of large superconducting magnets.

(*) As of October 2024 (according to Toshiba Energy Systems & Solutions Corporation research)

2.15 Completion of EPC Projects for Overseas Thermal Power Plants

Van Phong 1 Thermal Power Plant Units 1 and 2, Vietnam

Matarbari Power Plant Units 1 and 2, Bangladesh

Construction of Unit 1 at the Van Phong 1 BOT Thermal Power Plant (Van Phong 1), a supercritical coal-fired thermal power plant in Vietnam, was completed in October 2023, followed by Unit 2 in January 2024. Construction of Unit 1 of the Matarbari Power Plant, an ultra-supercritical coal-fired power plant in Bangladesh, was completed in December 2023, followed by Unit 2 in July 2024.

Toshiba Energy Systems & Solutions Corporation supplied the turbine island equipment for these power plants, which incorporates advanced technologies for highly efficient turbine cycles to reduce CO_2 emissions.

Van Phong 1 marked our first EPC project in Vietnam. We organized a four-member EPC consortium to secure a contract with Sumitomo Corporation, the owner. Serving as the consortium leader, we obtained government permits and licenses and ensured complete audit compliance. We supplied a computerized maintenance management system that helps with facility operation and maintenance using plant information. Despite the effort required for installation and commissioning due to offshore outsourcing of mechanical engineering, we successfully completed the project with local support.

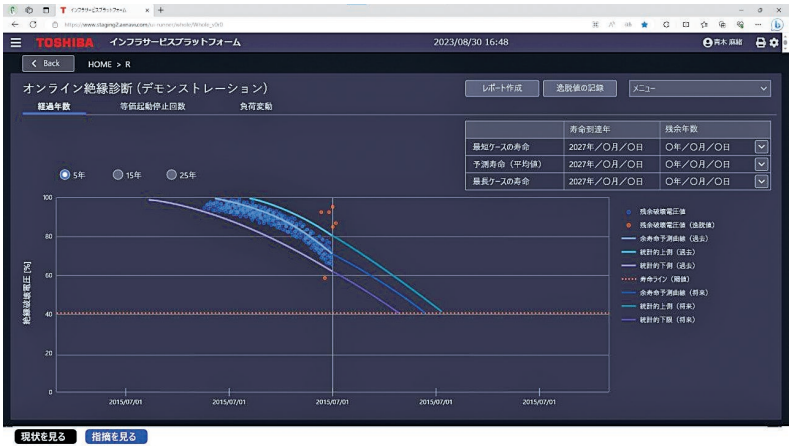
For Matarbari, we adopted a new turbine exhaust evacuation system to prevent the high-pressure steam turbine exhaust temperature from rising, which had occurred in previous projects, and verified its effectiveness through a commissioning test. Additionally, we introduced an online plant performance analysis, diagnosis and optimization (PADO) system to stabilize plant operation.

Although both projects faced difficulties because of the COVID-19 pandemic, we managed to minimize the impact on the project schedules by proactively using remote engineering systems and employing third-party organizations for vendor shop floor inspection, on-site installation, and commissioning. We completed plant construction by carrying out thorough infection

control measures and optimizing the team structure with Toshiba Plant Systems & Services Corporation.

In the future, we will focus on improving the operational efficiency and promoting the decarbonization of thermal power plants by utilizing digital transformation (DX) technologies.

2.16 Commencement of PoC for Predictive Generator Diagnosis Using IoT Application

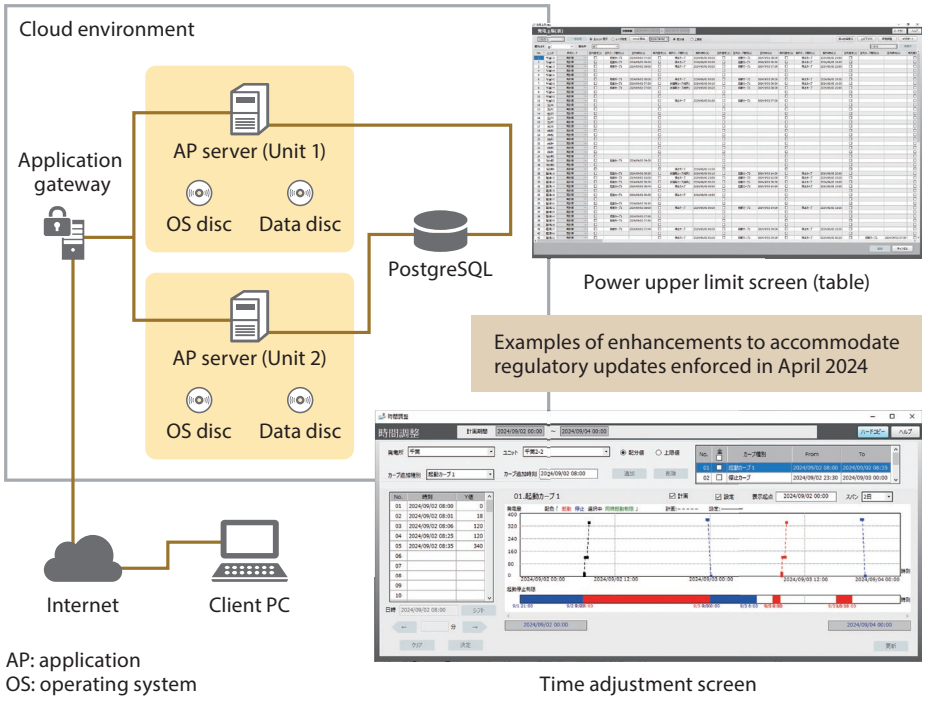


Screenshot of Toshiba IoT application for online generator stator insulation diagnosis

With the spread of renewable energy, the role of thermal power plants has shifted to adjustment power sources, resulting in increased concerns over accelerated generator aging due to output fluctuations and an increased risk of operating failures. With this in mind, Toshiba Energy Systems & Solutions Corporation has developed and commercialized a monitoring system equipped with a partial discharge (PD) detector for online predictive generator stator insulation diagnosis using an Internet-of-Things (IoT) application.

We installed the new monitoring system at The Chugoku Electric Power Co., Inc. Shin-Onoda Power Station Unit 1 to start a proof-of-concept (PoC) demonstration. Operational data are exchanged using memory cards and imported into the IoT application to evaluate generator stator insulation deterioration. We are also developing rotor fault detection, cooler performance degradation prediction, and collector spark monitoring functions. In the future, we will provide menus tailored to customer needs, including online data exchange.

2.17 Start of Cloud Version of Thermal Operation Planning System for JERA Co., Inc.



Configuration of cloud version of Thermal Operation Planning System for JERA Co., Inc.

JERA Co., Inc. previously used the on-premises version of the Thermal Operation Planning System (TOPS) high-performance optimization software provided by Toshiba Energy Systems & Solutions Corporation. We have recently delivered the newly released cloud version of TOPS to JERA, which provides new enhancements for thermal plant operations based on Japan's revised regulations on power generation, sales plans, and balancing energy markets, which went into effect in April 2024.

While satisfying all the operating constraints of each power plant, TOPS minimizes total fuel cost, considering electricity demand for all the thermal power plants located in JERA's service area in eastern Japan. It can also solve some of the world's largest-scale problems, finding the optimal timing at which to start, stop, and change the output of each power plant.

Because this is the first time TOPS has been deployed in a customer cloud environment, we have made it scalable according to the computational workload. We also improved its maintainability so that it can be upgraded at the customer's request for additional or updated functions to accommodate regulatory revisions.

We will deploy TOPS in JERA's service area in western Japan and at other electric companies.

2.18 Completion of Major Refurbishment Project for Unit C4 of Callide Power Station in Australia

Turbine and generator at Callide Power Station Unit C4, Australia immediately after incident

Upgraded turbine and generator at Callide Power Station Unit C4

In May 2021, the Unit C4 turbine and generator at the Callide Power Station in Australia were damaged beyond repair due to loss of power in the turbine protection system. As part of major refurbishments at the power station, Toshiba Energy Systems & Solutions Corporation manufactured a new turbine and generator, completing the installation in June 2023, with Unit C4 resuming commercial operation in August 2024.

The restoration process presented many technical difficulties. However, leveraging our extensive experience, we collaborated with Toshiba International Corporation Pty Ltd. to supply the new turbine and generator within a short period of time while ensuring smooth installation and commissioning. We also incorporated the latest technology into the new steam turbine to improve reliability and efficiency. High-performance blade rows and advanced sealing technology also contributed to increased efficiency and reduced CO_2 emissions.

The success of this project demonstrated our ability to meet customer needs and tight schedules, resulting in earning the trust of our customer and receiving a contract for the repair of the adjacent Unit C3 generator. We remain committed to contributing to the stable power supply in Australia.

2.19 Completion of Civil Construction Work for Goi Thermal Power Plant EPC Project

Goi Thermal Power Station Unit 1 turbine and control building

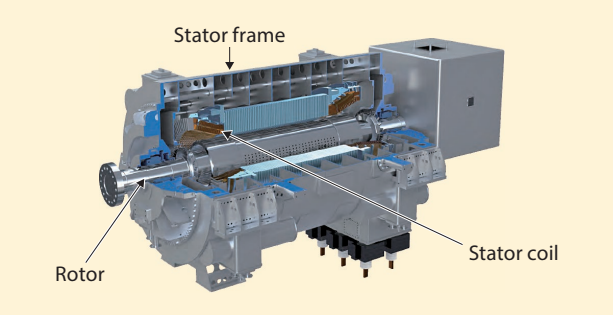
Service building

The Goi Thermal Power Plant operated by Goi United Generation LLC consists of three state-of-the-art combined-cycle units. Toshiba Energy Systems & Solutions Corporation constructed all the units under an EPC contract through a joint venture with Toshiba Plant Systems & Services Corporation, which commenced commercial operation in March 2025. We delivered both power generation equipment and civil and architectural facilities for the units. This project entailed the largest-scale civil engineering and construction work among all domestic thermal power plants for which we had served as the prime design and construction contractor. We delivered all civil engineering equipment by the end of July 2024, and the inspection of the completed building was finished in August as scheduled.

Aiming to maximize the value of the prime contractor's business, we optimized the civil engineering and construction processes in the equipment layout and building plan and implemented measures to shorten the construction period. We also avoided design iterations by aligning this plan with the power generation equipment plan. Additionally, we formulated a design concept for the entire power plant to enhance its functionality and aesthetic design.

We proceeded with the construction of the units while Goi United Generation LLC was still working on the demolition of the existing units. The project progressed smoothly thanks to well-coordinated efforts by all the parties involved and our consistent quality and safety management.

2.20 Completion of Generator Swapping at Calaca Power Station Unit 2, Philippines



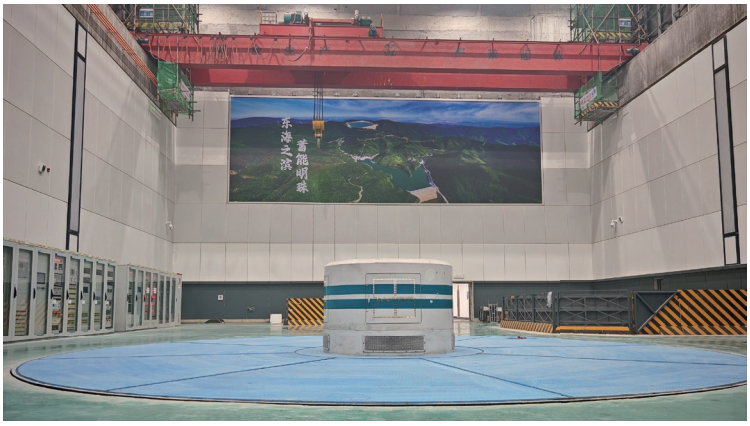
Typical steam turbine generator structure

Hoisting old generator stator onto foundation after stator coil rewinding at Calaca Power Station Unit 2, Philippines

The Calaca Power Station in the Philippines plays an important role in the country's power supply. The Unit 2 generator was manufactured in 1995 and was fully upgraded in 2020 by its original manufacturer. However, it was able to operate only at about 60% of its rated output because of two ground fault incidents and vibration issues. Consequently, the client asked Toshiba Energy Systems & Solutions Corporation to replace the generator. We proposed rewinding the stator coils and reusing the stator frame and rotor of the old generator in storage because this would be advantageous in terms of delivery time and cost.

The client's budget was limited, and we did not have full access to detailed drawings and information on generator materials and dimensions as it was manufactured by another company. We therefore split the generator replacement tasks with the client after rewinding the stator coils. This resulted in 12 handovers between us and the client, creating a complex work environment. However, we were able to adhere to the work schedule by actively supporting the client's process. This was possible largely due to the expertise of experienced engineers from Keihin Product Operations who established a robust internal and on-site support team. As a result of generator swapping, the power output of Unit 2 was restored to the rated 300 MW and has been operating stably.

2.21 Commencement of Commercial Operation at Ninghai Pumped Storage Power Station, China



Ninghai Pumped-Storage Power Station, China

Rotor installation

Toshiba Hydro Power (Hangzhou) Co., Ltd. completed the construction of Units 1, 2, and 3 at the Ninghai Pumped Storage Power Station, which commenced commercial operation in October 2024, December 2024, and January 2025, respectively. Located 220 km southeast of Hangzhou, the capital of Zhejiang Province, this power station consists of four 350 MW units with a total output of 1 400 MW. The 350 MW pumped storage turbine-generator unit has the largest capacity among all our products.

Toshiba Energy Systems & Solutions Corporation collaborated with Toshiba Hydro Power (Hangzhou) Co., Ltd. to receive a contract for this project in February 2021. We were responsible for hydraulic design and performance model testing, and supporting Toshiba Hydro Power (Hangzhou) Co., Ltd. in designing and manufacturing all the pump-turbines and generator-motors. The pump-turbine has a splitter runner with alternating long and short blades to reduce pressure pulsation and vibration even in the partial load range.

Unit 4 is scheduled to commence commercial operation in May 2025.

The ratings of the pump-turbines and the generator-motors are as follows:

- Pump-turbines: 351.7 MW, 459/507.6 m, 428.6 min^{-1}
- Generator-motors: 388.9 MVA, 384 MW, 18 kV, 428.6 min^{-1}, 50 Hz

2.22 Completion of Manufacturing of Refurbishment Equipment for the Cañaveral Hydropower Station, Honduras

Turbine runner upgrade at Cañaveral Hydropower Station, Honduras

Hybrid servomotor

In September 2024, Toshiba Energy Systems & Solutions Corporation completed manufacturing two units of turbines, inlet valves, and control systems for large-scale refurbishment of the Cañaveral Hydropower Station in Honduras. Signs of equipment aging were the motivation for a major plant refurbishment and modernization project aimed at improving environmental friendliness, maintainability, and long-term operability.

The turbines will be completely replaced except for embedded components. We have enhanced the performance of the new runner and guide vanes through computational fluid dynamics (CFD) analysis, increasing the turbine flow rate and achieving a 12% increase in turbine output.

We have also adopted a newly designed guide vane operating mechanism using a hybrid servomotor system for the first time for overseas power plants. The hybrid servomotor system employs a bidirectional hydraulic pump to replace the conventional hydraulic servomotor. This technology helps improve environmental friendliness thanks to greatly reduced hydraulic oil usage and reduces plant maintenance requirements due to a simplified mechanism.

The plant control system will also be replaced by TOSMAP-LX, an integrated digital control system designed to modernize generator unit control and management. The Cañaveral Hydropower Station is our first overseas hydroelectric power plant project using an integrated digital control system and the International Electrotechnical Commission (IEC) 61850 communication protocol.

Additionally, the generator units will be refurbished with new bearings and air coolers.

On-site work is scheduled to begin in December 2025 and is expected to be completed by March 2027.

The ratings of the uprated turbines and generators are as follows:

- Turbines: 16 500 kW, 145 m, 514 min^{-1}, 2 units
- Generators: 17 000 kVA, 13.8 kV, 60 Hz, power factor = 0.95, 2 units

2.23 Completion of Renovation of Bajina Bašta Pumped Storage Hydropower Plant Unit 1, Serbia

Installation of new pump-turbine runner for Unit 1 at Bajina Bašta Pumped Storage Hydropower Plant, Serbia

Unit 1 of the Bajina Bašta Pumped Storage Hydropower Plant operated by Elektroprivreda Srbije (EPS) in Serbia resumed commercial operation in January 2025, following renovation and testing.

Equipped with the pump-turbines and generator-motors that we provided, the Bajina Bašta Pumped Storage Hydropower Plant has a total output of 620 MW (310 MW×2 units), which accounts for approximately 8% of the total power generation capacity of EPS.

Having been in operation for 42 years since 1982, the plant underwent a second renovation, following the previous one in 2003. For this project, we developed high-performance runner and guide vanes by using our latest technology, achieving an approximately 1% increase in pump and turbine efficiencies. To overhaul Unit 1, we disassembled the pump-turbine and generator-motor to inspect components and replace consumable parts. This renovation will contribute to the stable and efficient operation of EPS' important plant.

We began restoring Unit 2 in March 2025.

The ratings of the pump-turbines and generator-motors are as follows:

- Pump-turbines: 296/314 MW, 614/610 m, 428.6 min^{-1}
- Generator-motors: 315 MVA/310 MW, 11 kV, 50 Hz, 428.6 min^{-1}

2.24 Delivery of New STATCOM for Stable Electric Power Grid Operation

STATCOM at Shikoku Electric Power Transmission & Distribution Co., Inc. Nakamura Substation (view inside valve hall)

The increasing power feed-in from renewable energy sources and the resulting changes in the flow of electricity within the power grid are driving the need for measures to maintain grid stability. Static synchronous compensators (STATCOMs) are used to mitigate voltage fluctuations and help stabilize the voltage levels of power grids.

Toshiba Energy Systems & Solutions Corporation has developed a new STATCOM using a modular multilevel converter (MMC) which was delivered to the Shikoku Electric Power Transmission & Distribution Co., Inc. Nakamura Substation in August 2024. Connected to a 66 kV power grid, this STATCOM provides a reactive power output range of ±40 Mvar. Because of the limited installation space at the substation, we integrated the functionality of buffer reactors into the transformer winding to achieve a compact equipment layout.

The new STATCOM is driven by a large-capacity, low-loss power semiconductor device called an injection-enhanced gate transistor (IEGT) from Toshiba Electronic Devices & Storage Corporation and is equipped with a power system stabilizer (PSS) to stabilize the power grid. The new STATCOM also features the capability for coordinated operation with existing shunt capacitors. We performed commissioning tests to confirm that the new STATCOM provides appropriate control to improve power grid stability before the start of operation.

Power grids are facing heightened challenges such as the increasing integration of renewable energy sources and ever-rising electricity demand, making power grid stabilization using STATCOMs even more important. Leveraging the new STATCOM, we will contribute to enhancing energy resilience and achieve carbon neutrality.

2.25 Start of Operation of Chugoku Electric Power Transmission & Distribution Co., Inc. Integrated Resilience System for Bulk Power System

Control computer at Chugoku Electric Power Transmission & Distribution Co., Inc.

Master station (digital protective relays)

Since the Eastern Iburi Earthquake caused a large-scale blackout across Hokkaido in September 2018, demand for enhanced power grid resilience has grown. Japan's national advisory committee(*1) decided to implement measures to mitigate the risk of large-scale blackouts in the event of simultaneous loss of four main transmission lines (N-4 fault). However, an excessive frequency drop could occur if solar and non-utility power generators are disconnected from a grid during a frequency drop, resulting in demand for enhanced grid frequency resilience.

With this in mind, Toshiba Energy Systems & Solutions Corporation has developed the Integrated Resilience System (IRS) for Bulk Power System to stabilize power grids in the Chugoku region by improving grid synchronization stability, preventing overload events, maintaining grid frequency, and enhancing grid voltage stability.

The IRS consists of a control computer and digital relays composed of a master station and a set of equipment for fault detection, transmission line shedding and voltage-ampere reactive (VAR) control, steam turbine generator tripping, pumped storage tripping, and load shedding. Its main functions are twofold: (1) maintaining grid synchronization stability in the event of an N-4 fault and (2) controlling grid frequency.

The first function uses a control computer to perform synchronization stability calculations (for approximately 1 000 cases) at regular intervals (30 seconds minimum) based on online

power grid data and transmits the optimal control variables (control table) to the master station. When the fault detection equipment detects a fault, the master station sends control commands to each tripping equipment based on the control table. The tripping targets include steam turbine generators (including power lines), pumped storage generators, and inter-regional transmission lines (Kanmon interconnectors) within the Chugoku region.

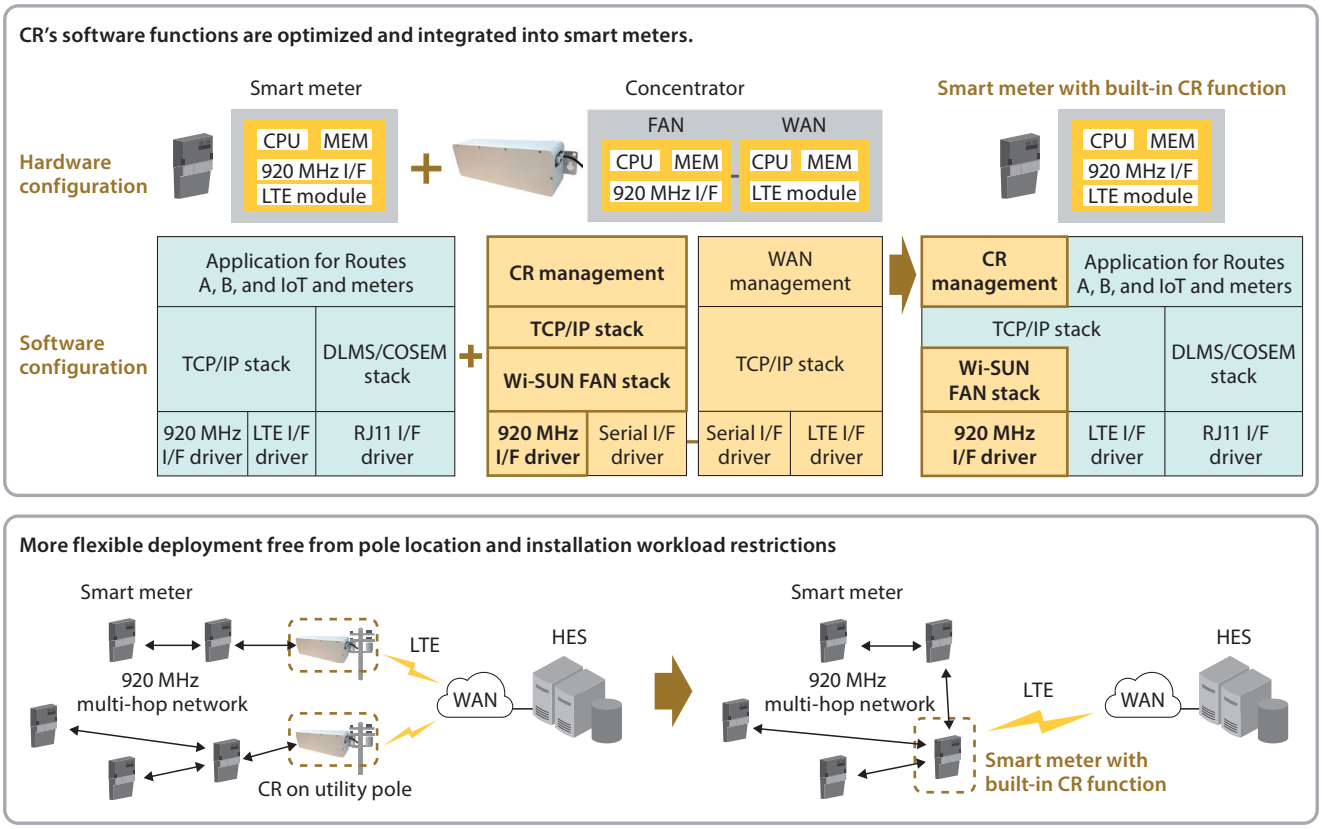
The second function uses the master station to pre-calculate the amount of electricity to be controlled and select the target to be disconnected from the grid to achieve the target. In the event of an excessive frequency deviation due to generator loss or separation of an inter-regional transmission line, it disconnects pumped storage generators, grid load lines, and steam turbine generators (including power lines) within the Chugoku region to maintain grid frequency within an allowable range. Alternately, it separates part of the power grid to prevent a total blackout of the entire Chugoku region.

The IRS is the first system in Japan capable of dealing with N-4 faults that could affect an entire region(*2). It commenced operation in March 2024, contributing to the improvement of power grid resilience in the Chugoku region.

(*1) Basic Policy Subcommittee on Electricity and Gas within the Subcommittee on Electricity and Gas Business under the Advisory Committee for Natural Resources and Energy

(*2) As of March 2024 for grid stabilization systems in Japan with an online pre-calculation capability for transmission line faults that are more serious than an N-2 fault, or simultaneous loss of two main transmission lines (according to Toshiba Energy Systems & Solutions Corporation research)

2.26 Smart Metering Solution with Concentrator Function



MEM: memory I/F: interface TCP/IP: Transmission Control Protocol/Internet Protocol
DLMS/COSEM: Device Language Message Specification/Companion Specification for Energy Metering RJ11: Registered Jack 11
CR: concentrator WAN: wide area network

Smart metering solution with built-in concentrator function

Toshiba Energy Systems & Solutions Corporation has developed and evaluated a prototype smart meter with a concentrator function supporting the Long-Term Evolution (LTE) network for Route-A communication(*).

In conventional smart metering systems, a concentrator on a utility pole forms a 920 MHz wireless multi-hop smart meter network and uses LTE to relay communications to a head-end system (HES). In our new solution, smart meters with a concentrator function form a multi-hop network and relay communications to an HES. Through prototyping, we confirmed that our Wireless Smart Utility Network for Field Area Network (Wi-SUN FAN) middleware can be optimized to suit the smart meter's hardware resource conditions.

The new solution eliminates the need to install concentrators on utility poles. It supports a pure-LTE network and a network consisting of LTE and 920 MHz-band smart meters, making it applicable in areas where concentrators cannot be installed.

This solution can also be useful when it is difficult to maintain network connectivity and ensure a specific service level in the early phase of migration to next-generation systems. Because utility poles for concentrator installation and staff available for installation are usually

restricted, it is difficult to install many concentrators across a wide service area. In comparison, it is relatively easier to deploy smart meters across a wide area and use them as concentrators to achieve a high level of connectivity even in the early phase of migration.

Our next step is to verify the practical effectiveness of the new solution through field evaluations and connectivity simulations based on an actual deployment plan.

(*) Communication between smart meters and a utility company's HES

2.27 First Overseas Application of GR200 Relay and GMU200 Merging Unit Compatible with IEC 61850 Process Bus

GMU200 merging unit compliant with IEC 61850 process bus standards

Toshiba Energy Systems & Solutions Corporation has successfully completed the factory acceptance test of the GR200 relay and the GMU200 merging unit (MU) compatible with the IEC 61850 process bus (PB)(*), which were delivered for the full turnkey project of the Tata Power Co., Ltd. 110 kV Parel Substation in Mumbai, India. This marks our first overseas project and the first application of PB technology to a substation of Tata Power.

At the Parel Substation, we installed a hybrid protection system that combines traditional protection relays which directly receive analog signals from impedance and current transformers with PB-compatible GR200 protection relays that stream sample values from the GMU200 MU. This hybrid protection system allowed us to evaluate the effectiveness of the PB-compatible system in comparison with traditional systems. PB technology helps to reduce the amount of copper wiring, digitalize information, improve construction efficiency, enhance safety, and strengthen overall system operations. As substations incorporating PB technology are increasing worldwide, we will leverage this technology to contribute to the electric power industry.

(*) A communication bus between primary monitoring and measuring equipment in a substation and protection, automation, and control (PAC) devices

2.28 Certification of GRB200 Low-Impedance Busbar Protection Relay by Tenaga Nasional Malaysia

GRB200 low-impedance busbar protection relay

In May 2024, the GRB200 low-impedance bus protection relay from Toshiba Energy Systems & Solutions Corporation obtained official certification from Tenaga Nasional Berhad (TNB), a Malaysian power company, demonstrating our commitment to meeting TNB's stringent requirements to provide high-quality, reliable solutions. Following the GRL200 line protection relay, the application of the GR200 series to TNB's substation has expanded even further.

The certification process involved our explanation of the specifications and performance of the GRB200 to TNB, followed by a thorough document review and specification compliance verification by TNB. We tested the characteristics of the GRB200 at a factory of Toshiba Transmission & Distribution Systems Asia Sdn Bhd in Malaysia and simulated various bus configurations at our Fuchu Complex in Japan in the presence of TNB officials using a real-time digital simulator to verify its performance.

Additionally, the TNB research institute confirmed that the relay can be connected to TNB's existing system via a communication bus compliant with IEC 61850.

2.29 Expansion of TOSHIBA SPINEX for Energy Service

Toshiba Energy Systems & Solutions Corporation launched the software-as-a-service (SaaS) version of TOSHIBA SPINEX for Energy in February 2024. Since then, we have offered services to meet customer needs. Its major applications include the following:

(1) Release of an advanced power plant operation service for Tokushima-Tsuda Biomass Power Plant G.K. (funded by RENOVA, Inc. and other companies) (November 2024)

The power operation system incorporates EtaPRO™, monitoring software for power plant operators that consists of two major functions for advanced anomaly prediction and performance diagnosis. Taking advantage of a cloud service, further data utilization may be expected across multiple plants operated by Tokushima-Tsuda Biomass Power Plant G.K.

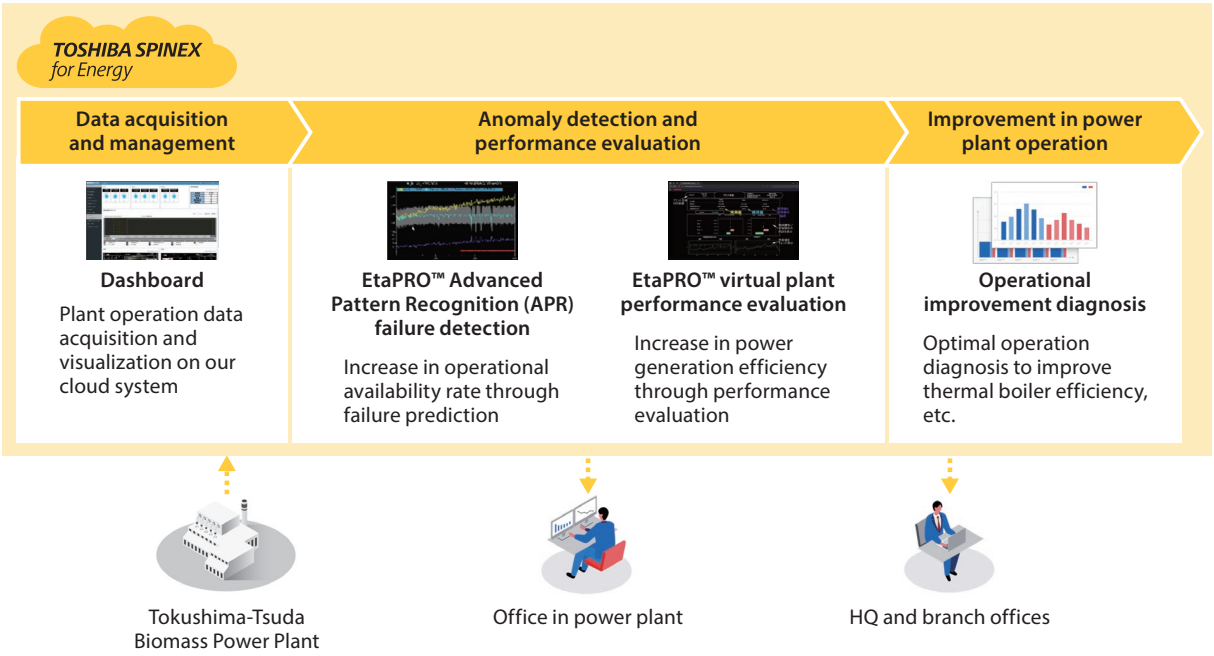
(2) Release of integrated management services for PV power plants (November 2024)

These cloud services for PV power plant operators support operation and maintenance work. A single integrated dashboard shows all relevant operating conditions in real time, allowing users to integrate PV power plant management. It can also accommodate various types of monitoring systems for different PV power plants. The integrated management services also provide diagnostic and daily performance monitoring functions for PV power plants and calculate operational availability rates using our proprietary algorithm.

In addition, Toshiba Group's factories have achieved good results using TOSHIBA SPINEX for Energy. For example, one factory anticipates an estimated 20% reduction in fuel cost while another one forecasts a 2 400 ton reduction in CO_2 emissions per year.

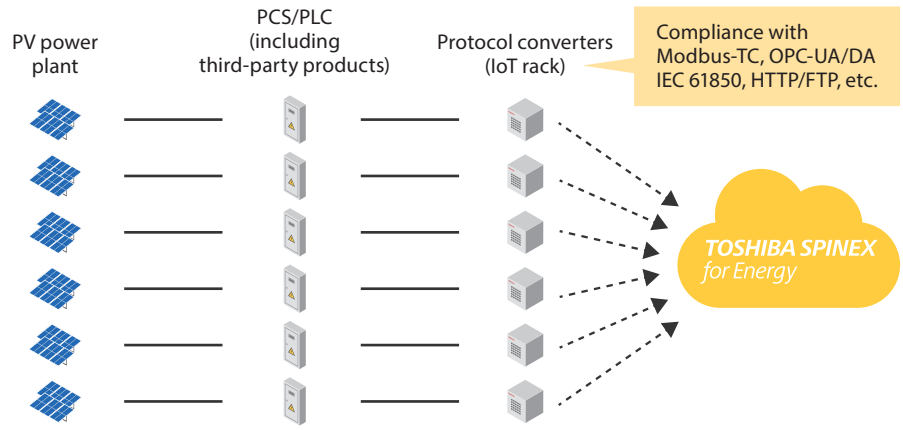
TOSHIBA SPINEX for Energy is also being widely used by large factories and plants for green transformation (GX) engineering to save overall energy consumption.

The service lineup of TOSHIBA SPINEX for Energy is expanding and we will continue to contribute to solving customer issues by leveraging our many years of energy sector expertise.



PLC: programmable logic controller OPC: Object Linking and Embedding (OLE) for Process Control
UA: Unified Architecture DA: Data Access HTTP: Hypertext Transfer Protocol FTP: File Transfer Protocol

Advanced power plant operation system for Tokushima-Tsuda Biomass Power Plant



Examples of user interface screenshots

Integrated management services for PV power plant