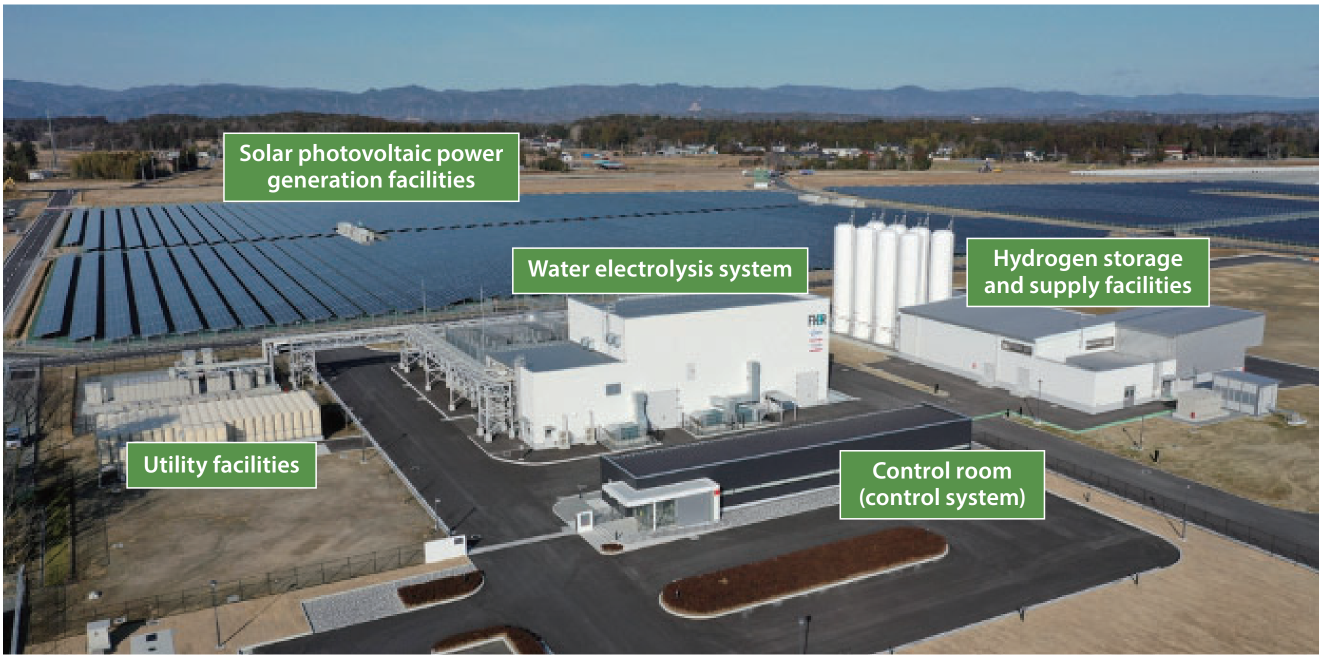
3. Energy Systems

3.1 Commencement of Demonstration Operation of Large-Scale Hydrogen Energy System Using Renewable Energy



Completed renewable energy-powered large-scale hydrogen energy system at Fukushima Hydrogen Energy Research Field (FH2R)

Toshiba Energy Systems & Solutions Corporation has been participating in the Fukushima Hydrogen Energy Research Field (FH2R) project since 2016. This project, to develop, construct, and demonstrate a hydrogen plant equipped with a 10 MW water electrolysis system and a 20 MW solar photovoltaic power generation facility, is being carried out in Namie, Fukushima Prefecture.

One of the objectives of the FH2R project is to establish a business model for hydrogen utilization in order to achieve electricity supply-demand balancing so as to ensure the stability of the power grid in the face of the increasing deployment of renewable energy. Another objective of this project is to establish a business model for hydrogen sales in order to realize demand-based production of hydrogen. To date, we have developed a control system with the following two features:

(1) Optimization of the plant operation plan to meet hydrogen demand and grid balancing requirements

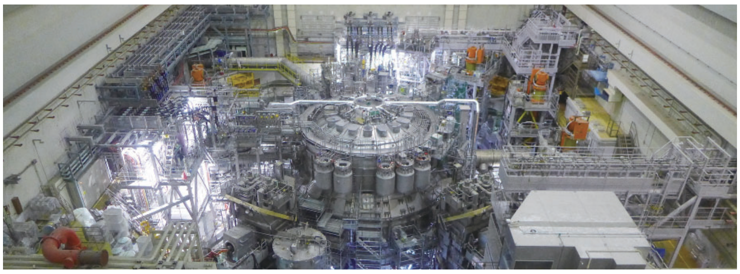
(2) Control of the amount of energy generated by solar panels according to the power consumption of the water electrolysis system to achieve the above plant operation plan.

In 2019, we completed the construction and commissioning run of the hydrogen plant as well as the development, evaluation, and implementation of the control system. In 2020, we performed an integrated system test of the hydrogen plant to verify the safety and basic functions of the control system and commenced demonstration operation. In light of the electricity system and market reforms taking place in Japan, we have also added a function to provide appropriate control in the case of a reverse power flow in the solar photovoltaic system as part of our research aimed at improving the utilization of the hydrogen energy system as a means of electricity supply-demand balancing.

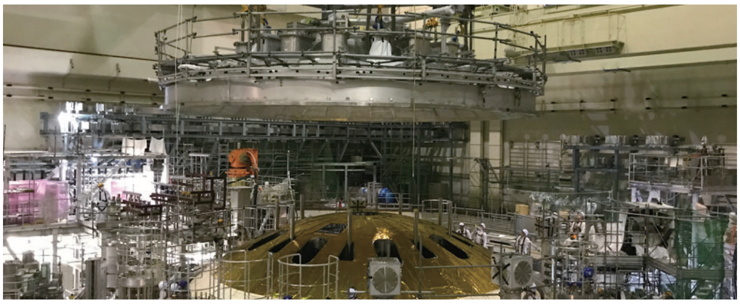
Through this project, we are aiming to enhance power-to-gas systems using hydrogen.

This work has been commissioned by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

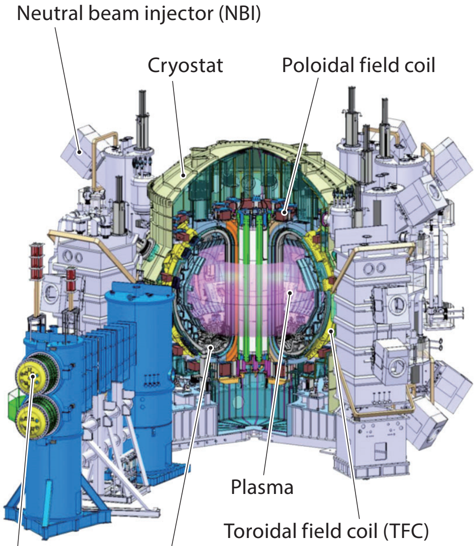
3.2 Completion of JT-60SA Experimental Thermonuclear Fusion Device



Completed assembly of JT-60SA experimental tokamak type thermonuclear fusion device



Installation of cryostat top lid



Courtesy National Institutes for Quantum and Radiological Science and Technology

Configuration of JT-60SA

The JT-60SA is an experimental tokamak type thermonuclear fusion device with the world's largest size(*) that has been constructed at one of the research facilities of the National Institutes for Quantum and Radiological Science and Technology (QST) as a joint project between Japan and the European Union, with the aim of establishing an operating method for maintaining plasma conditions in the reactor core for a long period (about 100 seconds). This project complements the research plan for the International Thermonuclear Experimental Reactor (ITER).

Toshiba Energy Systems & Solutions Corporation was assigned the manufacturing of the vacuum vessel and the on-site assembly of other main equipment. We have completed this phase of the project after six years of manufacturing and seven years of assembly work.

On-site assembly was extremely difficult because of the need to install, with high precision, large devices manufactured by various European and Japanese companies, including a Spanish-made cryostat base that supports the main equipment weighing 1 700 tons and 18 Italian- and French-made superconducting toroidal field coils (TFCs) surrounding the vacuum vessel.

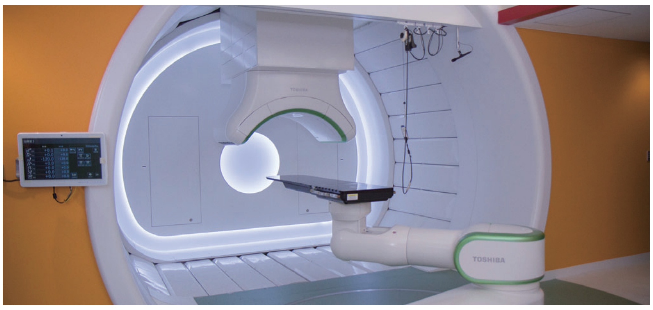
The vacuum vessel is a large structure with a total weight of 150 tons. Shaped in the form of a doughnut, it has a height of about 6.6 m, a width of about 3.5 m, and a diameter of 10 m. We successfully completed the assembly and installation work simultaneously within a tolerance of ±10 mm relative to the design value. This precision was achieved by (1) manufacturing the 10 D-shaped sectors comprising the vacuum vessel at our factory, (2) welding the D-shaped sectors in the circumferential direction on-site, and (3) adjusting their positions using a three-dimensional (3D) measurement instrument while predicting possible deformations caused by the welding process.

On the other hand, each TFC has a height of about 10 m and a width of about 5 m. The assembly of the TFCs was completed within a tolerance of ±1 mm by making full use of our expertise in 3D laser measurement.

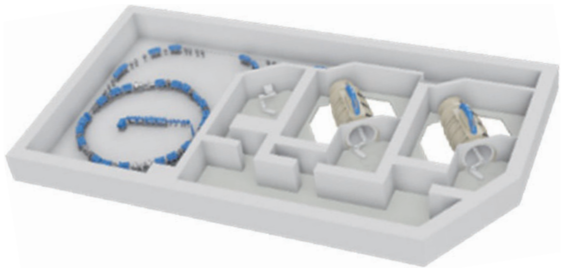
Following the assembly of the above components and other internal devices, we installed the top lid of the cryostat at the end of March 2020, completing the assembly of the main equipment of the JT-60SA as scheduled. Although the milestones of this joint project were stringent, we contributed significantly to the success of the assembly work. We will leverage the high-precision assembly techniques cultivated through this work to make further contributions toward the early realization of nuclear fusion energy.

(*) *JT-60SA Newsletter*, No. 113, April 2020 (as researched by Toshiba Energy Systems & Solutions Corporation)

3.3 Commencement of Cancer Treatment Using Heavy-Ion Radiotherapy System at Yamagata University, Japan, and Installation of System at Yonsei University, Korea



Treatment room equipped with downsized superconducting rotating gantry at East Japan Heavy Ion Center, Faculty of Medicine, Yamagata University



Rendering of heavy-ion radiotherapy facility for Yonsei University Health System, Korea

Heavy-ion radiotherapy helps to reduce the physical and mental burden of cancer treatment because it causes less damage to healthy tissues and reduces the treatment time, improving patients' quality of life.

Toshiba Energy Systems & Solutions Corporation has completed the installation and beam adjustment of a heavy-ion radiotherapy facility at the East Japan Heavy Ion Center of Yamagata University's Faculty of Medicine, the first such facility constructed in the Tohoku region of Japan.

This radiotherapy system is based on our standard model consisting of an advanced high-speed scanning irradiation system and the world's smallest superconducting rotating gantry(*), contributing to downsizing of the facility and reducing the treatment time.

The East Japan Heavy Ion Center has two treatment rooms. We have handed over a fixed-beam treatment room to the Center, which commenced clinical treatment in February 2021. The other treatment room equipped with a rotating gantry is currently undergoing an acceptance test, with clinical treatment scheduled to commence as planned in the latter half of 2021.

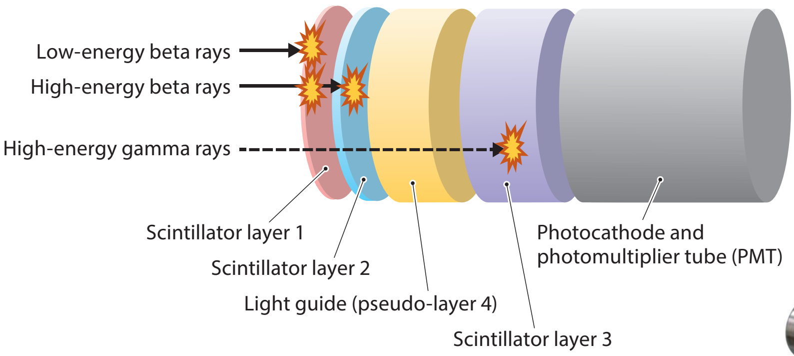
The heavy-ion radiotherapy system for the Yonsei University Health System (YUHS) in Korea is our first overseas project. It will be the world's first radiotherapy facility equipped with two superconducting rotating gantry treatment rooms(*). Following the design, production, and transportation of the system's components, we commenced the installation work in February 2021 at YUHS in Seoul. Radiotherapy treatment is scheduled to begin at the new facility in 2022.

Furthermore, we received a contract for a heavy-ion radiotherapy system in August 2020 from the Seoul National University Hospital in Korea.

We will continue to contribute to high-quality cancer treatment around the world.

(*) As of April 2021 for heavy-ion radiotherapy systems (as researched by Toshiba Energy Systems & Solutions Corporation)

3.4 Development of Novel Dosimeter Using Quadruple Phoswich Detector for Simultaneous Measurement of Beta and Gamma Rays



Structure of quadruple phoswich detector

Prototype dosimeter

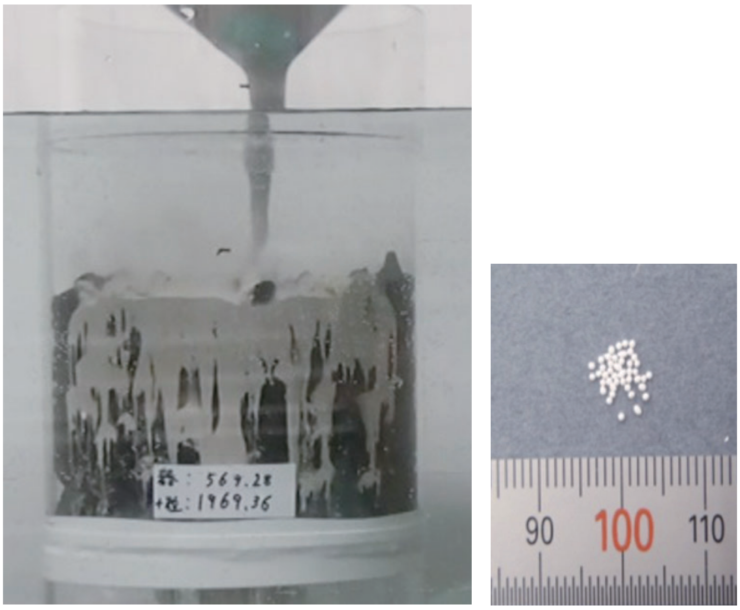
A large amount of beta nuclides released at the time of the March 2011 nuclear accident remains in the Fukushima Daiichi Nuclear Power Station. Beta nuclides have a highly adverse effect on the lens of the eye. A revision to the regulations concerning reduction of the occupational dose limit for the lenses of the eyes became effective in April 2021. As a result of this revision, the need for precise radiation dosimetry and reliable radiological protection has further increased.

Since conventional dosimeters are sensitive to gamma radiation, the beta dose rate is calculated by subtracting the dose of gamma rays from the total dose of beta and gamma rays. This method is time-consuming and results in calculation errors.

To resolve these issues, Toshiba Energy Systems & Solutions Corporation has developed a novel quadruple phoswich (phosphor sandwich) detector consisting of three types of scintillators and a light guide that also acts as an energy absorber. This phoswich detector discriminates between beta and gamma rays based on the difference in signal waveforms. Beta rays inevitably react with materials when travelling through them due to their continuous energy distribution, while on the other hand gamma rays pass through materials while stochastically reacting with them. The new phoswich detector is capable of measuring beta and gamma rays simultaneously and provides more accurate measurement than a conventional dosimeter.

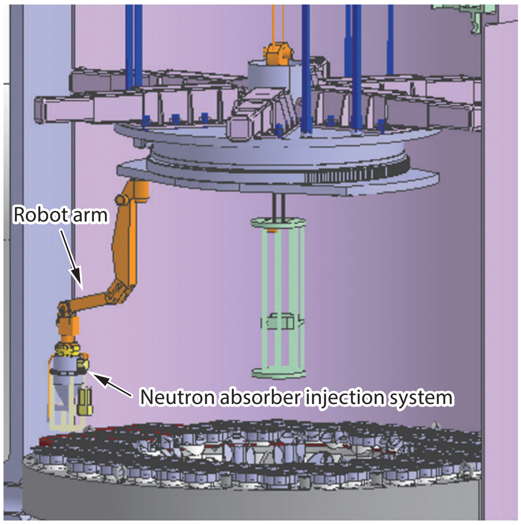
We have completed the fabrication of a prototype dosimeter incorporating the new phoswich detector and conducted a fundamental validation of its radiation discrimination algorithm. At present, we are developing a dosimeter compliant with the Japanese Industrial Standards (JIS).

3.5 Nuclear Criticality Control Technology for Fuel Debris Using Insoluble Neutron Absorbers



Solidifying neutron absorber　　Solid type neutron absorber

Prototype solidifying and solid type insoluble neutron absorbers



Planned neutron absorber injection system

To safely remove fuel debris from the reactor buildings of the Fukushima Daiichi Nuclear Power Station, it is necessary to prevent nuclear criticality events during its retrieval. Soluble materials are preferable to coat the fuel debris of various shapes; however, they are not generally used because the integrity of the containment structure of the reactor buildings was compromised by the nuclear accident.

As a solution to these issues, Toshiba Energy Systems & Solutions Corporation has developed two types of insoluble neutron absorbers.

One of the newly developed neutron absorbers is a mixture of liquid glass and gadolinium oxide powder developed in collaboration with Fuji Chemical Co., Ltd. When mixed with gadolinium oxide powder, liquid glass turns viscous and then solidifies over time. This neutron absorber can be used to cover the surface of fuel debris of any shape and fill the gaps in the debris.

The other neutron absorber, consisting of solid sintered gadolinium oxide particles with a diameter of roughly 500 μm, was developed in collaboration with Nuclear Fuel Industries, Ltd. This neutron absorber is easy to handle and can accommodate changes in the shape of the fuel debris during its retrieval.

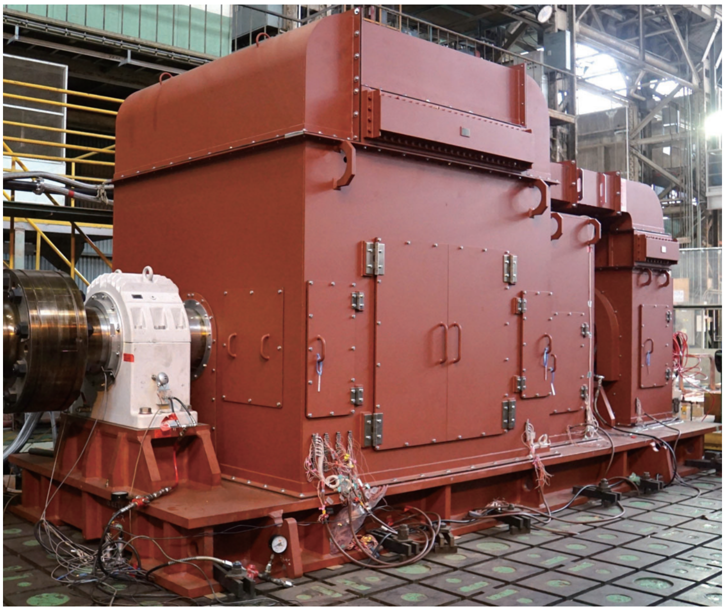
Both of the newly developed neutron absorbers prevent the fuel debris from reaching criticality because gadolinium absorbs neutrons.

We evaluated the physical properties, dissolution rates, nuclear characteristics, irradiation effects, workability, and side effects of the new neutron absorbers. Through experiments using the critical assembly of the Institute for Integrated Radiation and Nuclear Science of Kyoto University, we confirmed that they exhibit appropriate nuclear characteristics for the prevention of criticality events. We also performed experiments at the Takasaki Advanced Radiation Research Institute of the National Institutes for Quantum and Radiological Science and Technology (QST) in order to verify that the new neutron absorbers exhibit the appropriate irradiation effects to maintain their shape and performance even when they are exposed to the doses expected during debris retrieval.

We have proposed a method of applying the neutron absorbers using an injection system composed of a hopper and a pump attached to the tip of a robot arm as a means of remotely pouring the absorber onto the fuel debris. We will further study how to apply the neutron absorbers to the fuel debris as the design of the debris retrieval system takes shape.

This work was conducted as part of the Development of Technologies for Controlling Fuel Debris Criticality Project funded by the Ministry of Economy, Trade and Industry (METI) of Japan.

3.6 Brushless Excitation System for Large-Capacity Turbine Generators



Brushless excitation system for 4-pole 1 700 MVA-class turbine generators

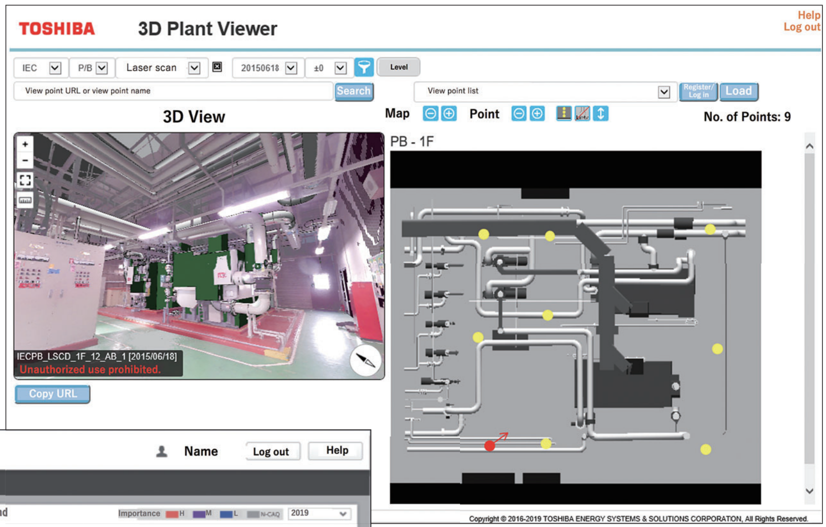
The European Union (EU) and other countries have established regulations on the network code requirements for grid connection of generators, which apply to all turbine generators. There are strict requirements, including fault ride-through (FRT) capability during grid voltage dips.

Under these circumstances, Toshiba has developed a demonstration model of a fast-response brushless excitation system for large-capacity turbine generators. In contrast to the slower response time of conventional brushless excitation systems compared with that of static excitation systems, the newly developed brushless excitation system has succeeded in achieving a response ratio of more than 2.0(*) and a high initial response(*). These capabilities will contribute to compliance with the network code requirements and improvement of transient stability. This brushless excitation system supports four-pole turbine generators with the largest capacity of 1 700 MVA in our lineup.

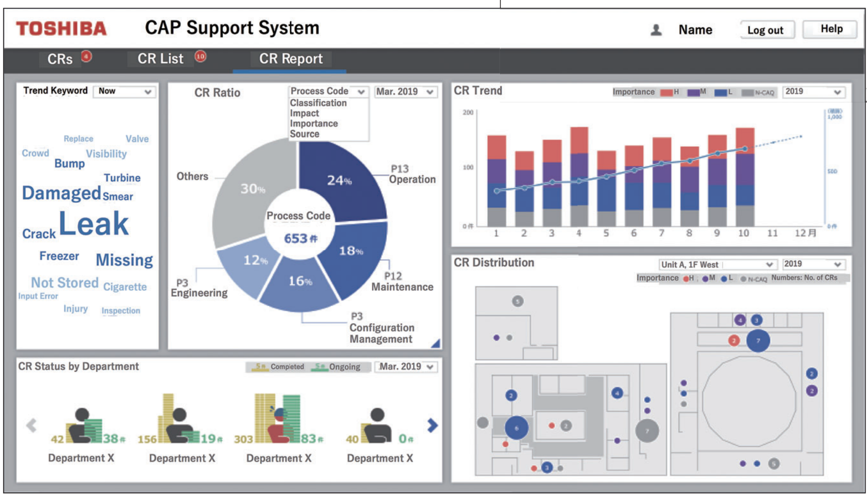
We are supplying both well-proven static excitation systems and fast-response brushless excitation systems featuring easy regular maintenance according to customers' requirements.

(*) As referenced in the Institute of Electrical and Electronics Engineers (IEEE) 421.1-2007 and 421.2-2014 standards

3.7 Plant Operation Support Services for Nuclear Facilities



Example of 3D Plant Viewer display



CR: condition report

Application of AI to Corrective Action Program (CAP) Support System

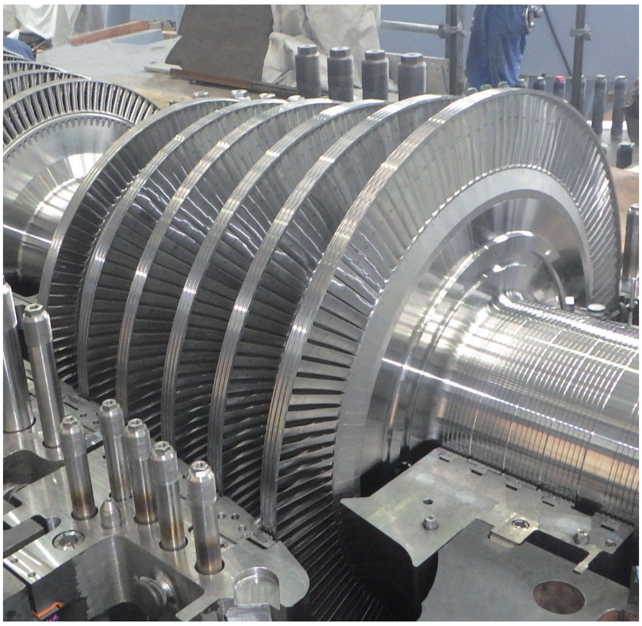
Following the introduction of new nuclear regulatory inspection rules for nuclear facilities in Japan, utilities are required to manage and analyze information on their nuclear facilities and the operating conditions of those facilities in order to proactively maintain and improve their safety and performance. Furthermore, to maximize plant value, there is an increasing need for the utilization of risk information and the optimization of condition-based maintenance (CBM) due to equipment degradation.

Toshiba Energy Systems & Solutions Corporation has launched new plant operation support services in response to this situation, including the 3D Plant Viewer and the Corrective Action Program (CAP) Support System. The 3D Plant Viewer utilizes three-dimensional (3D) computer-aided design (CAD) model data or 3D point cloud as-built data obtained by a laser scanner for operation & maintenance (O&M) engineering. The CAP Support System formulates corrective action plans using artificial intelligence (AI), making use of the experience and knowledge that we have accumulated through the design and construction of nuclear facilities.

We will utilize these services to help maximize plant value and support plant management.

3.8 Major Upgrading Projects for Thermal Power Plants

Installation of intermediate-pressure (IP) rotor at Mt Piper Power Station Unit 1, Australia



Installation of IP inner casing and rotor at Shinchi Power Station Unit 2 of Soma Kyodo Power Co., Ltd.

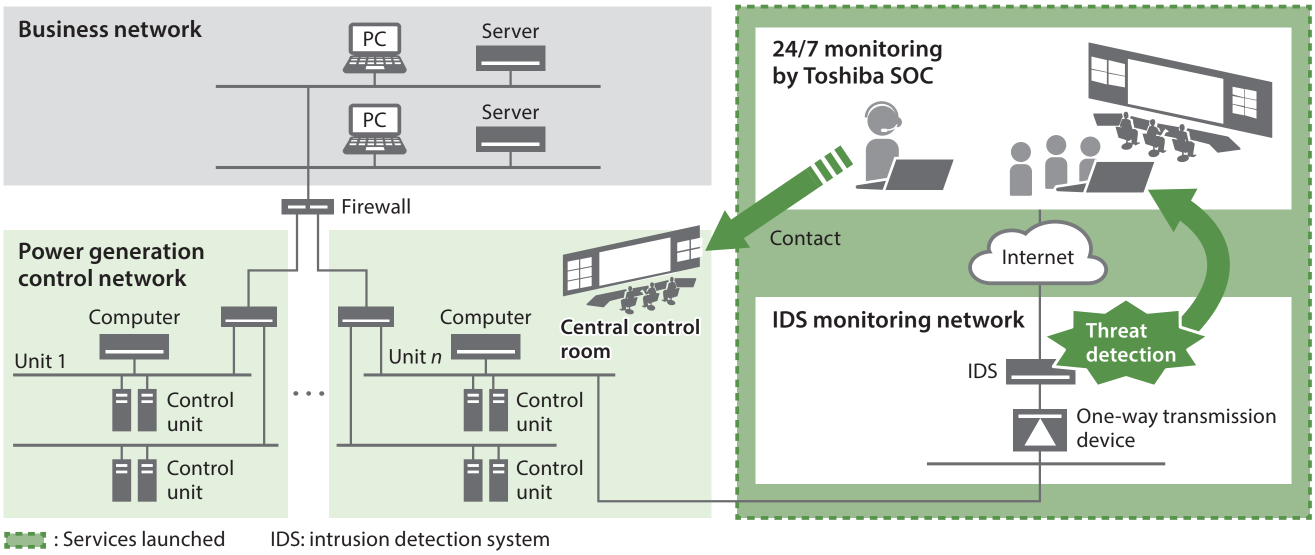
Mt Piper Power Station in New South Wales, Australia, had been in operation for more than 20 years and was due for a major upgrade. Toshiba Energy Systems & Solutions Corporation secured a contract for the supply and installation of the steam turbines, generators, turbine supervisory equipment, feedwater heaters, and other components by leveraging its expertise on various products and proposal capabilities, together with the excellent maintenance services provided by an Australian subsidiary. The supply components for Unit 1 were shipped from Japan in August 2020, and the upgrade outage was scheduled from October to December. As a result of upgrading the obsolete equipment with our state-of-the-art technology, the power output of Unit 1 increased by 30 MW without incurring any increase in fuel consumption.

Other major upgrading projects are also underway in Australia in which our steam turbines and other major equipment will be installed, with upgrade outages scheduled to take place up to 2023.

In Japan, many aging plants have been undergoing major upgrade outages in order to extend the remaining life of major components and improve plant performance. For example, Shinchi Power Station Unit 2 of Soma Kyodo Power Co., Ltd. had been in operation for more than 20 years since 1995. Its operator wished to improve the plant's competitiveness in the deregulated electricity market and decided to upgrade the entire set of high-pressure (HP) and intermediate-pressure (IP) turbines to extend their remaining life and improve the overall performance. Initially, only the HP and IP rotors were considered for upgrading; however, the operator opted for a complete upgrade package, including HP and IP inner casings, in order to shorten the outage period and further improve the plant's performance by replacing the existing doubleflow nozzle box with a single-flow nozzle box. The upgrade outage was completed in 2020 as scheduled. As a result, Shinchi Power Station Unit 2 achieved a performance improvement considerably exceeding the guaranteed values.

We will continue to contribute to the realization of a low-carbon society and stable electricity supply.

3.9 Launching of Security Enhancement Solution Service for Power Generation Control Systems



Overview of security enhancement solution for power generation control systems

As a host country for many international events that attract worldwide attention, Japan faces growing concern over cyberterrorism and other security threats to social infrastructure. In response, utility companies responsible for maintaining power generation infrastructure are becoming increasingly concerned about cybersecurity.

In light of this situation, Toshiba Energy Systems & Solutions Corporation has launched a security enhancement solution service to detect cyberattacks and other unauthorized intrusions without affecting the real-time control of a power plant. This service can be introduced without making major changes to the monitoring and control systems of power generation facilities already in operation.

To enhance security, we have added a function to analyze and evaluate the protocol specific to our control equipment to a general-purpose intrusion detection system (IDS). In addition to the security system, we also provide a 24/7 monitoring service through the Toshiba Security Operation Center (SOC).

We launched the service for power generation control systems on September 1, 2020. This service immediately notifies users in the event of any sign of a threat being detected and prompts them to take action.

Previously, it was often impossible to connect a power plant to an external network for security reasons. In order to ensure plant security, our new service uses a one-way transmission device along a communication line leading to the outside environment and deploys a technology to completely block intrusions from the outside. We have confirmed the effectiveness of our SOC service, which provides users with easy-to-understand security alerts and contacts them only when necessary.

We are making efforts to promote the expansion of this service to power plant operations.

3.10 Installation of CO_2 Capture Test Equipment for Verification of CCU System

CO_2 capture test equipment at CCU facility of Asahi Quality & Innovations, Ltd.

In recent years, it has become imperative to reduce carbon dioxide (CO_2) emissions from industry in order to mitigate global warming. Toshiba Infrastructure Systems & Solutions Corporation offers CO_2 capture technology based on chemical absorption, which is characterized by the purity of the extracted CO_2 gas exceeding 99 vol% (dry). Because of this advantage, it is highly compatible with applications that utilize CO_2 as a resource and can be applied to carbon capture and utilization (CCU) for the recycling of CO_2 as various carbon compounds.

In December 2019, we supplied a CO_2 separation and recovery test facility for the verification of CCU to Asahi Quality & Innovations, Ltd. Roughly one and a half years will be required to ensure the reliability of the CCU system before the customer's group companies are provided with CO_2 for food and beverage production.

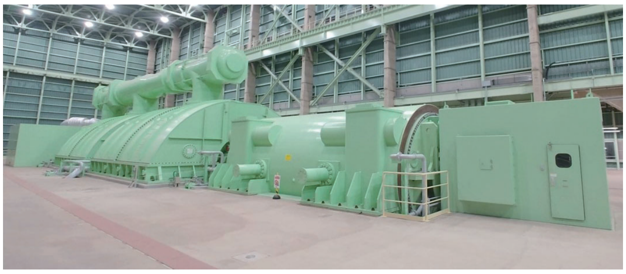
We conducted interviews regarding the verification concept of the CO_2 capture test facility early from the design stage and adopted a CO_2 gas cleaning mechanism to increase the purity of the CO_2 as well as system controls to ensure stable system operation.

In June 2020, continuous operation was commenced to collect data and verify the requirements for proper system operation and maintenance. Our next step is to construct a CCU system that is optimal for food and beverage production, drawing on the issues identified and the knowledge acquired through the verification process. It is essential to recover CO_2 from various flue gas sources in order to mitigate global warming, and CO_2 gas with properties suitable for each specific application must be provided in order to achieve CCU. We will continue to work on technological development for the realization of CCU.

3.11 Commencement of Commercial Operation of Large Thermal Power Plants in Japan

Steam turbine and generator for Matsuura Power Station Unit 2 of Kyushu Electric Power Co., Inc.

Steam turbine and generator for Noshiro Thermal Power Station Unit 3 of Tohoku Electric Power Co., Inc.



Steam turbine and generator for Kashima Thermal Power Plant Unit 2 of Kashima Power Co., Ltd.

Steam turbine and generator for Takehara Thermal Power Station New Unit 1 of Electric Power Development Co., Ltd.

The following four large high-efficiency ultra-supercritical (USC) coal-fired thermal power plants commenced commercial operation between December 2019 and July 2020. Toshiba Energy Systems & Solutions Corporation provided engineering, procurement, and construction (EPC) services for the steam turbines, generators, and related auxiliaries of these power plants, including commissioning.

(1) Matsuura Power Station Unit 2 of Kyushu Electric Power Co., Inc.
Generator output: 1 000 MW; handover of the turbine and generator (TG) foundation: December 2017; commencement of commercial operation: December 20, 2019

(2) Noshiro Thermal Power Station Unit 3 of Tohoku Electric Power Co., Inc.
Generator output: 600 MW; handover of the TG foundation: April 2018; commencement of commercial operation: March 2, 2020

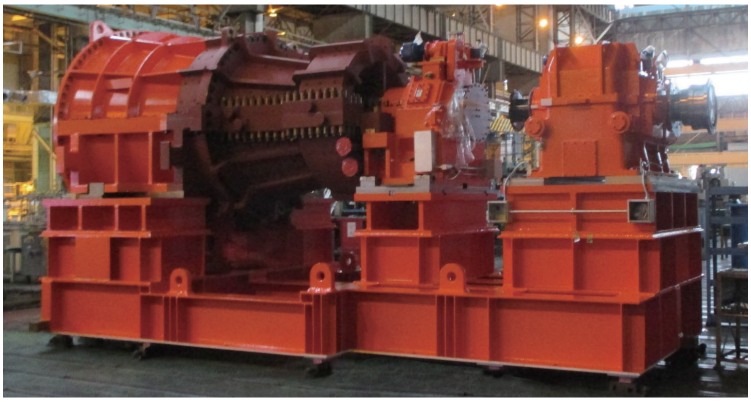
(3) Kashima Thermal Power Plant Unit 2 of Kashima Power Co., Ltd.
Generator output: 645 MW; handover of the TG foundation: July 2018; commencement of commercial operation: July 1, 2020

(4) Takehara Thermal Power Station New Unit 1 of Electric Power Development Co., Ltd.
Generator output: 600 MW; handover of the TG foundation: October 2018; commencement of commercial operation: June 30, 2020.

Since these projects proceeded in parallel at almost the same time, it was important to appropriately manage the resources and schedules for design, manufacturing, and construction. Therefore, our project teams shared information with one another in order to optimize resource allocation and meet project milestones. When one project team had a problem, it was promptly shared with the other project teams to prevent the occurrence of similar problems. As a result, all four power plants achieved commercial operation within the specified periods. We have greatly benefited from this experience in enhancing our project management capability.

3.12 Initiatives in Geothermal Power Generation Business in Indonesia

Lumut Balai Geothermal Power Plant Unit 1, Indonesia



Shipment of turbine for Dieng Small Scale Geothermal Plant, Indonesia

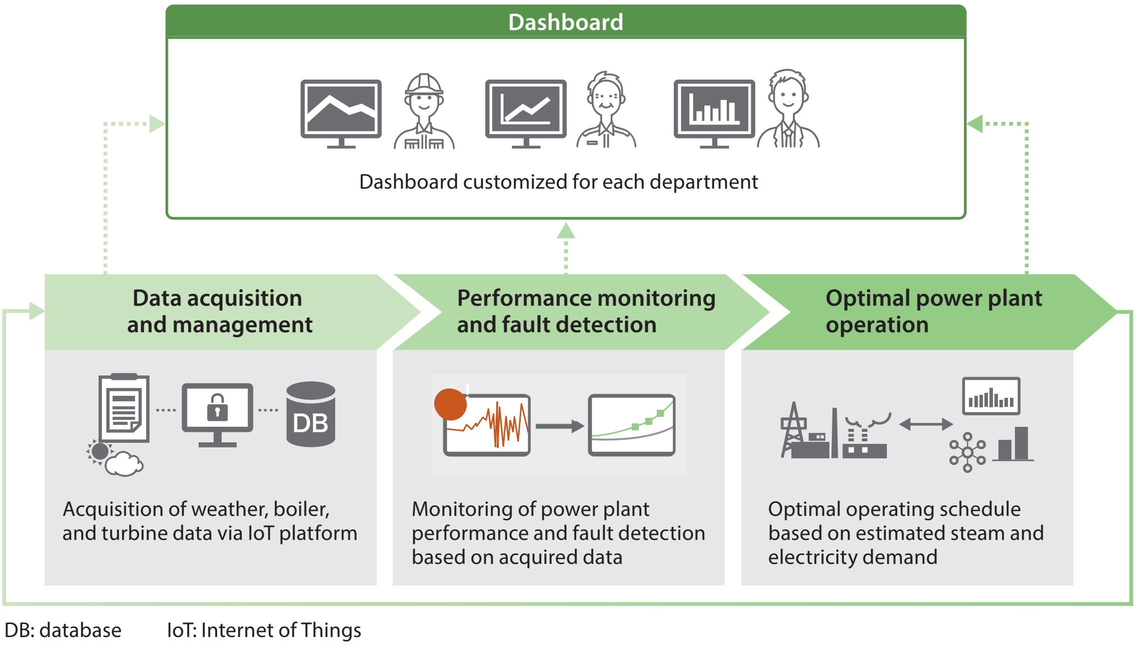
Lumut Balai Geothermal Power Plant Unit 1 (rated capacity: 55 MW) operated by PT Pertamina Geothermal Energy in Indonesia commenced commercial operation in February 2020. Toshiba Energy Systems & Solutions Corporation provided the turbine, generator, and auxiliary equipment for Unit 1. The construction project started in January 2015, but was suspended for a prolonged period thereafter. Upon resumption of the project, we successfully completed on-site installation, commissioning, and performance tests.

In addition, in October 2020 we shipped a turbine and a generator to the Dieng Small Scale Geothermal Power Plant being constructed by PT Geo Dipa Energi. This steam turbine is our first standardized 10 MW-class model, which we will deploy to future geothermal power generation facilities in the same capacity range.

Although Indonesia has the world's largest geothermal power generation potential of approximately 27 GW, only about 8% of it is utilized. The Indonesian government plans to increase the ratio of renewable energy in the energy mix from about 9% in 2019 to 23%. Therefore, Indonesia is one of the most important potential markets for the geothermal business.

We will continue to actively expand the application of our steam turbines and generators for geothermal power generation and contribute to the spread of renewable energy.

3.13 Introduction of Operation Optimization System at Non-Utility Power Plant



Outline of operation optimization system for non-utility power plant of Kuraray Co., Ltd.

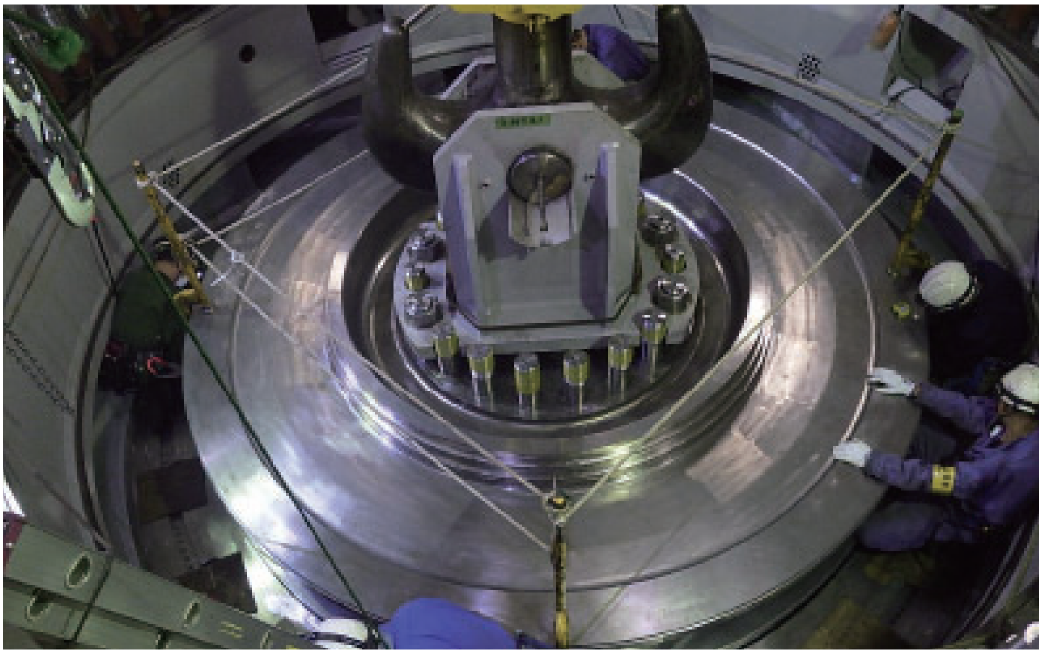
In October 2020, Toshiba Energy Systems & Solutions Corporation shipped an operation optimization system to a non-utility power plant operated by Kuraray Co., Ltd. Following a trial operation, the system commenced operation in December 2020.

Consisting of multiple power generation facilities, Kuraray's non-utility power plant supplies steam and electricity to the equipment at one of its factories. The operation optimization system optimizes the operating schedule of the power plant based on the estimated demand for steam and electricity while satisfying the operational constraints of boilers, turbines, etc.

We have developed the operation optimization system making full use of our engineering expertise cultivated through extensive experience in the development of power plant facilities.

This system also provides functions for model-based performance comparison, fault detection, and big-data utilization.

3.14 Completion of Overhaul of Okumino Pumped Storage Power Station Unit 6 for Chubu Electric Power Co., Inc.



Installation of water turbine runner

Following the completion of its overhaul, Okumino Pumped Storage Power Station Unit 6 recommenced commercial operation in April 2020. All of the six pump-turbines and two generator-motors of Units 5 and 6 of this plant were manufactured by Toshiba Energy Systems & Solutions Corporation.

This is the second overhaul of Okumino Pumped Storage Power Station since it commenced operation in 1995. All six units have been overhauled sequentially, starting with Unit 1 in 2014.

We cooperated with Chubu Electric Power Co., Inc. to estimate the amounts of wear based on the changes in the amounts of wear measured during past overhauls, and accordingly determined the machining dimensions prior to disassembly. As a result, we succeeded in reducing the overhaul period by one month compared with the time required for the overhaul of Unit 1.

The specific measures implemented for the overhaul and their effects are as follows:

(1) Bushes and liners

In the past, we manufactured these components based on the results of on-site dimensional measurements after disassembly. This time, we shortened their manufacturing period by determining the machining dimensions based on the estimated amount of wear and the initial design value.

(2) Oil cylinder on the lower part of the generator, etc.

In the past, we determined whether it was necessary to manufacture new components based on the results of an on-site overhaul inspection. This time, we shortened the manufacturing period by deciding in advance whether to manufacture new components based on the estimated amount of wear.

(3) Water turbine stay vanes, etc.

In the past, we determined the necessity of repairing these components based on the results of an on-site overhaul inspection. This time, we decided which components needed to be repaired in advance based on the estimated amount of wear, in order to reduce the repair period.

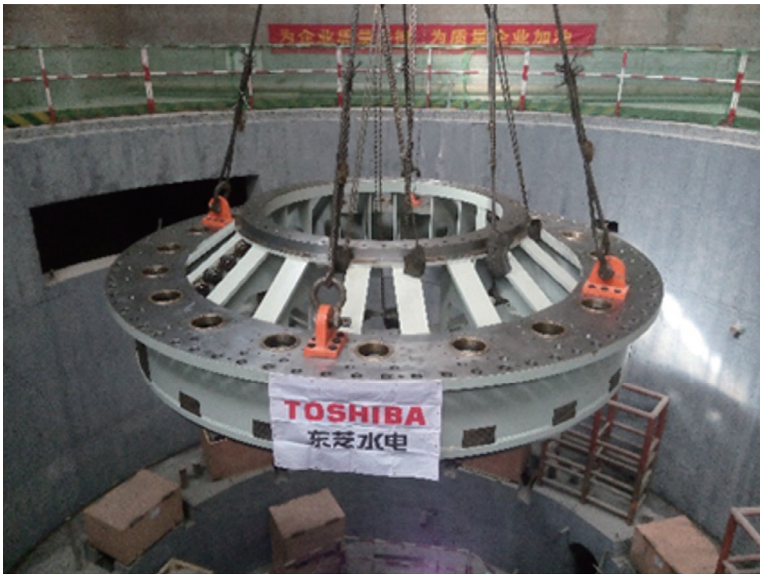
(4) Shop tests

We replaced the governor actuator and performed part of the combination tests on site instead of conducting shop tests, in order to shorten the period of shop work.

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

- Pump turbines: 259 MW/260 MW, 485.75 m/530.5 m, 514 min^{-1}
- Generator-motors: 279 MVA/271 MW, 13.2 kV, 514 min^{-1}.

3.15 Commencement of Commercial Operation of Two Units Comprising Jiangpinghe Hydropower Station, China



Installation of turbine head cover at Jiangpinghe Hydropower Station, China

The Jiangpinghe Hydropower Station is located on the upper reaches of the Loushui River. The Jiangpinghe Dam provides a water source for power generation while also serving as a means of flood control and water transportation.

In 2008, Toshiba Hydro Power (Hangzhou) Co., Ltd. (THPC) concluded a contract for the construction of the Jiangpinghe Hydropower Station, but the project was subsequently suspended because of a change of the project owner. The contract was signed again in 2015 to restart the project. We achieved commercial operation of Unit 1 in August 2020, followed by Unit 2 in September 2020.

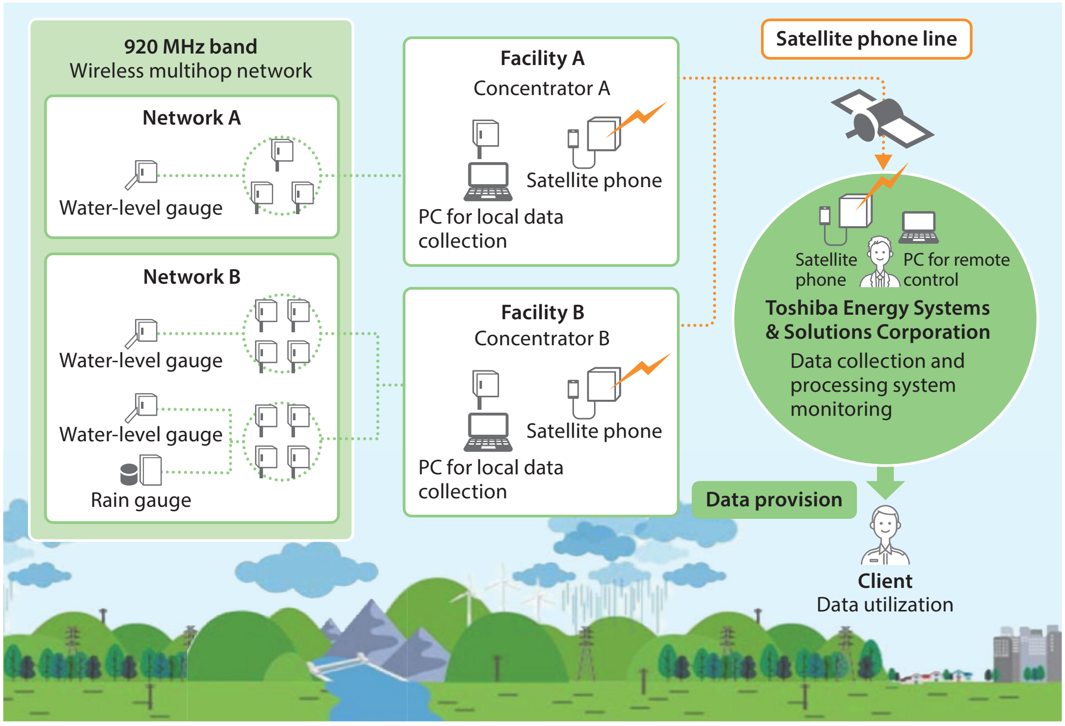
The turbine and the generator have the second- and third-largest capacities, respectively, in the experience of TPHC. The turbine features friction coupling for connecting the main shaft to the runner as well as an axial main shaft seal.

TPHC designed and manufactured the turbine and the generator while Toshiba Energy Systems & Solutions Corporation performed the model turbine performance test.

The ratings of the turbine and the generator are as follows:

- Turbine: 228.4 MW, 131.26 m/178.89 m, 187.5 min^{-1}
- Generator: 250.0 MVA, 15.75 kV, 187.5 min^{-1}, 50 Hz.

3.16 Commencement of Data Collection Service to Measure River Water Levels Using LPIS™ Installed at Takasegawa No. 5 Hydropower Plant of TEPCO Renewable Power, Inc.



Overview of continuous measurement of river water levels and rainfall amount using LPIS™ low-power wireless IoT solution

Toshiba Energy Systems & Solutions Corporation has commenced the first subscription-based data collection service using LPIS™, a power-efficient wireless Internet of Things (IoT) solution incorporating 920 MHz-band wireless multihop technology. This service provides TEPCO Renewable Power, Inc. with data about the water levels of mountain streams around the Takasegawa No. 5 Hydropower Plant. Since the river observation posts are located in cellular dead zones, it was previously necessary to walk around the mountainous area for half a day to collect such data.

The newly developed solution wirelessly connects three water-level gauges and one rain gauge via 20 relay nodes to enable continuous observation of water levels and rainfall. The relay nodes are attached to portable self-standing poles in consideration of the surrounding environment. The wireless network provides redundancy so that data collection can be continued even if the operation of a relay node is interrupted by a rockfall, flooding, snowslide, etc.

The wireless network is combined with a satellite phone circuit so that we can monitor its operating condition at our head office in Kawasaki and meet customer requests in a flexible manner. The satellite phone connection also makes it possible to acquire water-level and rainfall data without being affected by the weather or season.

3.17 275 kV Three-Phase Gas-Insulated Shunt Reactor for Outdoor Substations

275 kV gas-insulated shunt reactor for Minami-Kawasaki Substation of TEPCO Power Grid, Inc.

Toshiba Energy Systems & Solutions Corporation has developed a 275 kV three-phase gas-insulated shunt reactor for use in outdoor substations.

The newly developed shunt reactor uses sulfur hexafluoride (SF_6) gas as an insulating medium. Smaller and about 20% lighter than the conventional shunt reactor, the newly developed shunt reactor is suitable as a replacement for an aged shunt reactor.

The external dimensions of the main tank are smaller than the limits for railway transportation in Japan. Therefore, the new shunt reactor with the SF_6 gas sealed in the main tank can be transported by rail and Schnabel trailer. This makes it possible to shorten the time required for on-site construction by about 20% compared with conventional shunt reactors.

To achieve this size reduction, we have simplified the insulation specifications and the cooling design through the use of new technologies such as a three-phase canceling type clamping magnetic shield and a newly developed tank structure.

We have delivered the first shipment of this shunt reactor to the Minami-Kawasaki Substation of TEPCO Power Grid, Inc., which commenced commercial operation in April 2020.

The new shunt reactor can also reuse an existing foundation and helps to reduce the amount of ancillary equipment required. It is therefore expected to have extensive applications.

3.18 Newly Developed 300 kV Gas Circuit Breaker with Spring Operation Mechanism

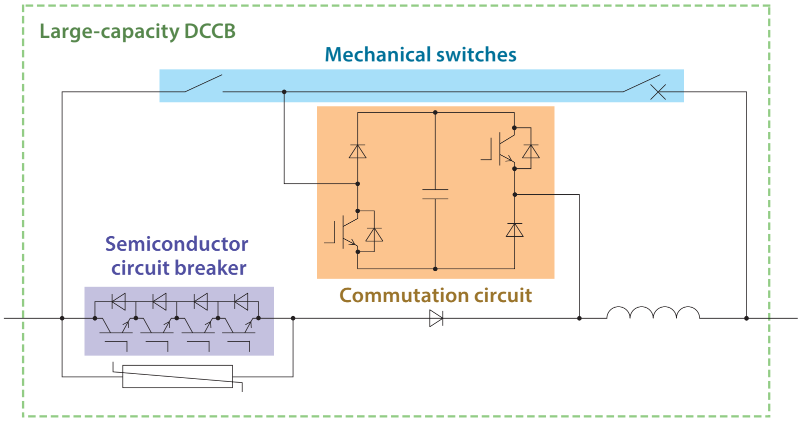
Newly developed 300 kV gas circuit breaker

Toshiba Energy Systems & Solutions Corporation has developed a new 300 kV gas circuit breaker (GCB) that incorporates a motor-charged spring operation mechanism instead of the conventional hydraulic operation mechanism. The motor-charged spring operation mechanism has fewer parts than the hydraulic operation mechanism because it eliminates the need for high-pressure seals, contributing to a reduction in the number of items requiring periodic inspection and maintenance.

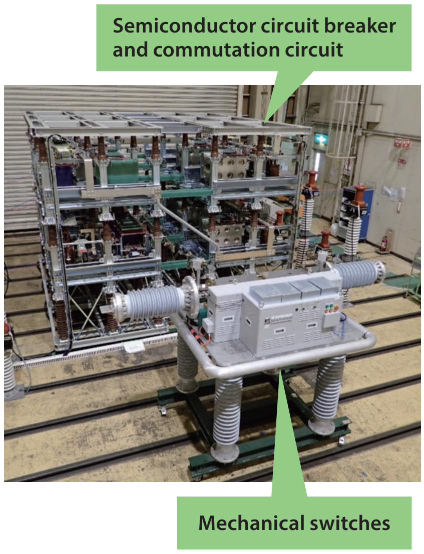
We successfully developed the new GCB model in a short period by combining the existing motor-charged spring operation mechanism with an appropriate driving force and the arc-extinguishing chamber of the existing 300 kV GCB. In addition, various sensors and condition monitoring units can be optionally attached to the new GCB so as to enhance maintainability utilizing digital technology.

Hamakawasaki Operations in Japan and Toshiba Transmission & Distribution Systems (India) Pvt. Ltd. are set to manufacture the new spring operation mechanism in order to ensure stable manufacturing and procurement capabilities. The first GCB unit is scheduled for delivery in 2022.

3.19 Large-Capacity DC Circuit Breaker for Multi-Terminal HVDC Transmission Systems



Circuit block diagram of large-capacity DC circuit breaker (DCCB)



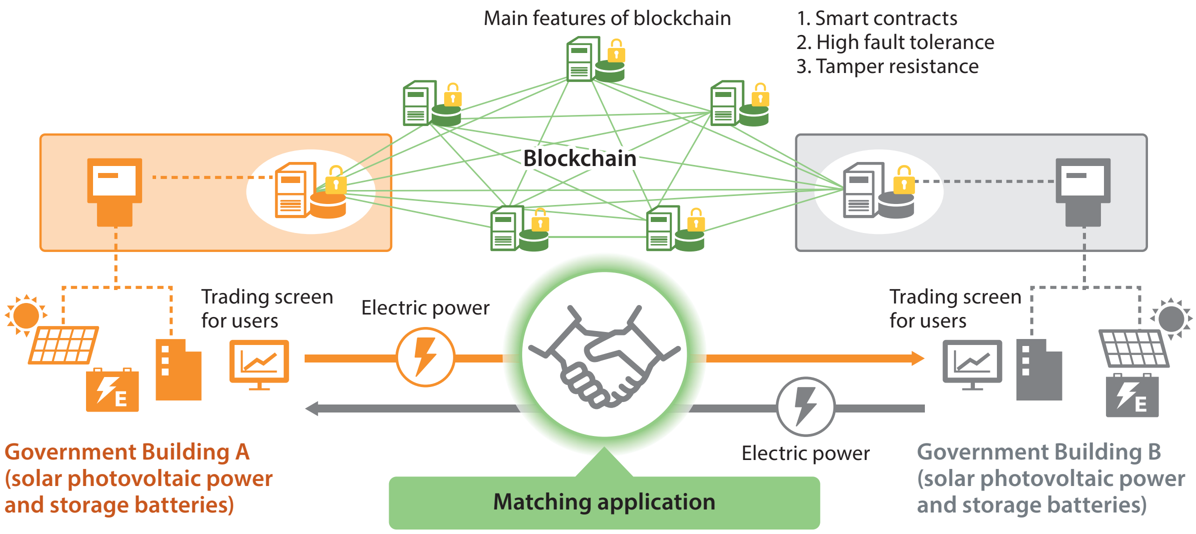
Configuration of large-capacity DCCB

Toshiba Energy Systems & Solutions Corporation has developed a large-capacity DC circuit breaker (DCCB) for high-voltage DC (HVDC) transmission systems.

First, we clarified the requirements for the large-capacity DCCB in a multi-terminal HVDC transmission system composed of DC/AC converters with three or more terminals. We then developed specifications for the DCCB accordingly so as to achieve instantaneous current interruption in the event of a fault current flowing in the HVDC transmission system, and to continue operation of the system outside the fault point. This DCCB circuit has a unique configuration consisting of mechanical switches with little conduction loss and a semiconductor circuit breaker capable of quickly interrupting DC current. As a result, it achieves low power loss and fast current interruption. A 40 kV-class experimental model interrupted a 14.9 kA DC current with an internal commutation time of 2.9 ms (i.e., the time required by the semiconductor breaker to interrupt the DC current after receiving the open command). Through this project, we have successfully established the basic technology necessary to commercialize large-capacity DCCBs.

Part of this development effort was conducted under the Next Generation Offshore HVDC System R&D Project supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

3.20 Demonstration System for Peer-to-Peer Electricity Trading Using Blockchain Technology



Outline of peer-to-peer (P2P) electricity trading demonstration using blockchain technology

Example of transaction result confirmation display at intervals of 30 minutes

Matching application 10:00

Sell bid (yen/kWh)	Buy bid (yen/kWh)
9.50	11.00

Transaction result

Surplus power (kWh)	Buy/sell	Suppliers	Amount of power traded (kWh)	Unit price (yen/kWh)	Trading volume (yen)
−14.00	Buy	Government Building A	1.70	○○○	●●●
	Buy	Government Building B	0.23	△△△	▲▲▲
	Buy	Government Building C	6.87	◇◇◇	◆◆◆
	Buy	Electricity retailer	5.20	□□□	■■■
Total					×××

Toshiba Energy Systems & Solutions Corporation has developed a demonstration system for peer-to-peer (P2P) electricity trading that allows individuals to directly sell surplus electricity generated by solar panels.

In recent years, P2P electricity trading has been attracting attention as a new business model because of the progress of digital technology and the spread of renewable energy and storage batteries. To realize P2P electricity trading, it is necessary to properly secure a large number of online transactions. Blockchains, which employ a cryptographic mechanism, are considered effective for the processing and storage of trading and other records in a decentralized manner.

Tohoku Electric Power Co., Inc. and Miyagi Prefecture conducted a demonstration of our newly developed system under a project entitled “Demonstration of virtual power interchange and virtual power plant utilizing each joint government building in Miyagi Prefecture” starting in 2019. In this demonstration, blockchain technology was utilized to record transactions among seven government buildings in Miyagi Prefecture, including the amount of solar power generated, the amount of power received, the amount of energy charged to and discharged from storage batteries, and trading bids. In addition, virtual matching transactions were conducted between government buildings with surplus power and those with a deficit of power.

As a result of this demonstration, we confirmed that a blockchain featuring smart contracts, high fault tolerance, and tamper resistance is effective for P2P electricity trading.