Power Systems

In recent years, the business environment surrounding Power Systems has seen much discussion on increasingly important issues such as deregulation of the industry, regulation of CO_2 emissions, protection of the environment, and implementation of IT. The Hitachi Group is aggressively developing technology for the Power Systems field with the aim of achieving advanced systems on a world-class level and improving the reliability and cost performance of related products. This issue introduces newly developed technology with a focus on thermal power generation and preventive maintenance.

The Tokyo Electric Power Co., Inc. (TEPCO), Futtsu Thermal Power Station Group No. 3 1,520-MW LNG-fired Advanced Combined-cycle Power Generation Facility

The construction of the TEPCO Futtsu Group 3, Stages 3 and 4, Thermal Power Station has been successfully completed and these units have been put into commercial operation.

This plant is a combined-cycle power generation facility, using the latest 1,327°C class latest gas turbine unit along with other equipment that has been selected from state-of-the-art technologies and integrated to minimize environmental impact as well.

Futtsu Group 3 was planned and developed as a major power source to meet the rapidly increasing power demand of the Tokyo Metropolitan area. The power train equipment was supplied by General Electric in the U.S. and Hitachi, in addition to supplying all of the other equipment, including Heat Recovery Steam Generator (HRSG), also supplied and constructed all the installation and commissioning work including the power train.

The main features of the plant are summarized as follows:

(1) Plant thermal efficiency is over 50% as a result of using the MS9001FA++ Gas Turbine, which is an improved version of the MS9001FA that was specifically designed for application in Advanced Combined-Cycle (ACC) generating systems.

(2) Both the enhanced dry low NO_x combustor and the high efficiency DeNOx facility built in the HRSG satisfied the strict environmental protection regulations in all load ranges.

(3) The HRSG was designed to be of minimal size (25% smaller compared with previous unit) and large-sized modules were used to minimize installation costs.

(4) The latest highly reliable autonomous-distributed digital-control system "HIACS-7000" is used, resulting in auto-operation and the human interface function both being enhanced.

(5) A method of house load operation was adopted to enhance unassisted plant operation and to support rapid recovery of electric power in case of power grid trouble.

(6) Effective cost reduction was achieved in accordance with the aim of adopting new technologies, new manufacturing methods and employing well-conceived design and construction methods to satisfy customer requirements.

Further 2 stages of Group 3 commercial operation are scheduled for December 2004 and June 2005, respectively. Total rated power output of Futtsu Power Station is to be 3,520 MW after completion of the Group 3. (Groups 1 and 2 : 1,000 MW each, Group 3 : 1,520 MW)

The construction planning for Group 4 using a 1,500°C class gas turbine is ongoing.

TEPCO Futtsu Thermal Power Station (left) and HRSG modules just before on-base (right)
Latest ACC power generation facility, whose features are high efficiency, high reliability, and low construction costs.

The Okinawa Electric Power Co., Inc. Kin Thermal Power Station 220-MW Coal-fired Nos. 1 and 2 Units

Maximum power demand in Okinawa Electric Power Company went up last year and is forecasted to continue to increase in the future. The Kin Thermal Power Station is the largest power station in Okinawa Pref. and it was designed and developed as a base-load operated power station to respond to the increasing power demand.

Main features are as follows;

(1) Steam turbine is one-flow exhaust type using a 102-cm (40 inches) last stage bucket made of titanium alloy and the HP/IP/LP rotor is of monoblock construction.

(2) Effective cost reduction is considered, but environmental preservation facility is fully implemented.

(3) This project is a full turnkey project constructed under the auspices of a consortium in which Hitachi has filled the position of "Engineering Leader" company whose function is to coordinate all activities and ensure the project goes forward smoothly.

Reclamation of land from the Kin Bay in June 1998 was the first step in construction work executed by KOKUBA-GUMI CO., LTD. The No.1 unit was put into commercial operation in February 2002.

No. 2 unit is under construction and is scheduled to begin commercial operation in May 2003.

Expected Outline of Kin Thermal Power Station
The site was prepared by reclaiming land from Kin Bay in addition to site preparation work where the former power plant had been situated.

Development of Coal Energy Application for Gas, Liquid and Electricity (EAGLE)

Coal is a fossil fuel that is in abundant supply all over the world. It is a vital resource for maintaining the energy security of Japan, because the supply is stable. However, its CO_2 emission per unit of calorific value is greater than that of other fossil fuels. It is necessary to develop coal utilization technologies that are more efficient to expand the use of coal in a fashion that meets the social demand for a better environment. IGFC (integrated coal gasification fuel cell combined cycle) is a combination of gasifier, which converts coal into synthetic gas, a fuel cell, and gas turbine and steam turbine. This system is expected to realize a much higher efficiency compared with conventional pulverized coal-fired thermal-power generation. Also, it is expected to be the ultimate power generation system using coal. EAGLE (coal energy application for gas liquid and electricity) is doing researching ways to establish coal gasification technology for application to fuel cells (with a coal-fed 150 t/day pilot plant) aiming to implement an IGFC system. This technology development has been directly supported by the Japanese government and implemented under the entrustment of the New Energy and Industrial Technology Development Organization (NEDO).

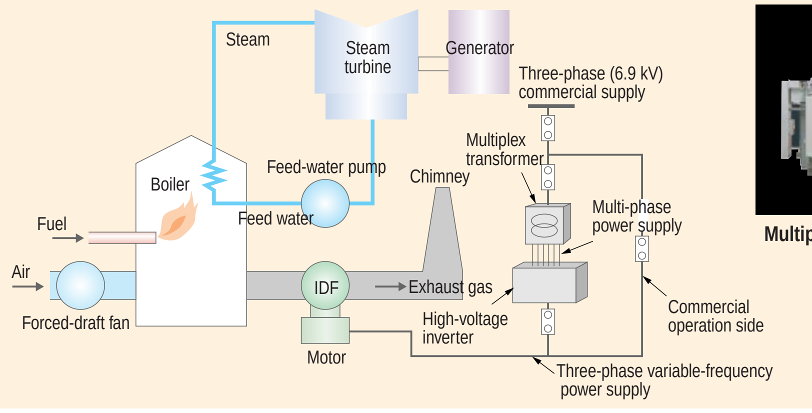
View of EAGLE pilot plant

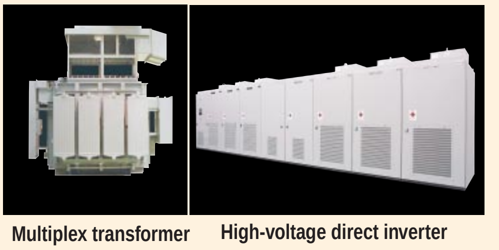
High-voltage Direct Inverter Applied to an Induced-draft-fan Motor

From the standpoints of carbon-dioxide-emission controls and energy-resource conservation measures, energy-conservation laws in Japan are being revised; consequently, even tougher energy-saving measures are being demanded. In response to these circumstances, one aim is to reduce the electrical power consumed by large-scale equipment at existing thermal power stations. Accordingly, in collaboration with EPDC (Electric Power Development Co., Ltd.), Hitachi, Ltd. has implemented a high-voltage direct inverter in conjunction with an existing IDF (induced-draft fan) motor of their Takehara Thermal Power Station No. 3 and started its long-term testing.

The high-voltage direct inverter, with a rated power of 8,250 kVA, adopts a multiplex transformer and a multi-step configuration in order to reduce the harmonic components of the system. This inverter setup thus makes it possible to control the IDF motor under variable-speed operation as opposed to the conventional constant-speed operation under a commercial power supply. As a result, it is expected that the power consumption will be substantially reduced.

With the aim of evaluating the reliability of the inverter system, EPDC and Hitachi are currently testing it at Takehara Thermal Power Station No. 3.





Multiplex transformer High-voltage direct inverter

A schematic and images of the high-voltage direct inverter for IDF
A multiplex transformer and a high-voltage direct inverter are installed between the commercial power supply and the IDF motor. This set-up enables variable-speed control of the IDF motor.

EGAT Ratchaburi Combined-cycle Power Plant in Thailand

The Combined-cycle Power Plant Block-1 and -2 supplied to the Ratchaburi Power Station of the EGAT (Electricity Generating Authority of Thailand) were put into commercial operation in April 2002.

Hitachi, Ltd. received an order from the General Electric International, Inc. for six generators for gas turbines, three generators for steam turbines, and six heat recovery steam generators for Block-1 to Block-3.

The heat recovery steam generator for this project was the first supplied for an overseas project of Hitachi.

The Block-3 will start commercial operation in August 2002.

The specifications of the major equipment supplied by Hitachi are summarized below:

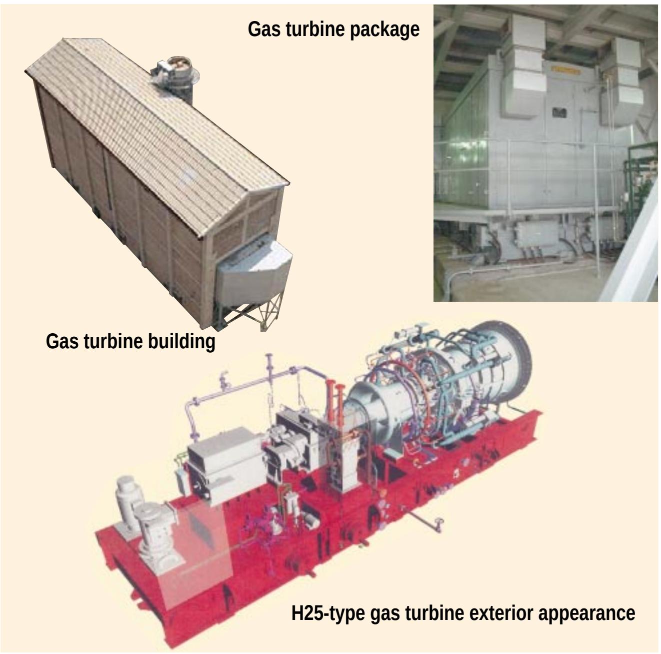
(1) Generator for gas turbine
Rated capacity : 325,000 kVA
Type : Totally enclosed, self-ventilated, forced lubricated, H_2 cooled, cylindrical rotor type, synchronous alternator

(2) Generator for steam turbine
Rated capacity : 325,000 kVA
Type : Totally enclosed, self-ventilated, forced lubricated, H_2 cooled, cylindrical rotor type, synchronous alternator

(3) Heat recovery steam generator
Steam evaporation : HP 270 t/h, IP 308 t/h, LP 27 t/h
Type : Natural circulation, triple pressure with reheat system

Overview of heat recovery steam generator for Ratchaburi Combined-cycle Power Plant Block-1

H25 Type Gas Turbine Supplied to TEC (Toyo Engineering Corp.) for the UFFL (Urea Fertilizer Factory Ltd. in Bangladesh)



H25-type Gas Turbine for UFFL
It is a co-generation system that combines the H25-gas turbine and the existing HRSG.

Upon final assembly of the gas turbine, it was delivered to TEC (Toyo Engineering Corporation) for installation at the UFFL (Urea Fertilizer Factory Ltd. in Bangladesh). Commercial operation began in August 2001.

This gas turbine was ordered to replace the existing gas turbine generator, the second export machine of the H25-type gas turbine, which had been also developed by Hitachi, Ltd. In addition to the gas turbine, we also supplied the control system and bypass stack.

Main Equipment Specifications:

(1) Gas turbine
 Output: 18.00 MW
 Type: H25 (heavy-duty type)
 Fuel: natural gas
 Exhaust gas: generating steam for the power station in the existing HRSG (heat recovery steam generator)

(2) Control system
 Type: digital control system

(3) Bypass stack
 Uses air-operated bypass dumper to control the flow rate of exhaust gas into the HRSG.

176-MW Srisailam Pumped-storage Turbine-runner Supplied to India

In May 1991, Hitachi received an order for six pumped-storage turbine units from APGENCO (Andhra Pradesh Power Generation Corporation Limited) with Sumitomo Corporation (main contractor) in Japan and BHEL (Bharat Heavy Electricals LTD in India, one of the consortium members). The turbine components were manufactured in both Hitachi and BHEL shops under model development and prototype design of the pump-turbine performed by Hitachi. The first unit was commissioned in April 2001.

In the pumped-storage power field, it is recognized that relatively high head (over 400 meters) pumped-storage power plants have been developed mainly in Japan, while on the other hand, relatively low-head pumped-storage turbines with large discharge have been developed in India from the view point of the more economical and larger availability of water resources. The machine size of low-head and large-discharge pump-turbines is relatively large, which requires more stringent and detailed engineering in designing, manufacturing, and quality control to ensure suitable rigidity of such a structure.

The runner, one of main key components in a turbine, is 6.7 meters in maximum diameter and is made of 13Cr-5Ni stainless steel. Due to the limitations of the available casting capacity and restrictions on transportation in India, the runner is split into two pieces and manufactured with a fabricated structure. For this application, detailed FEM (finite element method) analysis of the fabricated structure, the special welding technique used to minimize weld deformation and stringent quality control procedures were established prior to actual manufacturing.

Once all units are put on line by late 2003, more than 1,000 MW of electric power will be available for the central part of India.

Split runner ready for shipment
Due to the limits on land transportation in India, the two halves of the runner will be assembled into one piece on site.

Pump-turbine ratings

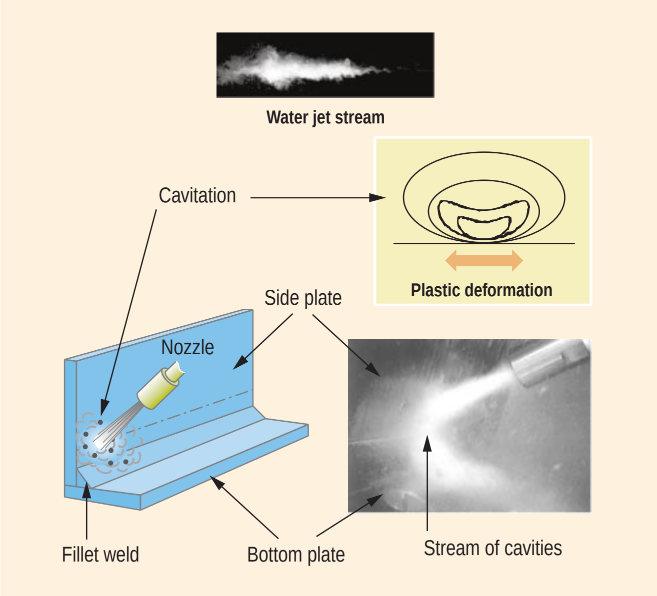
Turbine rating		Pump rating	
Max. turbine output	176,000 kW	Max. pumping input	170,500 kW
Max. effective head	107.1 m	Max. pumping head	106.8 m
Max. discharge	212 m³/s	Max. flow	205 m³/s
Specific speed	166.1 m-kW	Specific speed	57.8 m-m³/s
Rated speed	136.4 min⁻¹		
Type	VFR-1RS		

Water Jet Peening — Preventive Maintenance Technology

Water jet peening (WJP) is a stress corrosion cracking (SCC) prevention technology by reducing surface residual stress. Initiation of SCC requires the following conditions for a certain period of time; sensitized material, corrosive environment, and tensile residual stress. Therefore, it is effective to reduce tensile residual stress by WJP.

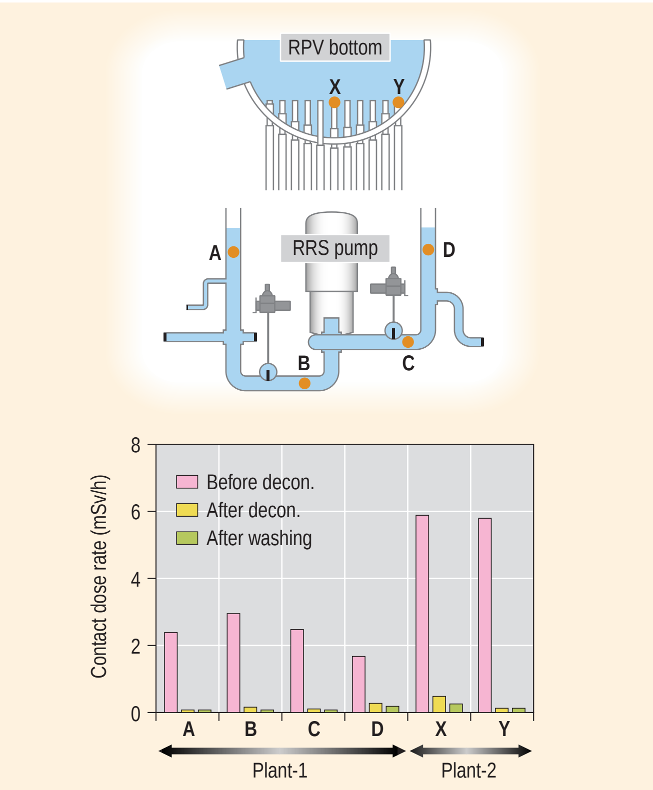
This technology uses a high-pressure water jet. However, water jet kinetic energy is not enough for the purpose. Hitachi has developed the technology using cavitation collapse energy against the surface of the structure to make a compressive stress state. A high-pressure water jet, pressure of 60-70 MPa and velocity of about 240 m/s, generates cavities from the sudden pressure drop at the nozzle underwater. The collapse of a cavity produces impact pressure as high as 1,000 MPa at the material surface. As a result of applying WJP, compressive stress generates on the surface since plastic deformation produced by WJP is elastically constrained by the surrounding material. The best part of WJP is that it only uses water and nothing else for the shooting material. The WJP can be applied to even narrow places, such as nuclear reactor internals. The photo shows the stream of the jet under water. The residual stress is improved not only at the side plate, which the jet is directly aimed at, but also at the bottom plate where the jet went around corner. Because water jet stream can even go around structures, such as curved structures and small pipes.

The WJP has been applied to reactor internals of three nuclear power plants in Japan.



Schematic of the water jet peening (WJP)
The WJP can reduce residual tensile stress by cavitation with high-pressure water jet.

HOP — Chemical Decontamination



HOP decontamination result
A remarkable dose-rate reduction is achieved.

The high-dose rate in a maintenance area during an outage is one of the major concerns of nuclear power plant operators. It results in not only the exposure of workers to radiation but also increases costs, an outage schedule extension, etc. Hitachi has developed a new chemical decontamination technology HOP using hydrazine, oxalic acid and potassium permanganate for reducing the toxicity of such a high dose rate. By using the HOP, we can achieve a remarkable dose rate reduction with small quantities of secondary waste and no corrosion problems.

The principle of HOP is as follows. First, some decontamination objects filled with water are heated to just below the boiling point of water. In the usual case, potassium permanganate is added for oxidation first. Then oxalic acid and hydrazine are injected to discompose the potassium permanganate. After that, additional oxalic acid and hydrazine are injected for reduction. By means of these agents, an oxide film including radioisotopes, such as radiocobalt, is resolved. At last, the reducing agent is decomposed by using catalyst columns. The series of procedure is reiterated for the necessary cycles depending on the required dose rate reduction level.

Over the last three years, HOP was used on nine occasions in Japan which included system decontaminations, full-system decontaminations, and tool and equipment decontaminations. The schema shows samples of HOP decontamination results. The upper one shows the vertical cross section of a reactor pressure vessel (RPV) and the lower one shows a reactor recirculation system (RRS). The orange marks indicate the measured points. As shown in the right side graph, a remarkable dose-rate reduction was achieved.

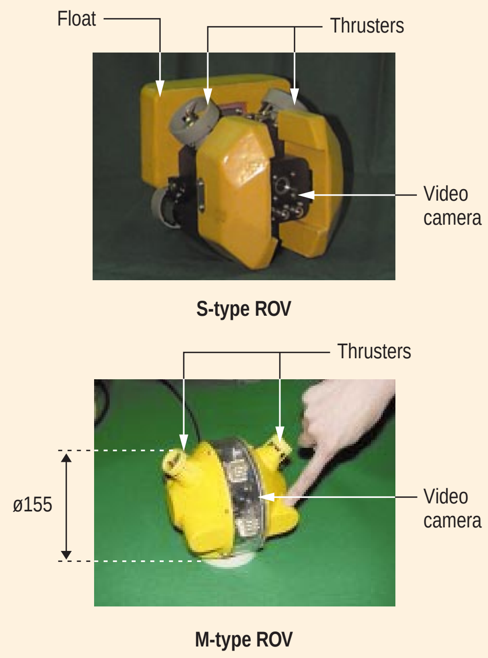
Remotely Operated Vehicles for Underwater Use

Remotely operated vehicles (ROVs) were developed for underwater inspections of a nuclear reactor vessel.

Photos show two types of ROVs (S-Type ROV and M-Type ROV). Both ROVs are remotely and easily operated by using a handy controller (joy stick), and made to approach the inspection area. The ROV can move forward, backward, up, downward, rotate about an axis and position itself sideways using four thrusters mounted on the body.

Each ROV has a video camera for visual examinations and to study the surface of the structure. The camera is easily operated by manipulating the handy controller. The camera tilt angle is from 0 degrees (horizontal) to ± 90 degrees.

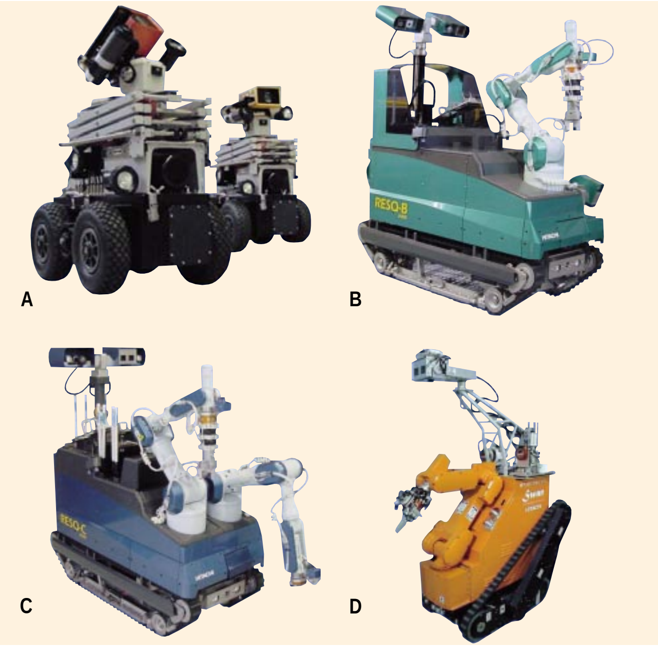
The ROVs have a small body, small enough to be able to access narrow areas (e.g., shroud support area and the bottom of the reactor vessel). The S-Type ROV is used to inspect the suppression chamber of the primary containment vessel. A scanner for a loadable ultrasonic test is available as an option on the S-Type ROV. The M-type ROV is used to inspect a reactor vessel and is the smaller (155 mm diameter) of the two.



Pictures of remotely operated vehicles (ROVs)
S-type ROV can perform various operations (visual test and ultrasonic test). The M-type ROV is the smaller of the two. It is small enough to access the narrow parts in a reactor vessel.

Development of Nuclear-disaster-prevention Support Robots

Hitachi has developed nuclear-disaster-prevention support robots for the purpose of carrying out disaster-prevention missions in a nuclear facility. Two types of robots were developed: the first type is an information gathering robot and the second type is a working robot for disaster-prevention operations. Each robot can pass through the narrow passages in a nuclear facility, and can be made to approach work areas by remote control. The robot with a crawler mechanism can pass up or down stairways having pitches of up to 40 degrees, climb cross gaps and other obstacles.



Information gathering robots (A-C) and work robot (D)

The information gathering robots transmit environmental information in passage ways and accident areas by using a radioactivity sensor, a thermal sensor, cameras, etc. The working robot performs operations like opening doors, valve open/close operations, collecting samples of dust, water and gas, control board operation, etc.

These robots can be operated safely and accurately in a hazardous situation with sensor-based automated control and specially designed tools. Some robots have a 3D view system with a stereoscopic camera and a multi-view system that uses several cameras to obtain visual information in real-time for operations that require dexterity and precision. As to the remote control equipment, the panel of the equipment was designed with a consideration for making the arrangement similar to that of the control board of a nuclear facility, such as switch layout and configuration, and by considering the human-machine interface in an hazardous situation to avoid errors and to reduce the amount of tension imposed on an operator.

These suitability robots were determined by mockup tests assuming nuclear accident situations. The robots demonstrated successfully their excellent capabilities in March 2001.

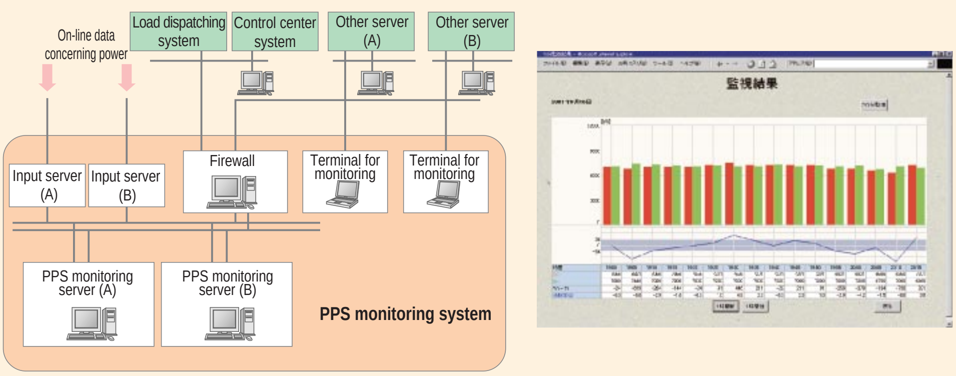
PPS (Power Producer and Supplier) Monitoring System

By the deregulation of Transmission Open Access (TOA) in Japan, private companies can supply electric energy to their users using power transmission lines owned by power utility companies.

Those private companies are so called PPS (power producer and supplier). PPS provides generations and demands, can use power network to dispatch loads by contracting with utility company. The contract requires PPS to match electric energy supply and demand every 30 minutes within the wheeling service maximum power. And, if not, a kind of penalties and/or fines will be charged to the PPS. On the other hand, for power utility companies it is necessary to monitor power supply and demand values of each PPS against the schedules and check the discrepancy between them including transmission loss.

This PPS monitoring system satisfies above needs of power utility companies. This system gathers the power supply and demand values of each PPS and provides current data and historical 30 minutes logs in the forms of the web-based tabular and/or trend graph.

The PCs with D.O.R.A. (Hitachi's EMS/SCADA architecture) are adapted to ensure high cost performance and system reliability.



Structure of the PPS monitoring system
Power can be monitored and past records can be displayed on a browser. Moreover, extra terminals can be easily added.

Saudi Arabia, Saudi Electricity Company Western Region JAMIA 380-kV Substation

The construction of the JAMIA 380-kV substation, in Jeddah was successfully completed in May 2001G. It was energized and connected with main power grid in Jeddah as the mainstay S/S in Jeddah. Construction started in December 1999G near King AbdulAziz University.

Hitachi, Ltd. won and constructed this substation as a turnkey project. Hitachi, in addition to supplying the 380-kV and 110-kV SF_6 gas insulated switchgear (GIS), 13.8-kV metal-clad switchgear, 500-MVA transformer, 40-MVA transformer, protection and control systems, power telecommunication system, also supplied all the civil works.

All engineering, supplied equipment, and civil works were upgraded based on proven reliability supported by field experiences of turnkey projects in the western region.

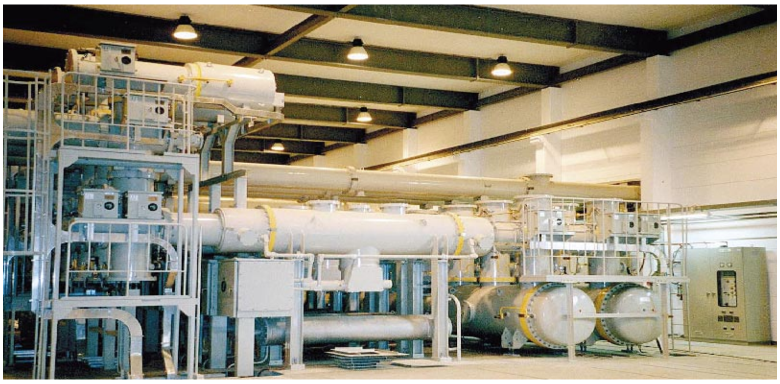
The layout and composition of the substation was carefully simulated to take full advantage of GIS such as compact sizing and harmonization with its peripheral environment located inside the university residence zone along a highway road.

Due to the non-availability of land for the 380-kV overhead transmission line to run directly the substation, a separate outdoor branch connection point located at about 6 km from the S/S area was constructed for an under-ground cable connection between the substation and the overhead transmission lines.

Hitachi also supplied 380-kV outdoor surge arrester, power-line carrier coupling capacitor unit, line trap, and cable protection system at this point.

The coordination of insulation for this hybrid transmission line and substation system was confirmed by surge analysis and the ensured insulation reliability of substation equipment by high-voltage impulse test on the 380-kV GIS on site after construction.

A partial discharge sensor was installed to be used for preventive maintenance after energization.



External view of 380-kV, 2,500-A/50-kA gas insulated switchgear at the JAMIA substation of the Saudi Electric Company in Saudi Arabia
The switchgear is equipped with partial-discharge sensors so that preventive maintenance can be performed during operation by external diagnosis.

Development of Digital Protective Device with Network Technology

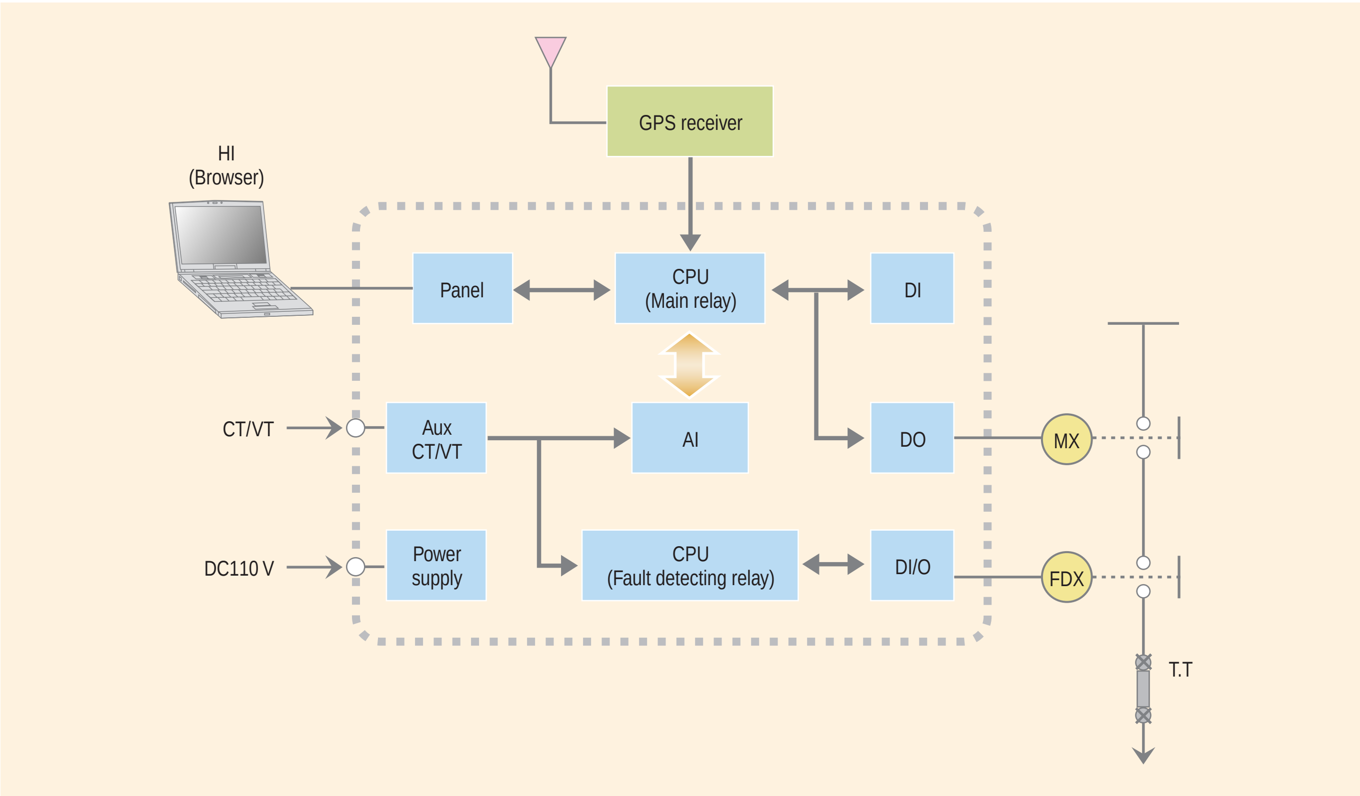
A protective device for power systems detects and removes abnormal phenomena to maintain operation of the power systems. It must have high reliability to supply electric power stably. In addition, it is required to heighten the efficiency of the maintenance tasks to reduce the facility cost. Hitachi has put digital relays with network technology (EDR+ Series) on the market that meet the above requirements.

The greatest feature of these relays is that they can be remotely controlled. The system information and trouble information of the conventional relays must be checked locally through a human interface (HI). Since the HI of the new relays can be controlled using a web browser from a remote place, such as a maintenance base, etc., the maintenance work efficiency is heightened. Furthermore, a web server is installed at each relay to heighten the response.

The second feature is each of the new relays is small and lightweight and all the functions are incorporated in a single unit. With this feature, the overall cost is lowered by the reductions in size and power consumption and unification of facilities. The size and weight were reduced by applying an analog input that uses a toroidal core, heightening the functions and degree of integration with a single-chip microcomputer having a large-capacity flash memory, and designing the unit to consume less power.

The third feature is the concept to eliminate human errors thoroughly. The software can be created by combining the basic modules and any logic circuit on a graphical user interface (GUI). Since it is made up on the GUI, it can be checked easily by anyone besides software maker. In addition, the time chart of the signals can be checked with the logic simulation function. Moreover, reliability is assured by eliminating human errors, such as mistakes in wiring, reading data, etc., with the automatic relay tester.

The development cost of the new relays was reduced by applying conventional technologies. The basic modules of the software and hardware were the standard modules that required no modifications. For example, various existing input and output modules can be used as they are, and high extendibility is obtained, since the bus specifications are common to the new relays and existing products. High reliability is also obtained by using modules that have been used in wide use for many years.



Digital protective device with network technology