Industrial Systems

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Power Systems

Nuclear Power

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Research & Development

New Epoch-making Technology for Preventing Stress Corrosion Cracking in Nuclear Reactors—Water Jet Peening

In the field of nuclear power generation, growing numbers of plants have been in service for more than 20 years and these aging plants require some treatment. Thus, it is becoming increasingly important to address the issue of developing and applying various techniques for inspection, repair, and maintenance to ensure the safety of running nuclear power plants, keep them sound, and assure their reliability. Water jet peening, which is a preventive maintenance technique, has been developed to prevent stress corrosion cracking that occurs in welds and other regions of the internal structures of nuclear reactors. Efforts are under way to apply this technology to actual equipment.

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What is Water Jet Peening?

Water jet peening developed by Hitachi, Ltd. is a technology for peening (impinging) by using cavitation bubbles generated by injecting high-pressure water in water. Injecting water pressurized to about 70 MPa into water through a nozzle causes cavitation bubbles. These bubbles are carried by a high-speed jet flow and crushed upon impinging on the surface of a material. Resulting impact pressure is used for impinging the material surface, thus generating residual compressive stresses.

Austenite-based stainless steel and nickel-base alloys, which constitute the internal structures of nuclear reactors, are rustproof. Any residual tensile stress may cause stress corrosion cracking. Consequently, water jet peening, which improves the residual stress to prevent stress corrosion cracking, is now an effective technology. There is another method called "shot peening" where small steel balls are made to strike a target material at high speed. Conversely, water jet peening only uses water and requires no such foreign matter as steel balls to be entered into or removed from a furnace. Thus, this technology is attracting much attention as a brand-new technology.

Water jet peening to the reactor internal

What are the Features of Water Jet Peening?

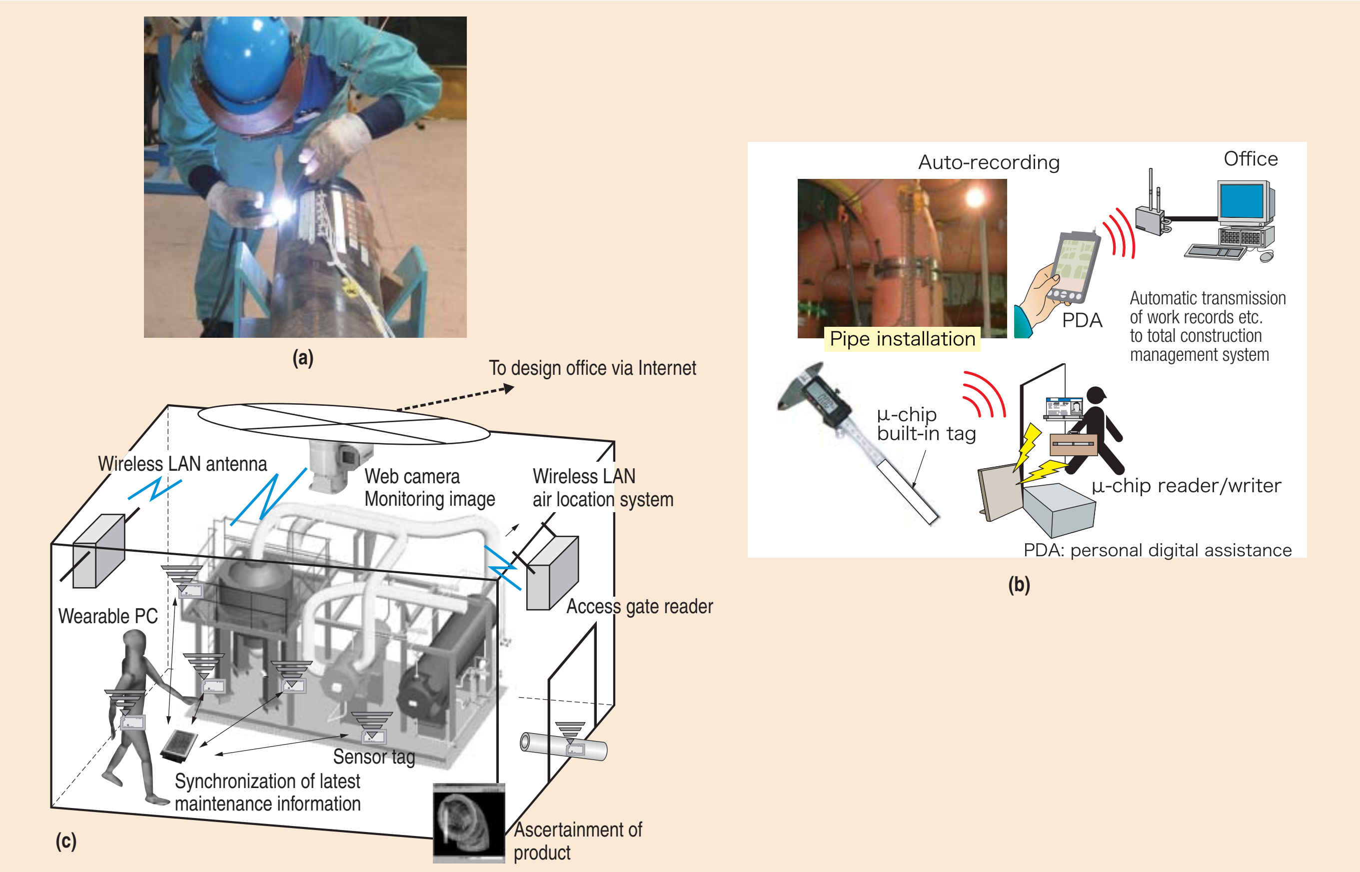
Conventional wisdom holds that cavitation bubbles are harmful to materials, such as causing damage to ship screws. One major feature of this technology is that it offers a complete method of peening in a nuclear reactor by converting cavitation bubbles into something useful. A nuclear reactor has a complex structure and requires that the device used for reactor preservation be taken to the target region through tiny gaps in the complex structure. Water jet peening uses a nozzle driver device that produces a water jet shaped to match the target region to be treated. In so doing, the technology easily accommodates the peening needs of various regions in a nuclear reactor, such as the inner and outer surfaces, corners, and cramped regions in circular structures, both large and small. The technology is also advantageous in that a single operation has wider effective coverage, thus shortening the time required for the work. Another advantage is the wide applicable range of working conditions, such as the distance from the nozzle tip to the target region, along with the angle of the nozzle, thus requiring no precise control and enabling straightforward setting and operating steps for the equipment.

In What Areas will Similar Technologies be Developed and Applied?

The internal structures of nuclear reactors should desirably be subjected to preventive maintenance by means such as peening. For this reason, water jet peening is being used in a steadily growing number of applications. Moreover, working technologies and devices are being developed for the main equipment in nuclear reactors in an attempt to further expand the scope of application of the technology. Furthermore, water jet peening is effective not only in preventing stress corrosion cracking but also in increasing the fatigue strength of metals as well. The technology is therefore expected to find applications not only in nuclear reactors but in various other fields as well, for transforming metal surfaces. Hitachi intends to continue its technical development by such means as increasing the effect of water jet peening. Moreover, the company also intends to extend this technology to more nuclear power plants, thus contributing to the stable running of nuclear power plants, maintenance of their soundness, and assuring their reliability.

Application of RFID to Highly Reliable Nuclear Power Plant Construction

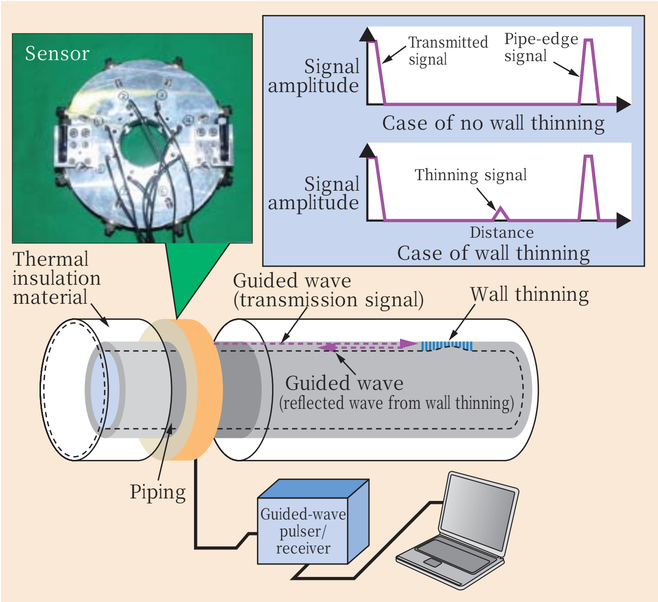
In nuclear power plant construction, more than one million parts, products, and jigs are used, and strict traceability of the history of their materials, manufacturing, and installation is required from the start to the finish of the construction. In addition, the operational efficiency and the effectiveness of the construction must be improved in order to suppress the initial investment for construction. The construction of a nuclear power plant is a large-scale project because numerous kinds of engineers, technicians, inspectors, managers, etc. are engaged. Therefore, systematically managing material amounts, product histories, and so forth is difficult.
On the other hand, RFID (radio frequency identification) technology, one of the fundamental technologies for a ubiquitous information society, has rapidly been expanding in terms of its functionality and general versatility in mass-production industries. Hitachi believes that RFID technology is also useful as one of the key solutions for issues in non-mass-production industries.
With this in mind, Hitachi initiated a project of next-generation plant construction, i.e. ubiquitous plant construction, using information and RFID technologies.
Hitachi has developed and introduced a total integrated construction management system with an integrated computer-aided engineering system to reinforce a quality management system, enabling precise planning and control of engineering schedules, assurance of high quality, and the rapid promotion of efficiency of all sorts of indirect operations.
However, all of the numerous sorts of information, particularly work records of manufacturing and installing countless products, inspection records, information on instruments used during inspection, etc., must be input by hand.
RFID can wirelessly receive and send data, and each RFID has a unique identification number like a bar code, which enables workers to easily identify components. Furthermore, the cover processing of RFID tags allows the tags to be used in several sorts of environments. Hence, attached to products, workers, work devices, and instruments, RFID tags used with an application system provide excellent traceability of information from planning to installation on site. Thus, Hitachi has many advantages such as a higher-quality assurance system and no human error.
Hitachi has been working to apply RFID technology to nuclear power plant construction for a long time. On the basis of the technology and system infrastructure developed so far, Hitachi aims to improve reliability and work efficiency and contribute to developing next-generation nuclear power plant construction technology that ensures safety and quality. This IT (information technology) application is Hitachi's concept to inspire the next method of constructing nuclear plants.



Expected RFID applications to highly reliable nuclear power plant construction; welding to demonstrate RFID resistance (a), overview of application plan of work-field on site (b), and Ubiquitous Plant Technology (c)

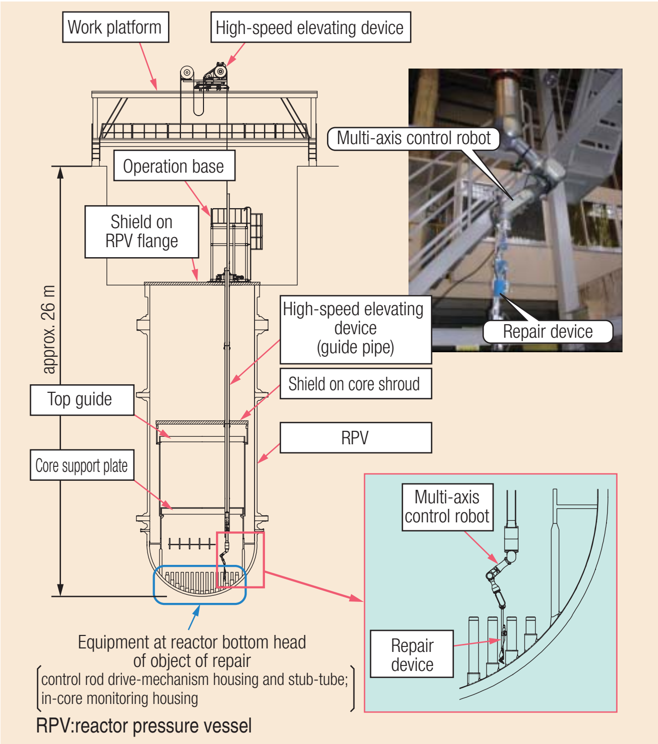
Wall Thickness Inspection System Using a Guided Wave

An inspection technique that uses a "guided wave"—a kind of ultrasonic wave—for checking the integrity of piping and so on in a nuclear power plant has been developed.
In regards to traditional wall thickness inspection of piping, in which an inspector performs measurements by placing an ultrasonic thickness meter at multiple points, the huge number of measurement points involved makes it necessary to improve the inspection efficiency. Moreover, from the inspection side, thermal insulation materials on the inspection surface must be cleaned from the whole inspection area—a process that takes considerable time.
In regards to guided-wave inspection, by means of a sensor located on one part of the piping, it is possible to inspect a range of 16 m around the sensor in one go; accordingly, auxiliary work such as removing thermal insulation materials and setting up scaffolding can be cut back. The guided wave, however, is affected by the problem of waveform distortion. To solve this problem, a unique transmission method—in which the distortion is predicted and a transmission waveform is formed—is introduced. With this method, wall thinning of 0.2% of piping cross-sectional area can be detected.



Overview of wall thickness inspection system using a guided wave

Repair Method for the Reactor Bottom Head of a Nuclear Reactor



A remote-controlled repair technique and the accompanying devices for equipment at the bottom head of a reactor pressure vessel of a BWR (boiling water reactor) nuclear power plant were developed.
[Main features]
(1) To repair the main equipment (with three-dimensional shapes) at the reactor bottom head, a repairing technique using multi-axis control robot affixed with various inspection and repair devices was applied. Repair of the equipment at the reactor bottom head is thus made possible.
(2) Using shield and high-speed elevating devices, an aerial repair method (which performs completely automatic, remote installation of inspection and repair devices and repair work under an air environment) is applied. All repair processes are executed in air environment, quality and reliability of repair welding are improved, and repair-work time can be shortened by shortening installation time of repair devices using high speed elevating devices.
(Completion date: July 2005)

Schematic of remote-controlled repair technique
for reactor bottom head equipment of a nuclear reactor pressure vessel

H-25 Gas-turbine Generator Sets for the Betara Project for PetroChina International Jabung Ltd. in the Republic of Indonesia

Three H-25 gas-turbine generator sets were delivered to the Betara natural-gas processing plant of the Republic of Indonesia. Chiyoda Corporation and its affiliate, Chiyoda International Indonesia, received an order for a whole plant from PetroChina International Jabung Ltd., and taking on part of this order, Hitachi, Ltd. has delivered the gas-turbine generator sets for this plant.

[Main specifications of the facility]

(1) Gas turbine

Type: H-25 gas turbine (heavy-duty type)

Output power: 23,300 kW

Fuel: natural gas

(2) Generator

Type: open ventilation type air cooling

Capacity/frequency: 29,130 kVA/60 Hz

Excitation type: brushless exciter

Full view of Betara Project gas-turbine generator sets

Egyptian Electricity Holding Company/Cairo Electricity Production Company Steam-turbine Generator for Cairo North Project in the Arab Republic of Egypt

Full view of Cairo North Power Station (top) and steam-turbine generator (bottom)

Installation work has been completed on a steam-turbine generator and condenser unit for the Cairo North Power Station of the Egyptian Electricity Holding Company and Cairo Electricity Production Company. Commissioning has been completed, and the unit is now in operation. This unit is the first large-scale combined-cycle unit for the Arab Republic of Egypt, and is also the first steam-turbine generator unit delivered to Egypt by Hitachi, Ltd.

[Main specification of the steam turbine]

(1) Output power: 259.5 MW

(2) Type: tandem compound reheat condensing turbine

(3) Main steam pressure: 11.95 MPa

(4) Main steam/hot reheat steam temperature: 559.7/557.8°C

(5) Rated speed: 3,000 rpm

Nos. 1 and 2 Steam-turbine Generators of the Kwang Yang Combined Power Plant of Daelim Industrial Co. of Korea

The Nos. 1 and 2 steam-turbine generator of the Kwang Yang combined power plant (located in Cholla-namdo in the southern coast of the Korean peninsula) of Daelim Industrial Co. of Korea is currently under commercial operation. With Daelim Industrial party to the EPC (engineering, procurement, and construction) contract of this project, Hitachi, Ltd. received an order from the said company in August 2002 for Nos. 1 and 2 steam-turbine generators of the Kwang Yang combined power plant. Daelim Industrial is carrying out the EPC contract with K-Power Co., Ltd., which—as an IPP (independent power producer) —is carrying out the electricity sales by pool system.

[Main specifications]

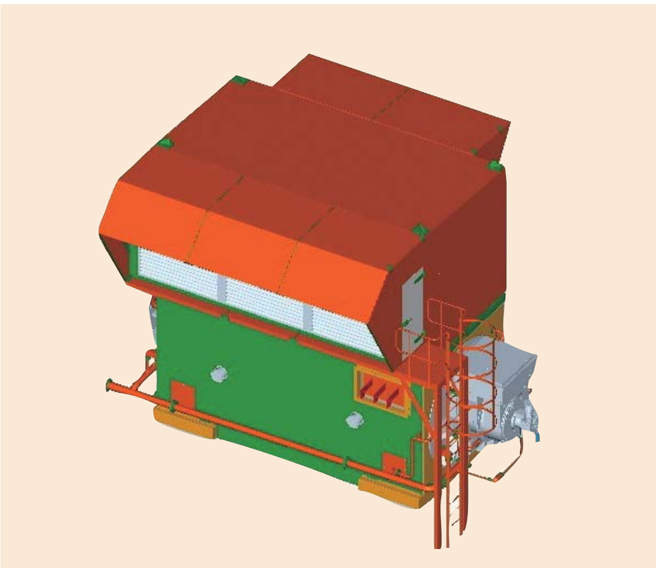
(1) Main steam input pressure: 12.75 MPa; main steam temperature: 564.6˚C; reheating-steam temperature: 565.3˚C

(2) Combined shipping of high- and medium-pressure turbines

(3) Air-cooled-type turbine generator

Installation work of steam-turbine generator set

Development of a 160-MVA-class Air-cooled Generator



Model of the 160-MVA-class air-cooled turbine generator

A 160-MVA (60-Hz)-class air-cooled generator with high efficiency and low noise was developed. This generator comprehensively covers various needs: it can be applied to power supplies all around the world and is constructed to adhere to the specifications in each region while accommodating terminal voltages within a certain band, and its structures are suitable for places from cold regions to tropical zones. Its no-load loss is lower than that previously attained, so its efficiency under partial loading is increased, thereby giving it higher efficiency at the rated power output. Furthermore, its internal noise level and sound leakage to outward are suppressed, and the lowering of maintenance frequency and the transportation mass are taken into account. The generator is positioned in the market as a standard medium-size air-cooled product.

Shipping of a Large-capacity Generator for the MidAmerican Energy Company

Shop performance testing of a large-capacity turbine generator (1,025 MVA; 3,600 r/min) for the Council Bluffs coal-fired plant of the MidAmerican Energy Company has been completed, and the generator has been shipped from Hitachi's production plant. This is Hitachi, Ltd.'s first 1,000-MVA-class generator for thermal-power plants for a single unit.

As for attaining large capacity, since it is necessary to improve the strength of the materials in each part in the rotating body, high-strength materials suitable to meet this need are adopted. Moreover, by increasing internal hydrogen-coolant gas pressure to improve cooling performance, large capacity—as well as a compact body—is accomplished.

Based on the achievements gained in delivering this new generator, investigating even higher capacity and meeting the needs for large-scale thermal-power plants will be pursued from now onwards.



Generator stator before shipping from plant (left), generator rotor before shipping from plant (middle) and view of testing of generator rotor at plant (right)

H-25 Gas-turbine Generator Units for Sohar Oil Refinery of the Sultanate of Oman

Commissioning of two gas-turbine GT (generator) units delivered to the Sohar Oil Refinery of the Sultanate of Oman were completed, and put into continuous operation in October 2005. JGC Corporation received an order for refinery plant including GT units from SRC (Sohar Refinery Company)—a government oil company—and under an FOB (free on board) contract with JGC, Hitachi received an order for two H-25 GT units for in-house power generation.

Providing full coverage of the power needs of the oil refinery plant, these GT units are expected to realize high reliability and efficiency operation.

[Specification of GT units]

(1) Gas turbine

Type: H-25 gas turbine

Output: 22,070 kW

Fuel: natural gas +refined gas (mixed)

(2) Generator

Type: totally enclosed, air cooled

Capacity: 25,965 kVA

Power factor: 0.85

Excitation type: brushless exciter

Overview of H-25 gas-turbine sets delivered to the Sohar Oil Refinery of the Sultanate of Oman

H-25 Gas-turbine Generator Units Delivered to Nippon Petroleum Refining Company, LTD.

H-25 gas-turbine generator units started operation at both Marifu Refinery and Osaka Refinery of Nippon Petroleum Refining Company, LTD. in July 2005. Each generator unit consists electrical-power generation and steam generation equipment composed of a gas turbine, a generator, and a heat recovery steam generator. The electrical power and steam generated by these generator units installed at Marifu Refinery and Osaka Refinery are supplied to these plants.

[Main specifications]
(1) Electrical-power-generation method: H-25 gas-turbine generator unit
(2) Steam-generation method: steam generation by heat recovery steam generator using gas-turbine exhaust
(3) Plant output power (rated output): 34,150 kW (Marifu Refinery); 19,900 kW (Osaka Refinery)
(4) Maximum steam-generation rate of heat recovery steam generator: 61,000 kg/h (Marifu Refinery); 3,000 kg/h (Osaka Refinery)

H-25 gas-turbine generator units delivered to Marifu Refinery (left) and Osaka Refinery (right) of Nippon Petroleum Refining Company, LTD.

Renewal of No. 4 Pump Turbine Runner of Shin-Narihagawa Power Station of Chugoku Electric Power Co., Inc.

At Shin-Narihagawa Power Station of Chugoku Electric Power Co., Inc., of the No. 4 pump turbine runner was renewed in response to overhaul carried out in 2004. This renewal involved replacing the common steel runner—which has been in operation for the 35 years since the start of the operation of the power station—with a stainless-steel one.

For improved water-source utilization ratio under the same design specification as an existing runner, the renewed runner utilizes the latest flow-analysis technology, thereby improving the efficiency of the water turbine and pump at each operation point. In addition, vibration generated in the equipment is reduced by improving the water-pressure pulsation characteristics. And the operating range on the side of low power output and low head under poor operating conditions during the water-turbine operation and the operating range on the high-pump-head side during the pumping operation are each enlarged.

[Main specifications]
(1) Head: 90.8 m
(2) Water-turbine output: 78,000 kW
(3) Rotation speed: 1,444 r/min

Installation of water-turbine runner

Development of the Latest EMS/SCADA Utilizing Next-generation Information Technology

In the environment surrounding the electric industries, in deregulated and partial liberalized power markets, cost reduction and restructuring are being required. Meanwhile, in the field of information-processing technology, as Internet and intranet have been rapidly spreading in recent years, most systems of international and domestic businesses are being interchanged with these technologies as a base. Given this trend, new EMS (energy management system)/SCADA (supervisory control and data acquisition) systems that provide the required "real-time operation" and "reliability" in electrical power system monitoring and control systems and that respond flexibly to cost cutting and restructuring have been developed. By way of broadband dedicated private communication networks, operational status of generators and substation equipment, and the electrical power systems surrounding them, is collected and input into a single SCADA server, and various operations (such as monitoring, control, operation, recording, operational calculation, and information transmission) are automated. As a result, operations and processing are made quicker, more precise, and more efficient. In particular, man-machine devices are developed with Java* applications, and a configuration that is not dependent on platforms can be created. Furthermore, as for monitoring panel, the latest liquid-crystal projectors (LCOS) are adopted, and maintainability and convenience—such as maintenance by users at electrical power system reconfiguration times and versatile display of converged content—are improved.

[Main specifications]

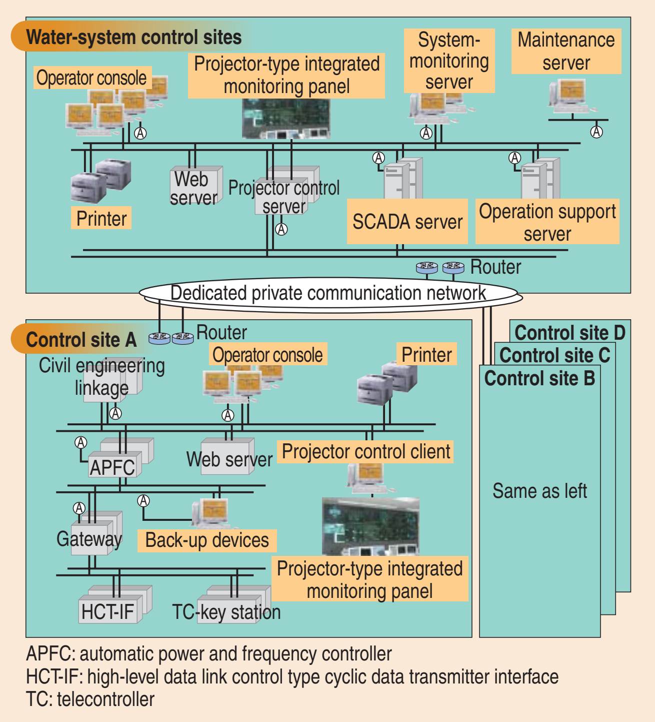
(1) Handling multi-platforms: operator console clients utilize general-purpose hardware, and under a mixed environment composed of Windows, UNIX, and so on, to realize the same display format and operability in regards to the operator, Java applications were developed.

(2) Projector-type integrated supervision systems: power equipment and system configurations are handled flexibly in a "software" manner, and to ensure space saving, a multi-projector is used for the monitoring panel. By using this projector, flexible operation—namely, displayed content can be switched from screens showing transmission networks and water-system figures to video pictures captured by facility-monitoring cameras—is possible. A mechanism that allows memos and tags to be freely displayed by switching the mouse cursor from the operator console display to the monitoring panel was also developed.

(3) Multi-site management: By dividing a single server logically, a monitoring and control function for multiple sites is realized. The monitoring and control function at each site can be operated in "standalone operation mode."

(4) Server changeover by private broadband network: changeover of duplex system servers at dispersed sites across a private broadband network is made possible by a switchover method called "IP takeover"—that is, unifying the network address between two sites. Moreover, for transmitting data to multiple devices at dispersed sites, the transmission method used on the private broadband network adopts middleware that performs multi-cast transmission and accomplishes high-performance transmission with high reliability.

* See "Trademarks" on page 94.



Configuration of a SCADA system using a dedicated private broadband network

Projector-type integrated monitoring panel