Completion of Hitachinaka Thermal Power Station Unit No. 1
— 1,000-MW Power Generating Plant of The Tokyo Electric Power Co., Inc.—

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OVERVIEW: In recent years, from the viewpoint of environmental conservation, it has become a top priority to improve the heat efficiency of thermal power plants. Under such circumstances, in December 2003, a 1,000-MW coal-fired power plant with the world's highest efficiency — Unit No. 1 of Hitachinaka Thermal Power Station of The Tokyo Electric Power Co., Inc. — was put into service. This generator consists of a coal-fired boiler with an extremely high critical pressure and a main steam temperature of 600°C as well as a state-of-the-art steam turbine with 41-inch-long (about 104 cm) final-stage turbine blades. Hitachi, Ltd. was in charge of the design and construction of the facilities for these two main components (i.e. the boiler and turbine) of Unit No. 1. Upon completing the plant design, Hitachi drew upon its collective strengths and latest technologies to develop these components. That is, by introducing the large-capacity, coal-fired boiler — which can handle many varieties of coal and meet the optimum steam conditions through increased pressure and temperature — and the high-efficiency steam turbine, both plant efficiency and reliability have been improved. Furthermore, a newly developed remote-monitoring system installed in the central control room of the plant utilizes expanded-display devices [large-size LCD (liquid crystal display) displays] and wider-scope operation by means of highly functional CRT (cathode ray tube) displays. As a result of this system set-up, plant operation in terms of labor saving and monitorability is improved. In addition, the remote-monitoring system is directly connected to the switchgear for auxiliary electrical equipment; consequently, the amount of cable materials used is reduced and the construction cost is lowered.

INTRODUCTION

CONSTRUCTION of the boiler of Unit No. 1 of Hitachinaka Thermal Power Station of The Tokyo Electric Power Co., Inc. was started in July, 1999, and the unit went into commercial operation in December 2003. Regarding the main facilities of this power plant, Hitachi, Ltd. took charge of the design and construction of the boiler and turbine generator of Unit No. 1. Taking full advantage of its collective strength in terms of plant engineering and technical skills, Hitachi

Fig. 1—View of Completed Hitachinaka Thermal Power Station. Located at Hitachinaka Thermal Power Station, Hitachinaka Port north quay Ibaraki Prefecture, Japan, Unit No. 1 — a 1,000-MW power-generation plant — was completed in December, 2003.

TABLE 1. Comparison of Design Specifications of Two Power-generation Plants
By adopting higher steam pressure and temperature conditions, thermal efficiency of Hitachinaka Unit No. 1 is 4.5% higher than Shinchi Unit No. 1.

Item			Unit	Shinchi Unit No. 1	Hitachinaka Unit No. 1
Basic design conditions	Rated power		MW	1,000	1,000
	Steam conditions (main/reheat)		MPa	24.1	24.5
			°C	538/566	600/600
	Fuel		—	Coal	Coal
Main machine spec.	Boiler	Type	—	Ultra-high critical pressure, variable through flow	
		Steam pressure	MPa	25.0	25.4
		Steam temperature	°C	542/567	604/602
		Evaporation volume	t/h	3,080	2,870
	Turbine	Type	—	Two-axis four-flow discharge	
		Revolution speed	min^{-1}	3,000/1,500	3,000/1,500
		Discharge vacuum pressure	kPa	–97.06 (728 mmHg)	–96.26 (722 mmHg)
	Generator	Type		Horizontal-cylinder revolving magnetic field	
		Capacity	MVA	634.8/519.9	675.0/488.0
Thermal efficiency			%	41.89	43.78

successfully completed construction of these two key facilities of this 1,000-MW power-generation plant and achieved world-leading thermal efficiency and reliability.

In the following sections, the main features of the two facilities designed and constructed by Hitachi — namely, the boiler and turbine generator — and the technologies applied are described.

OVERVIEW OF PLANT DESIGN

Table 1 compares the specifications of the new Hitachinaka No. 1 Unit and that of an existing unit with the same rated output power (i.e. No. 1 Unit of Shinchi Thermal Power Station (hereafter referred to simply as Shinchi Unit No. 1) developed in collaboration with Soma Kyodo Power Co., Ltd.).

As regards the basic design of Unit No. 1 of Hitachinaka Thermal Power Station (hereafter referred to simply as the Hitachinaka Unit No. 1), it is clear that the Hitachinaka Unit No. 1 seeks higher thermal efficiency and optimized economic efficiency through increased steam pressure and temperature conditions. That is, compared to the design thermal efficiency of the Shinchi Unit No. 1, that of Hitachinaka Unit No. 1 (under a main steam pressure of 24.5 MPa and main/reheat steam temperatures of 600°C) is 4.5% higher.

NEW BOILER TECHNOLOGY

As for the high-efficiency operation of the new boiler facility, by applying high-temperature, high-elevated temperature strength materials adapted to high-temperature, high-pressure steam under so-called maximum-level conditions, high reliability can be sustained. And improving combustion performance by means of utilizing the latest pulverized-coal-firing technology further improves efficiency.

Boiler Design

As for the boiler furnace specification, since high-temperature steam at 600/600°C is used, a variable-pressure-operation Benson boiler with a high-reliability spiral water wall is adopted. A schematic cross section of Hitachinaka Unit No. 1 is shown in Fig. 2.

As for the boiler design, streamlining the facility led to improvement in operation characteristics and maintainability.

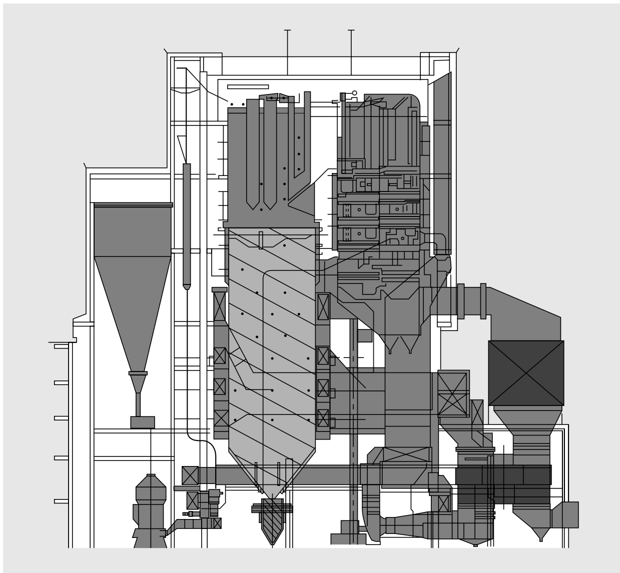

Fig. 2—Side Structural View of Boiler of Hitachinaka Thermal Power Station Unit No. 1.
The plant design combines the latest high-strength materials in the high metal-temperature range to attain high reliability and high economical efficiency.

The main features of the boiler are listed below:
(1) Hitachi's latest pulverized-coal burner (NR3) improves burning efficiency and decreases NO_x emission.
(2) By aligning all boiler reheater horizontally, controllability of steam temperature in the parallel gas damper is improved, so a gas-recirculation system is not required.
(3) Enlarging the heat-absorption in the furnace results in non-uniform temperature distribution in the water wall; therefore, a mixing bottle is located at the outlet of the spiral water wall to mitigate the non-uniform temperature distribution.
(4) Large-scale modular design using a sling-type tube support for the horizontal heating surface is used for the first time. As a result, using various module designs shortens construction time and, thus, improves efficiency.

High-efficiency Combustion Technology

In recent years, to simplify combustion facilities, the capacity of burners has been increased. In the new plant facility, 36 Hitachi-NR3 burner units are installed — providing the maximum capacity in Japan.

Regarding the Hitachi NR3 burner, in addition to the denitration technology used in Hitachi's standard low-NO_x pulverized-coal (NR2), a guide sleeve and flame stabilizing ring with a baffle plate are applied. As a result of this, a flow pattern of the secondary and tertiary air is optimized; consequently, a high-temperature reducing flame is enlarged and the NO_x emission is reduced.

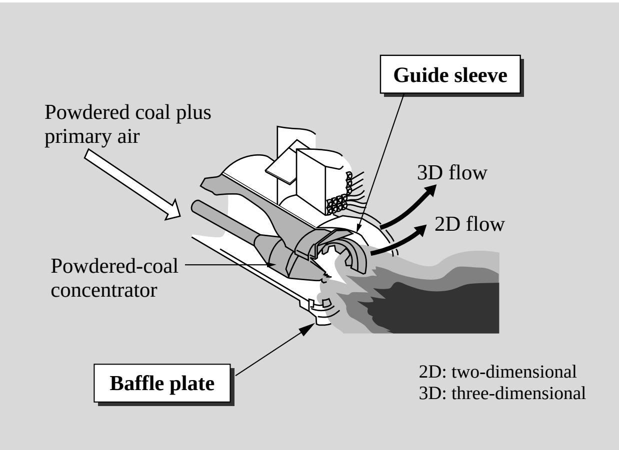

Fig. 3—Structure of Hitachi-NR3 Burner.
By utilizing Hitachi's low-NO_x NR3 burner, even lower NO_x emission, along with better combustibility and flame stability, is attained.

NEW STEAM TURBINE AND SYSTEM TECHNOLOGIES

By applying the latest technologies under high-temperature conditions for the main steam and reheat steam, the steam turbine attains high efficiency and high reliability. Furthermore, in the construction phase of the plant facilities, the steam turbine was made more compact.

New Steam Turbine Technology

Since the steam turbine operates under high-temperature-steam conditions, the main parts must handle temperatures of 600°C. Accordingly, the main-steam stop valve, regulator valve, and combined reheat valve are made of 9Cr-1Mo steel; the inside casing of the high-pressure turbine is made of Cr-Mo-V-B steel; and the inside casing of the intermediate-pressure turbine is made of 12Cr steel.

Moreover, on top of the improved combustion efficiency brought by the increased steam temperature, overall efficiency is improved as a result of the implementation of the latest AVN (advanced vortex nozzle). A photograph of the completed steam turbine-generator is given in Fig. 4.

Characteristics of System Configuration

In regards to the configuration of the system for the heat cycle (steam extraction, charging, and condensation), a structure that works well in a 1,000-MW power generator is used. Moreover, from the viewpoint of compactness, various features of the auxiliary equipment have been elaborately designed. The main features of the system configuration are listed as follows:
(1) Steam extraction, charging, and condensation

Fig. 4—View of Steam Turbine-generator Facility.
Completed steam turbine-generator applying the latest technology is shown.

The feedwater heater consists of a low-pressure, four-step deaerator and a high-pressure, four-step deaerator. The condensate pump and its booster pump are comprised of two units, each with 50% capacity; while the feedwater pump is comprised of two 50%-capacity turbine-driver units and one low pump-head motor-driver unit feedwater pump for plant start-up and shutdown.

(2) Simplified deaerator

Compared to a conventional deaerating chamber for removing dissolved oxygen from the boiler feedwater — which has a flush tank for the boiler water made from two blow molds — the new steam-turbine system has a enlarged flush tank made from a single mold. Accordingly, this monohull-type flush tank with a built-in deaeration capability is more compact and takes up less space.

(3) Cleaning filter

Up till now, the steam condenser has utilized a six-valve-switching backwash method. The new condenser, however, features a large-size cleaning filter at the input of the water chamber of the condenser. As well as improving the operation of the steam-condenser cooling system, introduction of this filter makes setting up the circulating water system more efficient.

REMOTE PLANT-MONITORING CONTROL SYSTEM

The facilities of the above-described 1,000-MW large-capacity coal-fired power plant are monitored by a large-scale remote-control system consisting of 700 auxiliary units for coarse control and monitoring points for collecting data (2,200 analog and 20,000 digital). This large-scale system coverage is provided by the Hitachi Integrated Automatic Control System (HIACS).

The HIACS is composed of distributed computer (RS-90/400) with automization and control functions, FA (factory automation) PCs with operation monitoring functions, and a high-speed, large-capacity controller series with control and safety functions. All these devices are connected via high-speed network — called μΣ-100 — to form an "all digital" system.

The characteristic features of this large-scale remote-control system, HIACS, are outlined in the following sections.

Human-machine Interface

(1) As well as integrating and sharing information, the HMI (human-machine interface) achieves excellent operability and controllability by utilizing a four-screen multi-window system provided by 110-type expanded-display devices [large-size LCDs (liquid crystal displays)].

A view of the main operator's control panel of the central control room is shown in Fig. 5.

(2) CRT operation is achieved by the distributed FA PCs and expanded-display devices by PC mouse operation. As well as covering the conventional range of control devices, it also extends to auxiliary electrical devices, so the main operator's control panel of the

Fig. 5—View of Main Operator Control Panel and Expanded-Display Devices in Central Control Room.
An HMI centered on 110-type expanded-display devices is adopted, and the integration of data enables the central control room to be streamlined.

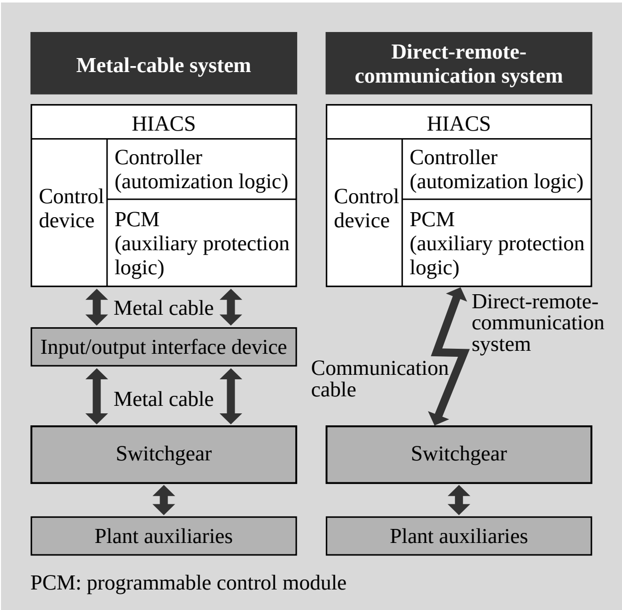

Fig. 6—Interface between Control Devices and Switchgears.
By utilizing remote-communication methods, the control system can be significantly streamlined.

central control room can be made more compact.

Interface between Control Devices and Switchgears

The conventional interface between control devices and switchgears utilizes metal cables; however, the new plant-control system uses remote communication between these devices as shown schematically in Fig. 6.

Each switchgear is fitted with a communication function so that it can communicate directly with a corresponding control device. As a result, the operating control panel is made more compact and the cable-engineering work is made significantly more efficient.

Improving Reliability of Boiler and Turbine-generator Safety Systems

Regarding the boiler and turbine safety panel, to assure higher reliability than that attainable up till now, a triple system consisting of a PCM — equipped with a ROM (read-only memory) and CPU (central processing unit) — is connected to a protection circuit. And a dual system is set up to cover abnormal-state detection and alarm monitoring by the detection elements and calculation circuitry. In conjunction with a digital protective relay board for protecting the generator machinery and main transformer, the above-described configuration has enabled the protection circuit to be completely digitized.

CONCLUSIONS

This paper described the main features of the boiler and turbine-generator of Unit No. 1 of Hitachinaka Thermal Power Station of The Tokyo Electric Power Co., Inc., and outlined the latest technologies applied in these facilities. Applying these new technologies enables stable operation of these coal-burning-power-plant facilities at high efficiency and large capacity.

In the future, Hitachi Group intends to apply these technical achievements in other thermal power plants. In particular, focusing on development of technologies for even higher efficiency and more plant streamlining, we are striving toward construction of sustainable thermal power plants.

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REFERENCES

(1) R. Okura et al., “Completion of a High-efficiency Coal-fired Power Plant; *Hitachi Hyoron*, **85**, pp. 163-166 (Feb. 2003) in Japanese.

(2) K. Umezawa et al., “Kin No. 1 1220 MW Thermal Power Station,” *Hitachi Hyoron*, **85**, pp. 167-170 (Feb. 2003) in Japanese.

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