Outline of 600MW Power Plant for Unit 1 of Noshiro Thermal Power Plant, Tohoku Electric Power Co., Inc.

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1. Introduction

Unit 1 of Noshiro Thermal Power Plant, Tohoku Electric Power Co., Inc., is a high-efficiency, up-to-date, coal-fired power plant with a large capacity tandem-compound turbine based on European technology. The unit passed MITI final inspection on May 28, 1993 and has started commercial operation.

Fuji Electric manufactured the steam turbine, generator, and station-service electrical equipment of the unit. The turbine and generator unit with an output of 600MW is of Fuji Electric's greatest thermal capacity. The company had carried out sufficient investigation for years and established a project system in 1989 to execute design, manufacture, on site erection, and trial operation.

This paper outlines the plan and results of trial operation of Unit 1 of the Noshiro Thermal Power Plant.

2. Plant Plan and Equipment Specifications

Unit 1 of the Noshiro Thermal Power Plant (**Fig. 1**) is a coal-fired unit with a rated output of 600MW. **Table 1** shows the main specifications of the turbine and generator.

The turbine is a 4-cylinder, 4-flow, tandem-compound type, having a rated output of 600MW and using a super-

Table 1 Main specifications of the steam turbine and generator

Turbine	Type	4-cylinder 4-flow tandem-compound reheat condensing reaction type
	Output	600MW
	Operating method	Variable-pressure operation with throttle governing
	Main steam pressure	24.6MPa (251kgf/cm² abs)
	Main steam temperature	538°C
	Reheat steam pressure	4.06MPa (41.4kgf/cm² abs)
	Reheat steam temperature	566°C
	Vacuum	728mmHg (at sea water temp. 18.7°C)
	Rated speed	3,000r/min
	Number of extractions	8
	Last-stage blade length	1,050mm (41.5 inches)
Generator	Type	Horizontal cylindrical-revolving-field hydrogen-gas-cooled type
	Capacity	670MVA
	Terminal voltage	19,000V
	Power factor	0.9
	Rated speed	3,000r/min
	Hydrogen pressure	4kg/cm²·g
	Cooling method	Direct hydrogen gas cooling of stator and rotor windings
	Exciting system	Brushless excitation

Fig. 1 Overview of the power station
(Unit 1 on the right and Unit 2 under construction on the left)

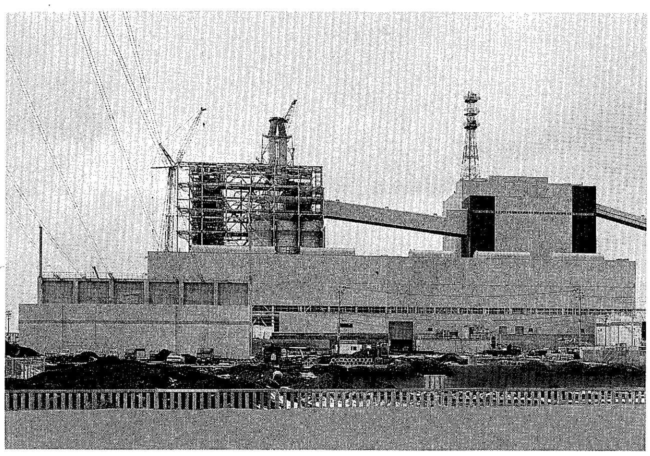

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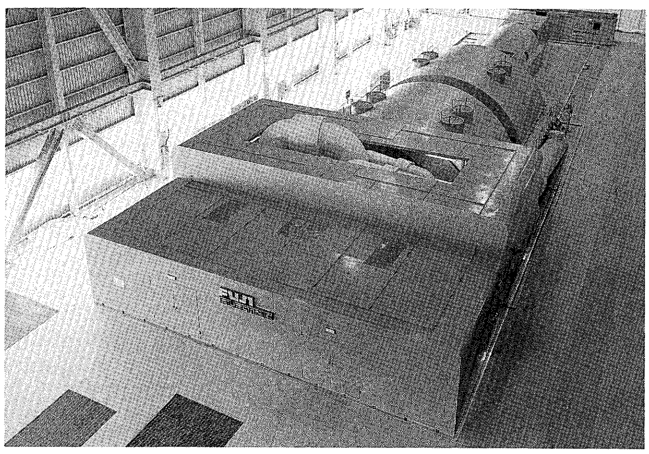
Fig. 2 External view of the 600MW steam turbine and generator



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critical steam condition of 24.6MPa (251kgf/cm^2 abs) and 538/566°C.

The generator has direct hydrogengas-cooled rotor and stator windings and uses a high-response brushless exciter for excitation. The unit capacity of 670MVA is the largest of the 3,000r/min machines in Japan.

Figure 2 shows the external view of the turbine and generator.

2.1 Main features of the turbine and generator unit

The main features are as follows:

(1) The unit is a large, coal-fired, thermal power plant with a compact building that houses a European-style, large capacity tandem-compound turbine. The building dimensions are 36m in width, 95m in length (including the entrance for large components), and 13m in height at the third floor. No basement is provided.

(2) For the last-stage blade of the LP turbine, high-efficiency blades of 1,050mm(41.5 inches) long are used, resulting in thermal efficiency relatively 0.6% higher than former turbines.

(3) Adopting a barrel-type construction for HP turbine and variable-pressure operation, the plant also can efficiently operate DSS (daily start-up and shutdown) and WSS (weekend start-up and shutdown).

(4) The wide use of automation with computers as a core (including operation guidance and facility diagnosis) and video display (such as CRT operation, large display, and ITV) has realized an automated, up-to-date plant, making operation and monitoring easier.

2.2 Basic flow of the turbine plant and its features

2.2.1 Basic flow of the turbine plant

Figure 3 shows the basic steam-water flow diagram of the turbine plant. The HP feedwater heaters are arranged in 2 flows each with 3 stages; the LP feedwater heaters, in 1 flow with 4 stages.

The boiler feedwater pumps consist of two 50%-capacity turbine-driven pumps and one 25%-capacity motor-driven pump. It was designed so that the turbine-driven pumps could start the Unit. A stand-by motor-driven pump was not provided.

To simplify and justify the facility, the condensate and sea water booster pumps each consist of two 50%-capacity pumps without stand-by.

2.2.2 Reliability verification and design verification

To secure and verify the operational reliability of the large capacity, tandem-compound turbine, the prediction and confirmation of reliability, using "Reliability Prediction Systems for Turbine Operation" as well as actual manufacturing and installation data, was carried out on site before trial operation.

In the design stage, design verification with model engineering (in a scale of 1/25) was carried out to improve the quality and appearance of the layout and piping design. In addition, workable and practical transportation and installation procedures of equipment and piping were fully investigated in advance.

Fig. 3 Basic steam-water flow diagram of the turbine plant

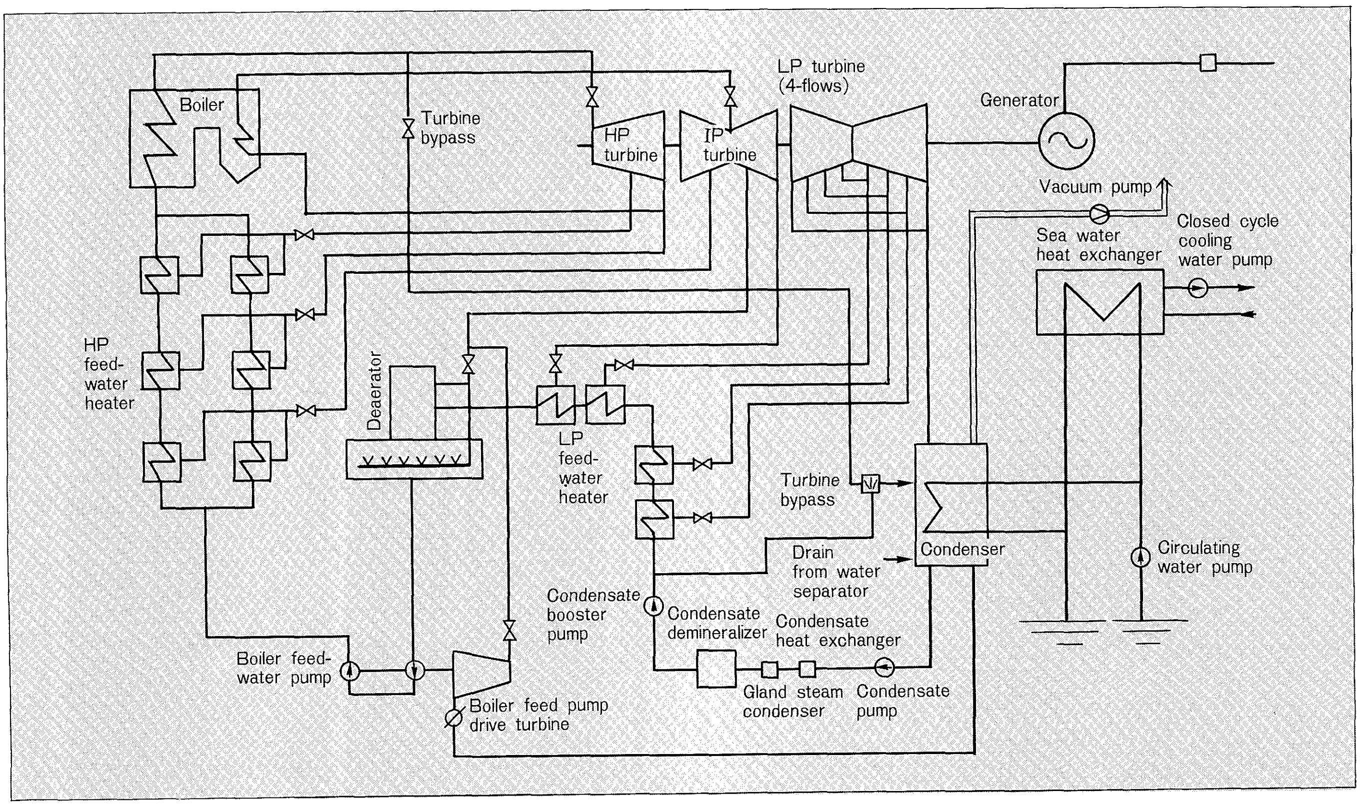
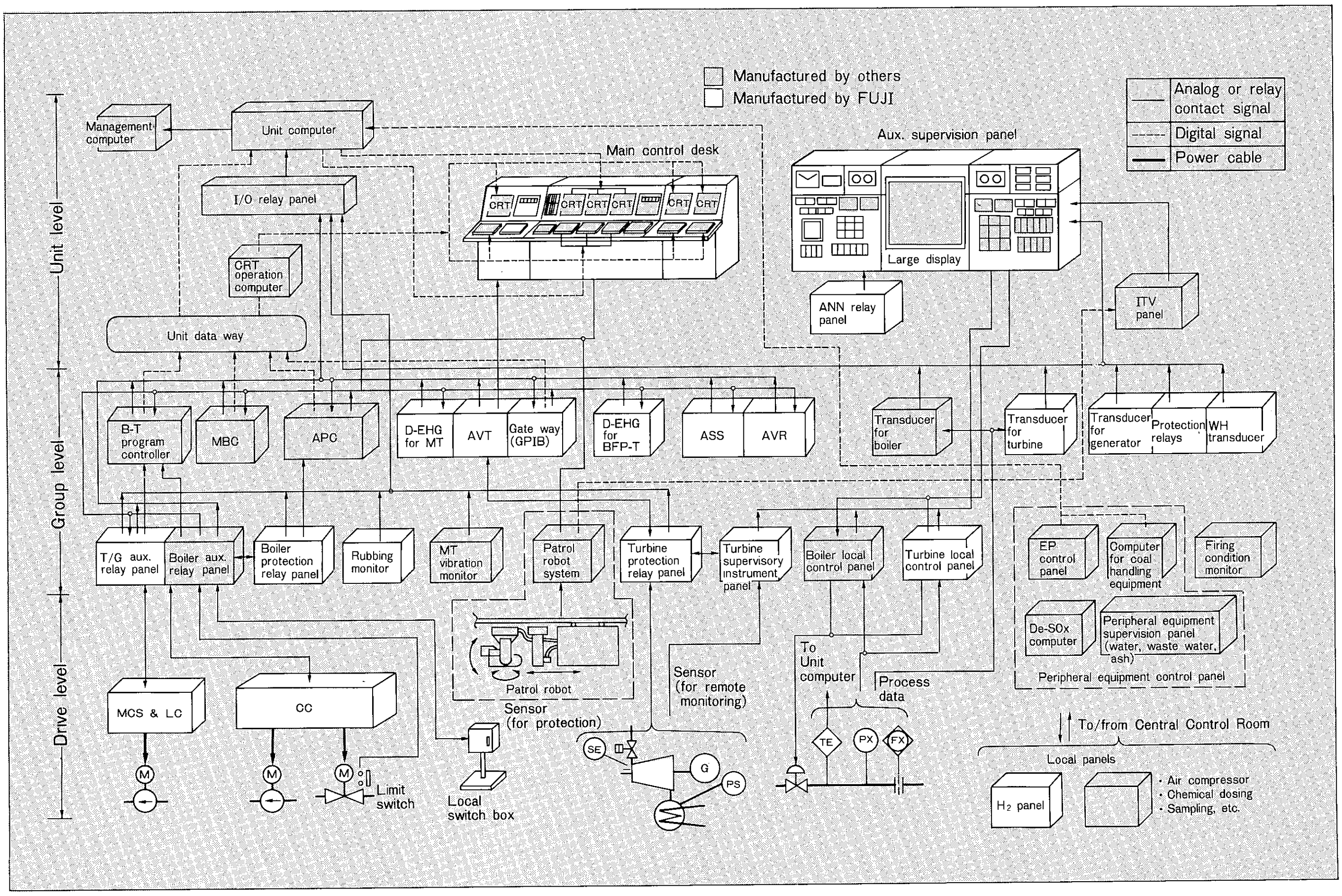


Fig. 4 Instrumentation and control system block diagram



3. Instrumentation and Control

3.1 Outline of the instrumentation and control system

The plant uses an integrated supervision and control system with the Unit computer at the core in order to realize an economical and high-efficiency operation, to improve reliability and expandability by function decentralization and operability with multiple types of coal, and to increase rationalization and minimize operation and maintenance persons.

3.1.1 System configuration

Figure 4 shows the system block diagram. The basic points considered in its planning are as follows:

(1) To raise the economy, reliability, and expandability of the control system, a hierarchical, function-decentralized, self-controlled system should be used, aiming for coordination of the hardware and systems.

(2) The systems should be organically linked to each other by data transmission units to optimize the supervisory and control functions of the systems and to perform the optimum supervision and control of the plant, including operation support functions.

(3) Expandable systems that need no restructuring should be designed to meet the steady improvement of a control equipment.

(4) The systems should be able to support fire prevention by linking up with the centralized fire alarm console provided in the central control room so that quick and proper measures can be taken against a fire.

(5) The system should be capable of data communication with supervision and control systems for peripheral equipment such as coal unloading and handling, De-SOx, ash handling, waste water treatment, and feedwater treatment equipment.

3.1.2 Basic design concept on automation

Basic design concept on the automation of plant supervision and control are as follows:

(1) Operation should be easy and labor-saving by adopting automated plant start-up and shutdown (APS). The automated range should be from the plant start up preparation process (the first CWP start) to a target load and from usual operation to plant shutdown.

(2) Operation should be easy and labor-saving by adopting operation guidance systems such as high-efficiency operation guidance, trouble shooting guidance, and most suitable operation guidance.

(3) In order that man-machine communicating functions can be improved visually and aurally CRT operation, large display, and voice announcement systems should

Fig. 5 External appearance of the D-EHG

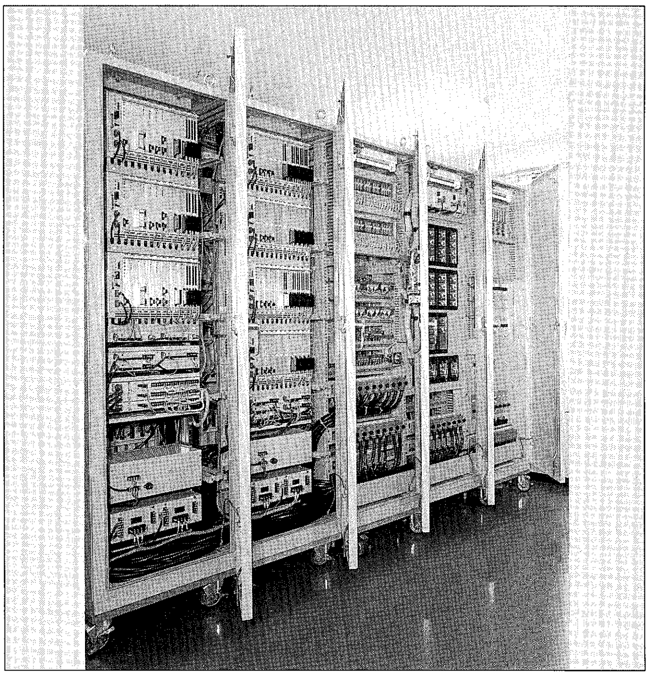


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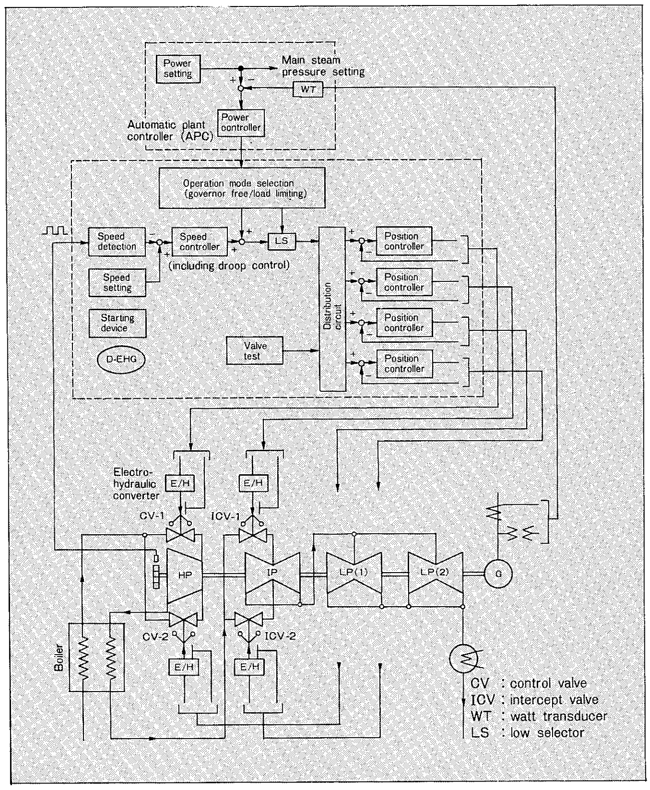
Fig. 6 D-EHG function block diagram



be adopted together with human error prevention, quick analysis and study of trouble shooting, efficiency improvement in plant education and learning, and console down sizing.

(4) To prevent plant failure, ITVs for monitoring plant parts and patrol robots (local abnormality monitors) should be adopted for important equipment such as around the burners in order to monitor reinforcement and easy patrol.

(5) A facility diagnosis system and a performance and life expenditure management system should be adopted so that plant reliability can be improved and easy maintenance (including high-efficiency operations) and failure prevention can be realized.

3.2 Turbine control equipment

The turbine governor is one of the most important parts of control system in a thermal power plant. The digital electro hydraulic governors (D-EHG) with superior in reliability, controllability, and maintenance are used for the main turbine and boiler feed pump turbine governors.

An outline of the main turbine D-EHG is introduced below. **Figure 5** shows the external appearance of the D-EHG.

3.2.1 Functions of the D-EHG

The D-EHG is provided with the following functions:

(1) Turbine start and automatic speed rise control
(2) Speed matching and initial load control
(3) Operation in a governor-free or load-limiting mode
(4) Automatic follow-up function of the setting device for the above
(5) Individual valve position control
(6) Load shedding relay function
(7) Automatic valve function

Fig. 7 Main control desk (in front) and auxiliary supervision panel (behind)

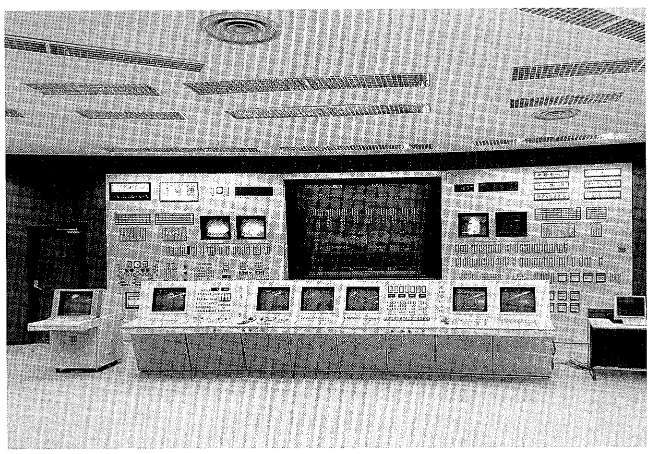


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Figure 6 shows the roughly function diagram and their interface with the machines.

3.2.2 Features of the D-EHG

The D-EHG is made up of Fuji Electric's MICREX-F500 as hardware and has the following features:

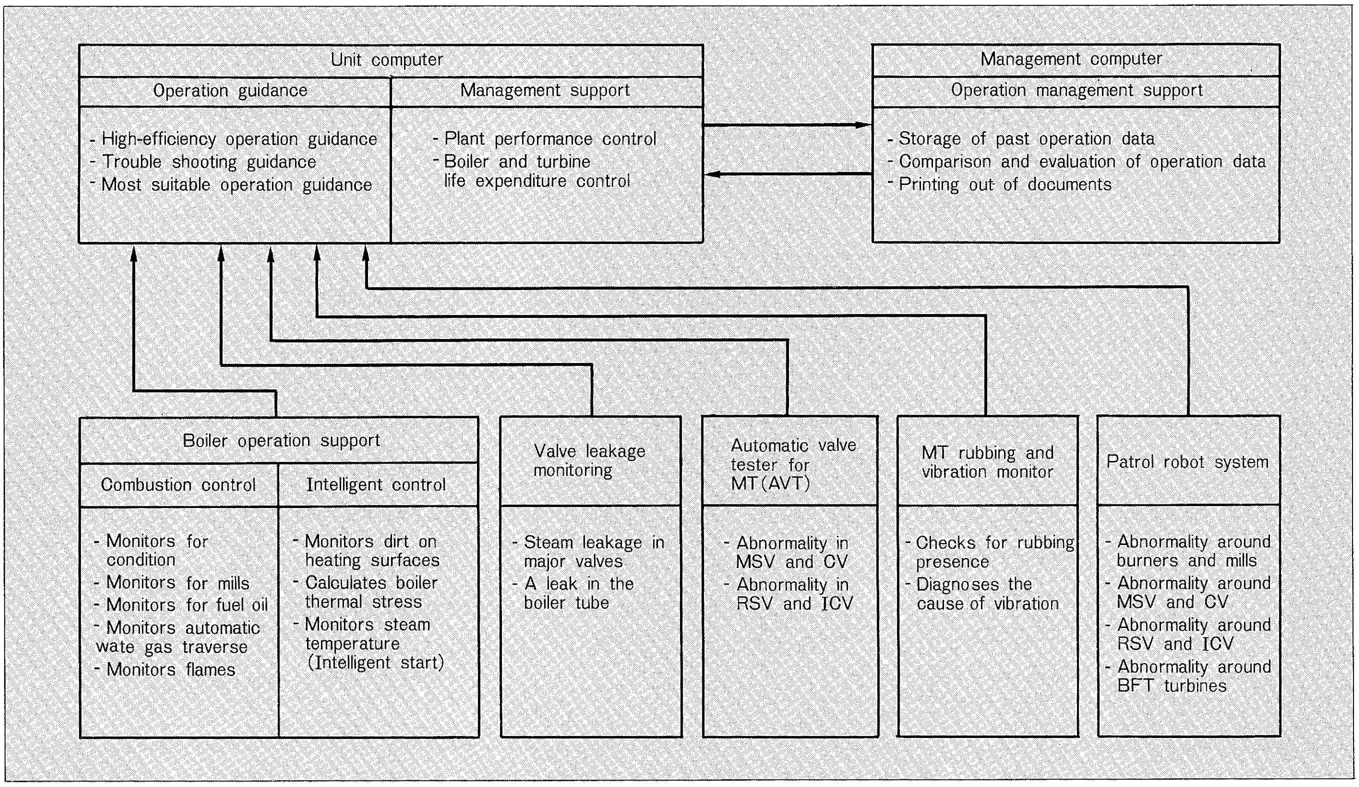
(1) Reliability improved by redundancy.

The main control part is provided with a triplicated system; the other parts, with a duplicated system.

(2) Maintainability improved with ample self-diagnostic functions and a module checker.

(3) Hardware standardization and international inter-

Fig. 8 Operation guidance and facility diagnosis system



changeability security.

(4) Open software systems.

3.3 Central control room

The central control room is a centralized supervision and control room for Units 1 to 3. The room contains all the equipment necessary for centralized supervisory control including a main control desk, an auxiliary supervisory panel, a typewriter, an environmental monitor panel, a centralized fire alarm monitor panel, and a communication table to study or check the operation monitor taking over, daily maintenance, stand-by equipment changeover, etc.

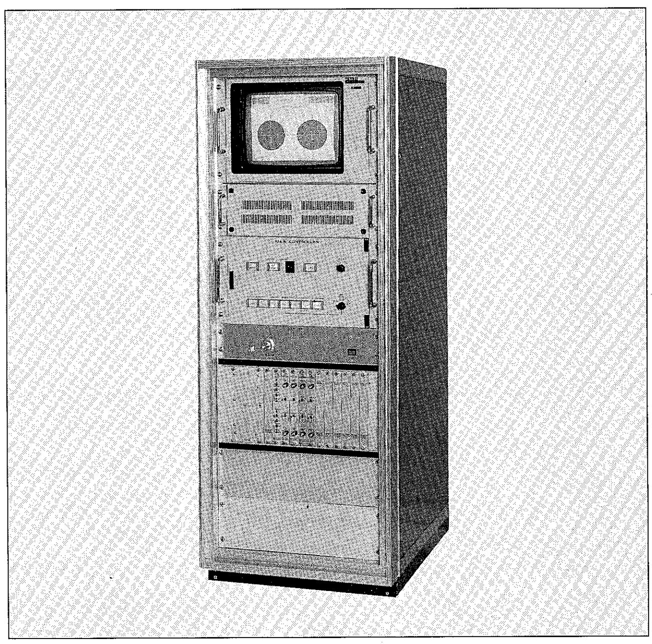
Operation and monitoring in the central control room is basically a one-man operation. Automation placing the Unit computer at the core and the wide use of CRT operation and video display (such as large display and ITV) have enhanced efficiency and minimized labor in monitoring and operation.

Figure 7 shows the external appearance of the main control boards (main control desk and auxiliary supervision panel) in the central control room.

Monitoring and operating instruments necessary for operating the unit are functionally arranged on the main control desk, as are auxiliary monitoring and operating instruments on the auxiliary supervision panel.

The control room is also environmentally superior, with the auxiliary supervision panel flush with the wall, the grained wall, soft lighting with OA louvers and downward light, and the window facing the turbine room.

Fig. 9 External appearance of the vibration monitor



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3.4 Operation guidance and facility diagnosis system

Figure 8 shows an outline of the system.

3.4.1 Operation guidance system

An outline of the system for operation guidance with the Unit computer (high-efficiency operation guidance

Fig. 10 External appearance of the patrol robot

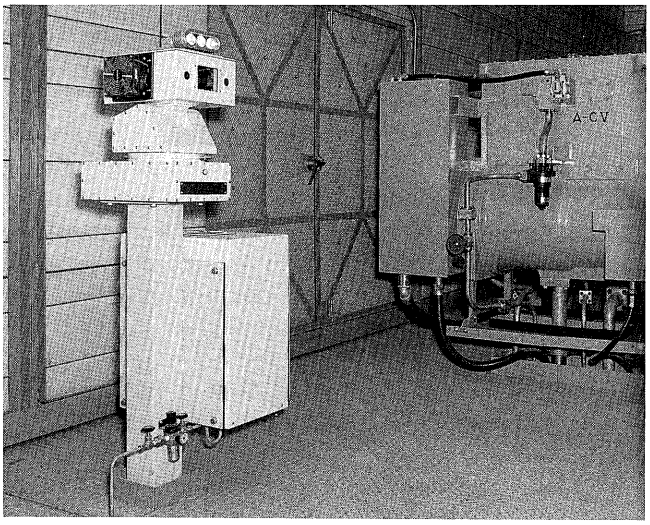


Fig. 11 Result of the turbine performance test
Turbine heat rate (kcal/kWh)

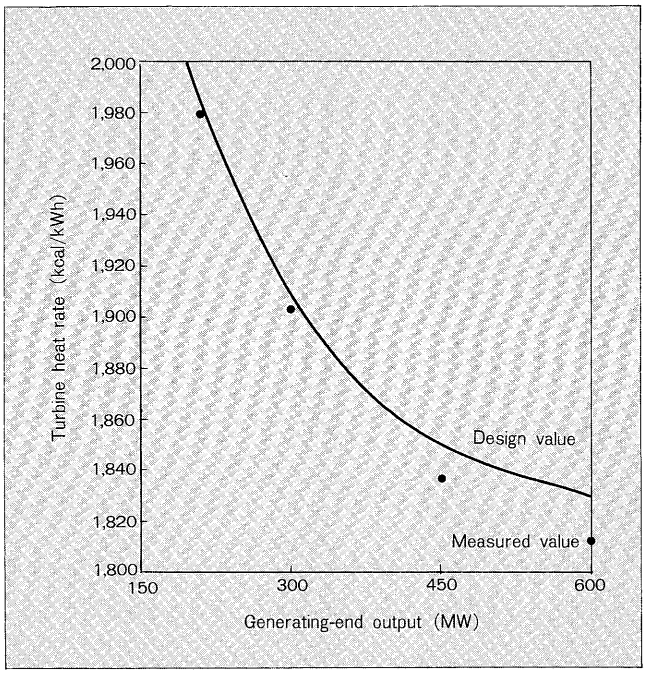
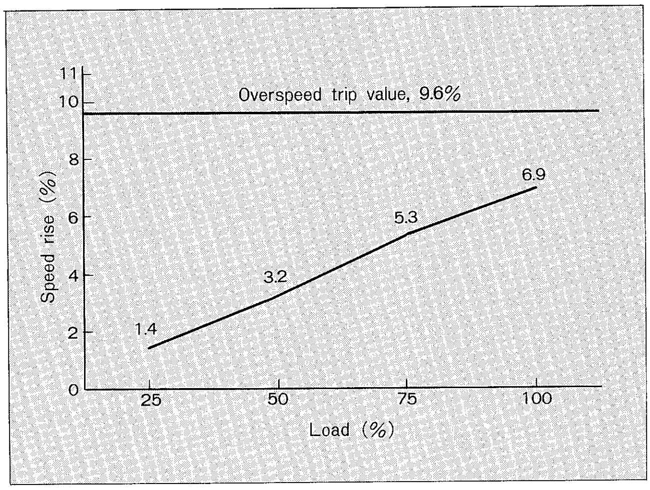


Fig. 12 Speed rise at the sudden load rejection test



through CRT, trouble shooting guidance, and most suitable operation guidance) is as follows:

(1) High-efficiency operation guidance

The system indicates guidance to the operator for operating at the most suitable point (e.g. CWP blade angle control data, start timing of condenser tube cleaning, main steam and reheat steam temperature setting points) and maintenance support guidance to keep each individual equipment's performance high (e.g. factors of efficiency deviation).

(2) Trouble shooting guidance

The system collectively processes information from the facility diagnosis system as well as other information (e.g. self-diagnosis information on the digital type control equipment and transmitters, and process signals). It indicates fault location, contents, and necessary measures to be taken by the operator.

(3) Most suitable operation guidance

The system indicates guidance to the operator for optimum response to load in usual plant operations (e.g. optimum preceding control data for coal feed into individual pulverizers, load changing rates considering plant life consumption).

3.4.2 Facility diagnosis system

The facility diagnosis system of detects any abnormalities relating to plant failure through the use of the Unit computer and/or exclusive use diagnostic equipment. This exclusive use equipment consists of the following:

(1) Main turbine (and generator) vibration monitor

This monitor automatically records shaft vibration data at the time of start-up, shutdown and usual operation, graphically displaying the result on the CRT mounted on the auxiliary supervision panel. In case of detecting an abnormal vibration, the monitor diagnoses the cause of vibration (e.g. out of alignment, unbalanced mass, steam whirl, oil whip) with an AI method and displays it on the CRT.

Figure 9 shows the external appearance of the vibration monitor.

(2) Main turbine rubbing monitor

This monitor detects rubbing signal during turning with the AE sensor and diagnoses the presence of rubbing with a kurtosis processing method.

(3) Local abnormality monitor (Patrol robot)

An outline of the patrol robot is as follows:

(a) 8 units of patrol robots, moving type for the boiler
(b) 6 units of patrol robots, fixed type for the turbine
(c) 1 set of control equipment (with image, sound and diagnosis processing functions)

This monitor diagnoses oil, steam, air and pulverized coal leakages, fire, partial overheat, abnormal rotation, etc.

Figure 10 shows the external appearance of the patrol robot (fixed type).

4. Results of Trial Operation

4.1 Progress of the construction and trial operation

Installation work on the site was started in June 1991, electricity was received in June 1992 followed by the test operation of the auxiliary machines, and turbine speed raising and first paralleling were carried out in December 1992. Trial operation was started thereafter and the rated 600MW was reached on February 6, 1993. Smoothly completing various adjustments during trial operation, the unit passed MITI's final inspection (for the whole work completed) on May 28, 1993 and started commercial operation. Construction schedules, quality, and performance all proceeded according to plan with excellent results.

4.2 Results of the performance test

Figure 11 shows the turbine heat rate in the performance test. The heat rate of 1,812.6kcal/kWh at the rated load was better than the guaranteed heat rate (1,830kcal/kWh) by 0.957% (relative). As shown in the figure, superior results were obtained over the entire load range, confirming the effect of long, last-stage blades of 1,050mm and the use of high-efficiency reaction blades on improved turbine efficiency.

4.3 Results of the sudden load rejection test

Figure 12 shows the result of the speed rise in the sudden load rejection test. It was confirmed that there is a sufficient margin of the overspeed trip value at each load. A speed rise in the sudden load rejection test at the rated load was 6.9%, proving the superiority of the D-EHG.

4.4 Results of the turbine start-up test

Figure 13 shows start-up characteristics after 8-hour shutdown (hot start). With regard to hot start, which is most frequently used in the operation. The start-up time from boiler ignition to full load was 200 minutes, and paralleling to full load was 138 minutes by full automatic operation, proving that the plant had high operational characteristics to meet DSS. The plant also showed superior start-up characteristics in overall operational inspections of shaft vibration, expansion and relative expansion, thermal stress, and controllability.

5. Improvement of Management Work on the Site and OA Application to On-site Work

The careful planning and exact follow-up of on-site work is as essential for plant construction as processes, quality, and cost.

The project team adopted a WBS (work breakdown structure) method for the management of on site work and confidently tackled the application of OA, achieving accurate and rapid progress.

5.1 On-site management with a WBS method

The WBS breaks work down from the final target and defines even the smallest detail in order to clarify the whole project. It is a project managing method in which the progress and schedule of the work is carefully controlled.

Figure 14 shows the actual progress of the installation work and trial operation. Actual progress was compared with planned progress from construction start to operation start, and suitable measures were taken.

Fig. 13 Starting characteristics after 8-hour shutdown (hot start)

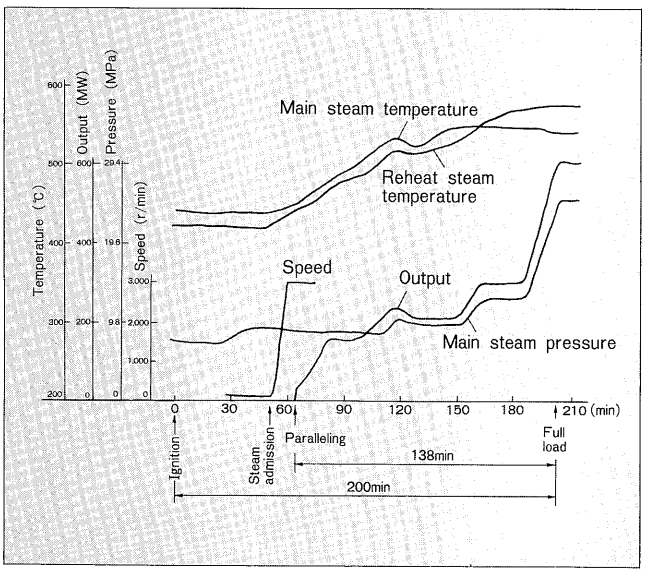


Fig. 14 Progress of the construction and trial operation with WBS method

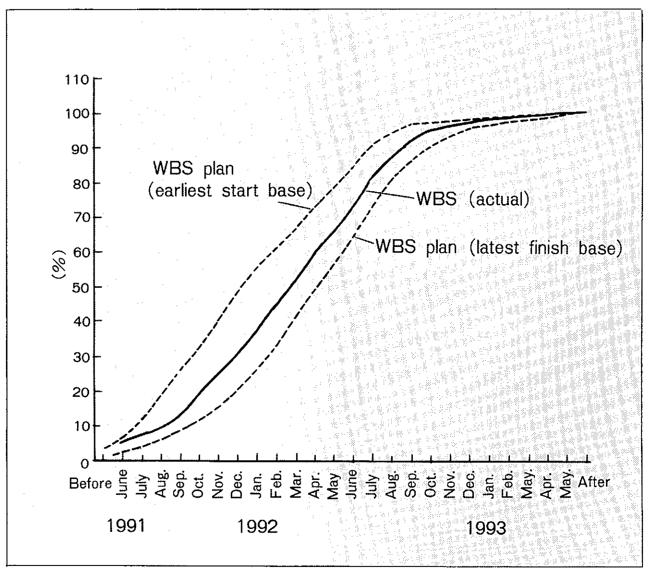
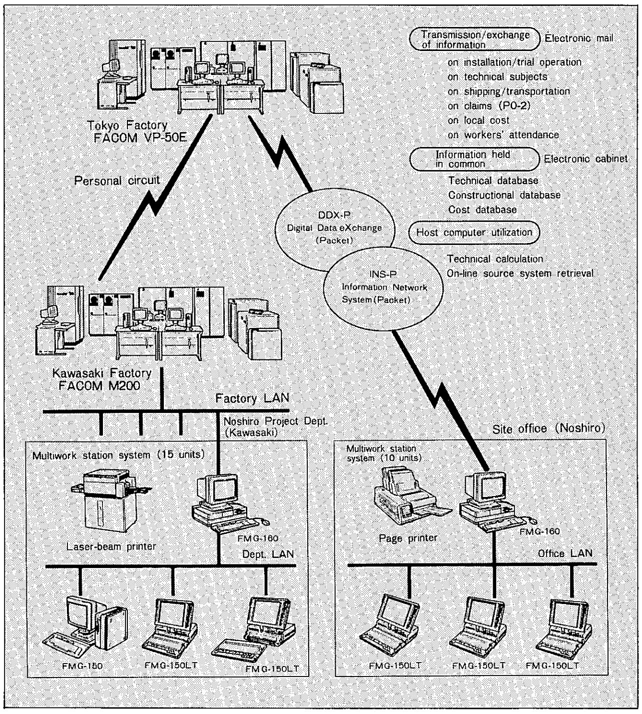


Fig. 15 OA network between the site and Kawasaki



5.2 OA application to on-site work

A multiwork station system with 10 work stations was structured in the construction office on site. A network linked to the Project Department (at Kawasaki) was created using a communication circuit. These system were utilized for transmitting and exchanging information and for holding information in common. OA application to the on-site work was positively promoted as well (**Fig. 15**).

6. Conclusion

Unit 1 of the Noshiro thermal power plant, Fuji Electric's largest thermal unit at present, has started commercial. operation following excellent trial operation. In building this unit, Fuji Electric's many years' experience in manufacturing thermal power systems and the essence of the latest technology was utilized.

The authors thank for the guidance and help of the persons of Tohoku Electric Power Co., Inc. during the design, manufacture, installation, and trial operation of this plant.