New-generation Integrated Monitoring and Control System

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OVERVIEW: Hitachi delivered a new-generation integrated monitoring and control system to Shanghai Municipal Electric Power Company's Waigaoqiao Power Station in Shanghai, China. Built around the HIACS-5000M (Hitachi Integrated Autonomic Control System-5000M), the system not only provides a powerful supervisory, operation, and control system for power plant equipment, it also supports enhanced plant operating efficiency and power plant management operations. Enhanced reliability and maintainability go without saying, but the system also introduces significantly more advanced capabilities for manipulating information that supports improved plant operation efficiency and better management capabilities for dealing with the liberalization of electric power transactions and sales. This power plant is a 900-MW large-capacity coal-fired supercritical plant, and is intended to serve as a model for future thermal power plant construction in China.

INTRODUCTION

SHANGHAI Municipal Electric Power Company's Waigaoqiao Power Station Units 1 and 2 began commercial operation on April 20 and September 22, 2004, respectively. The two 900-MW large-capacity supercritical coal-fired power plants were built with financial assistance from The World Bank Group. Turbines, generators and a boiler for the plant were supplied by German manufacturers, and the I&C (instrumentation and control) system was supplied by

Fig. 1—Inside of Central Monitoring and Control Room Set up for New-generation Integrated Monitoring and Control System.
All monitoring and control equipment and functions for two plant units are centralized in one control room featuring large-screen displays.

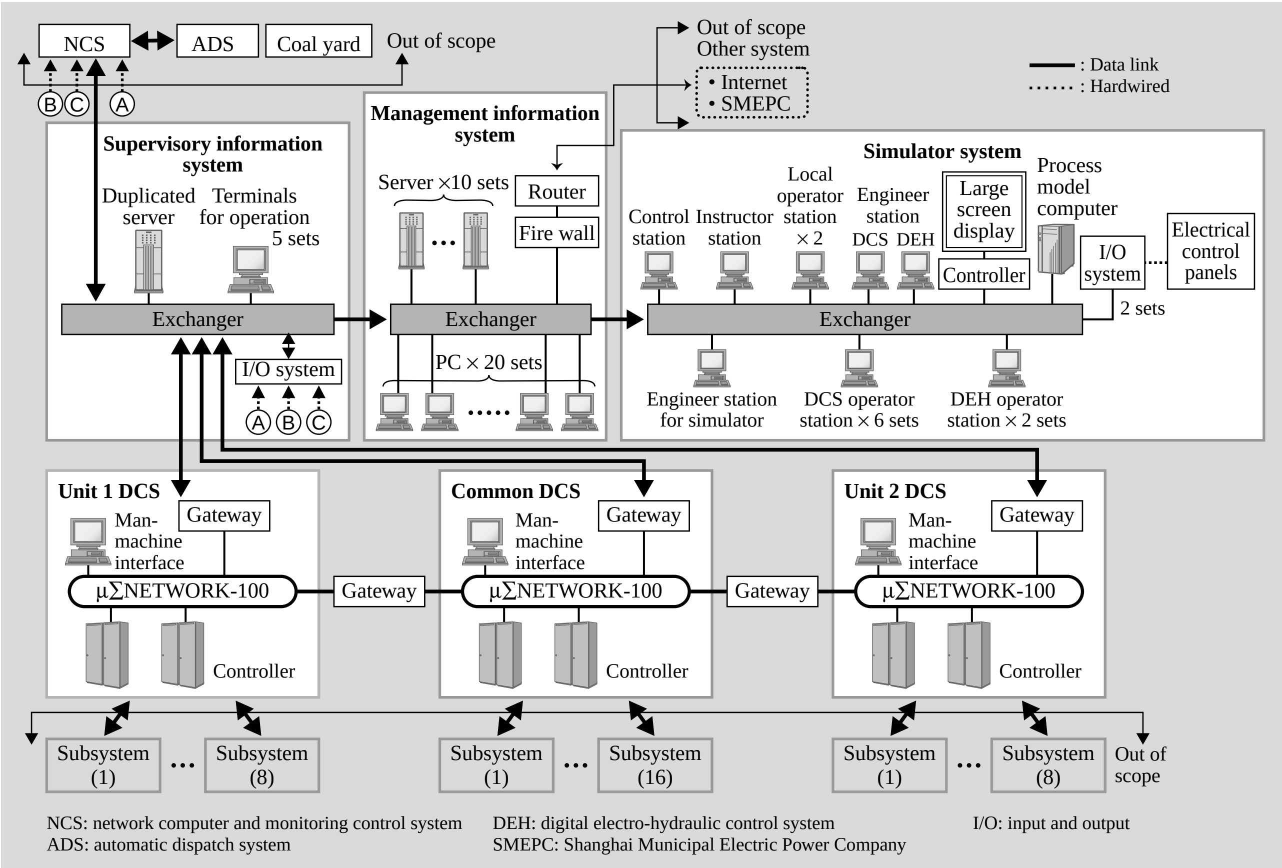

Fig. 2—Overall System Configuration of the New-generation Integrated Monitoring and Control System.
All DCSs, SISs, MISs, and subsystems are organically interconnected by a high-speed, large-capacity network.

Hitachi. In China as elsewhere, greater demands are being placed on I&C systems. In addition to supervisory, operation, and control capabilities, clients are also demanding more advanced capabilities for manipulating information that supports improved operating efficiency, better plant management operations, and other capabilities. Even in terms of control performance specifications, the requirements of the Waigaoqiao project were more exacting than the required performance specifications of Japan.

OVERVIEW OF NEW-GENERATION INTEGRATED MONITORING AND CONTROL SYSTEM FOR WAIGAOQIAO POWER STATION

The integrated monitoring and control system consists of a DCS (distributed control system) that monitors and controls the plant status, a SIS (supervisory information system) that keeps the plant operating at peak efficiency through optimal load distribution of each plant unit, an MIS (management information system) that supports management operations with a full range of office automation functions including management, recording, searching plant data, management of documentation, e-mail, electronic bulletin-board capabilities, and more. The plant simulator system that is linked to plant data via the MIS, and various plant subsystems such as the water treatment system and a coal-handling system.

All of these systems are interconnected by a high-speed large-capacity network enabling centralized monitoring by the DCS, and all constituent functions and systems to organically interwork (see Fig. 2).

FEATURES OF NEW-GENERATION INTEGRATED MONITORING AND CONTROL SYSTEM

DCS

A DCS is the heart of a power plant’s I&C system, and for this, we used Hitachi’s HIACS-5000M, which has proven to be very effective in plant installations in Japan and throughout the world. The proposed HIACS-5000M has the following features:

(1) The CPUs (central processing units) supporting the DCS are thoroughly distributed and are implemented in a double redundant configuration to ensure safe and continuous operation of the plant.
(2) The control network is connected to these CPUs through a high-speed and large-capacity optical network with a transmission rate of 100 Mbps. Because this network provides a loop-back function, possible malfunctions are avoided when cables break, communication equipment breaks down, or when other similar problems occur during transmission. Thus, communication can continue without a significant system disturbance.
(3) An APS (automatic plant startup system) was installed to promote plant automation. Moreover, a rational and excellent operability HMI (human-machine interface) system was offered. All plant operations can mainly be done on the HMI system, which features 70-inch × 6 multi-screens.
(4) The DCS is connected to some 20 subsystems including the water treatment system, the coal handling system, and the fuel oil system over redundant optical fiber lines so that all of the systems can be centrally monitored and operated from the DCS. With this arrangement, both plant units can be operated and monitored by one supervisor and four operators.
(5) An RTB (remote terminal block) is used for the connection between the DCS and the field, so the number of cables and the cost of construction are significantly lower.
(6) We applied a digital protection system with Hitachi’s dedicated module for boiler protection. The dedicated module is triple redundant with each system separate and independent so that the protective functions will not be lost in the event of a single failure or malfunction. Thus, high reliability and maintainability is ensured. The trip causes are input to a trip interlock in each dedicated module, and the output trip signals from each dedicated module are initiated through 2 out of 3 logic trip circuits. Thus, its reliability is also guaranteed.
(7) Hitachi’s experience with super critical pressure plant control has proven useful with control technology. Therefore, the response to the demand for electric power systems has been improved. Runback and FCB (fast cutback) functions are applied to prevent abnormalities from being generated in the plant equipment and the electric power system. These functions were verified to be effective in the commissioning test. The FCB function was first successfully applied in China. It led to an improvement in dealing with abnormalities in the electric power system.

Supervisory Information System, Management Information System, and Simulator

For convenience in carrying out actual operations, domestic Chinese manufacturers supplied these systems.

The SIS carries out processing and managing realtime data from the equipment at the plant’s six existing units, also calculates performance, monitors performance, analyzes the economic factors, and enforces the optimum load distribution of each unit.

The MIS creates an open database using the data collected in real time by the SIS, and also supports enterprise resource capabilities as well as data storage and retrieval functions. Central plant management has access to this information and uses it to support policy—and decision—making for the plant. The system is also capable of generating electric power rate estimates supporting future power transactions and sales, and exchanging information not only within the plant but with the Shanghai Municipal Electric Power Company and government agencies as well.

The simulator is capable of simulating all processes of a 900-MW capacity supercritical plant with a high degree of accuracy. In addition, control system software and new application software when equipment is upgraded or modified can be directly uploaded to the simulator with all changes immediately reflected by the simulator without additional programming. The simulator is capable of simulating any and every process controlled from the central control room on a one-to-one basis, and thus is extremely effective for testing and trying out operator actions, improved incident processing capabilities, and control systems.

CONTROL TECHNOLOGIES THAT SATISFY OTHER COMPANIES’ BOILER CONTROL AND MORE RIGOROUS CONTROL PERFORMANCE STANDARDS

Overview

Let us next take a closer look at Hitachi’s control technologies. The boilers used for the Waigaoqiao project are structurally very different from the boilers manufactured by Hitachi. In addition, the boiler control scheme provided by the client was also very different from Hitachi’s conventional approach. Fig. 3 summarizes the key differences.

At the same time, the control performance specifications stipulated in the purchase agreement

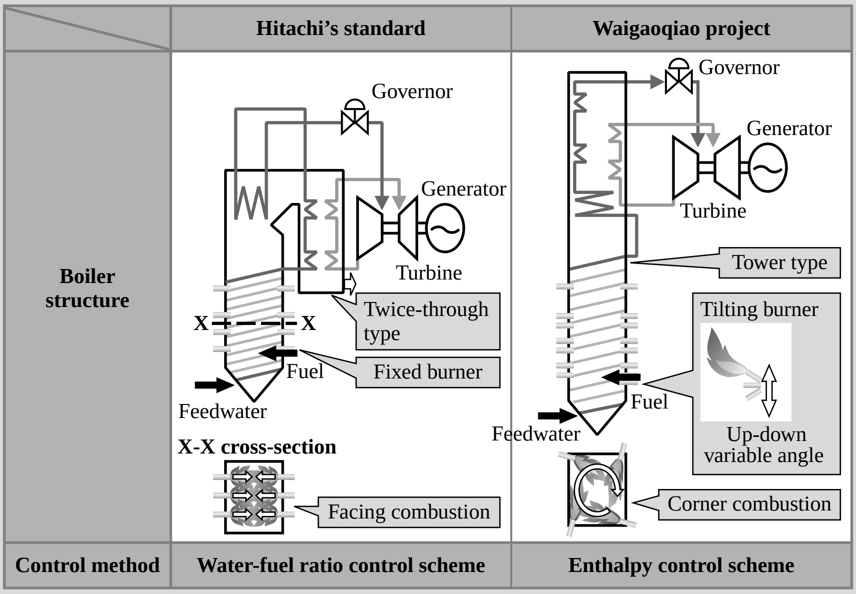

Fig. 3—Comparison of Hitachi and Waigaoqiao Project Boilers.
The boilers are substantially different in structure, combustion method, and control method.

were extremely rigorous. According to the specifications, for example, the permissible value for the main steam pressure control deviation at a 3% per minute load change is ±0.2 MPa, and the permissible range for main steam temperature control deviation is within +8°C and –5°C. By comparison, the usual guaranteed performance specifications at commercial thermal power plants in Japan are ±0.8 MPa for the main steam pressure control deviation, and +8°C and –14°C for the main stream temperature control deviation. Hitachi was able to meet this challenge by leveraging and extending its considerable expertise in plant simulation technology.

Analysis by Simulation

For this project, we started by constructing a boiler model. The basic challenge was to develop a model that could simulate the characteristics of a tilting burner that was used in the boilers of the Waigaoqiao project. A tilting burner is essentially a method of controlling reheater steam temperature by changing the angle of the burner to alter the heat distribution inside the furnace. Hitachi has never used this method, so the simulation model had to be developed from scratch. We succeeded in developing an effective tilting burner-based boiler model by first partitioning a furnace model for different burner alignments so we could simulate changes in the heat-transfer amounts attributable to variations in the burner angle, then calculating the furnace transient gas temperatures of each element of the partitioned model.

Next we investigated the control system using the new boiler model. For this project, the basic control scheme for the boiler was provided by the client. For once-through boilers of the type used in Waigaoqiao project, the steam temperature is determined by the ratio of fuel to feedwater. Hitachi controls this ratio by changing the fuel as an indicator of steam temperature, but the client stipulated an alternative approach of changing the feedwater as an indicator of enthalpy. We considered three schemes for constructing a master control system based on the boiler control method stipulated by the client:

Boiler follow control: generator output is controlled by the turbine, and main steam pressure is controlled by the boiler.

(1) Turbine follow control: main steam pressure is controlled by the turbine, and generator output is controlled by the boiler.

(2) Coordinated control: disadvantages of the boiler follow control and turbine follow control are corrected by adding compensation to both the turbine and boiler control based on the turbine follow control.

(3) First we incorporated the boiler control method stipulated by the client in the simulator, then carried out simulation analysis of different configurations of the master control schemes. Through the analysis we derived evaluation indices determining:

(a) whether the control performance guaranteed value was fulfilled, or

(b) which control scheme had to be adjusted in order to fulfill the guaranteed value.

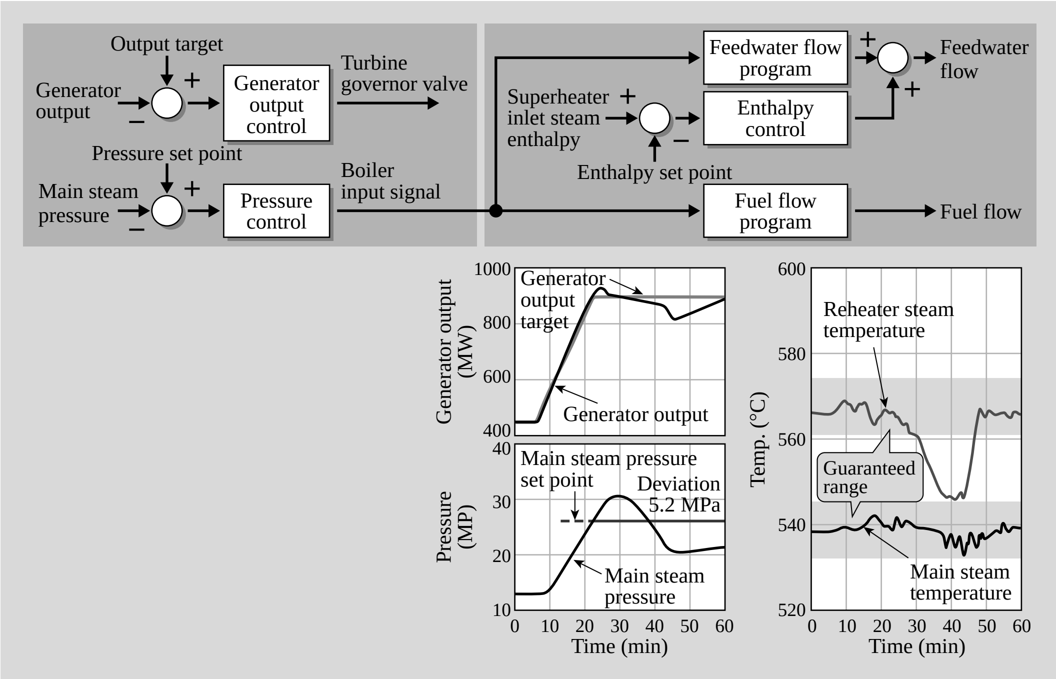

Fig. 4—Boiler Follow Control Scheme.
Generator output is controlled by the turbine and main steam pressure is controlled by the boiler.

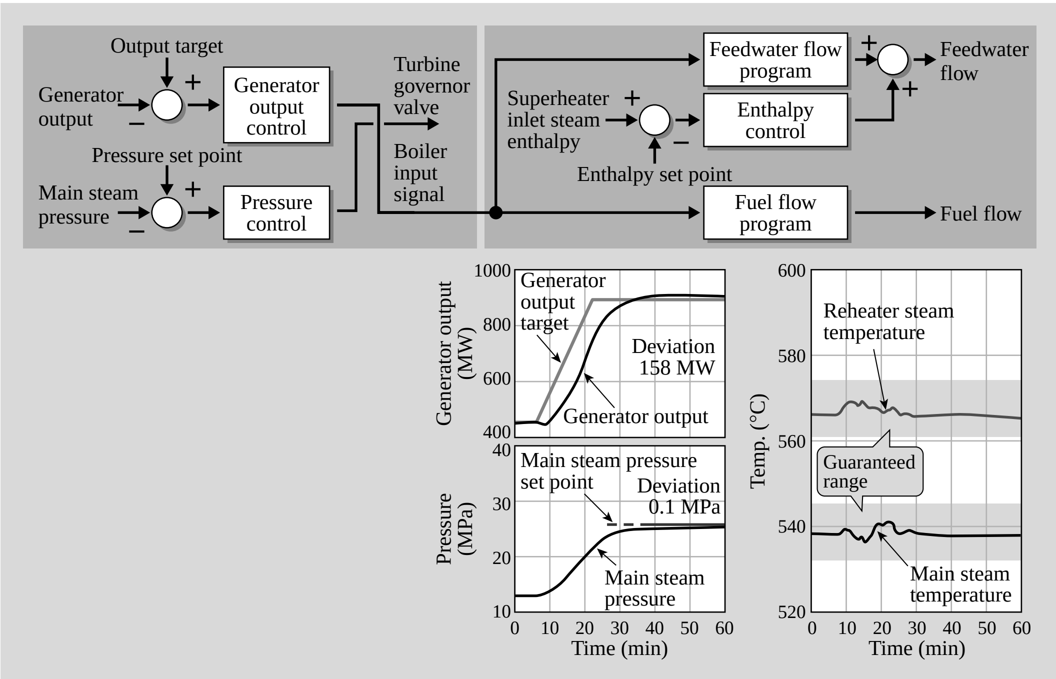

Fig. 5—Turbine Follow Control Scheme.
Generator output is controlled by the boiler and main steam pressure is controlled by the turbine.

We found that with the boiler follow control, the generation output follow performance improved during load changes, but the changes in steam pressure and steam temperature increased (see Fig. 4). Both the turbine follow control and coordinated control showed good prospects that the control performance guaranteed values could be satisfied. At the same time, we should note that one characteristic of the turbine follow control method is that the control on generator output is delayed (see Fig. 5). Note too that, although coordinated control yields better generator output follow performance than the turbine control, the coordinated control is somewhat more difficult to adjust (see Fig. 6). Table 1 compares the differences.

Having obtained simulation analysis results as outlined above and formulated control system adjustment guidelines through trial adjustments of control systems based on the simulation results, we

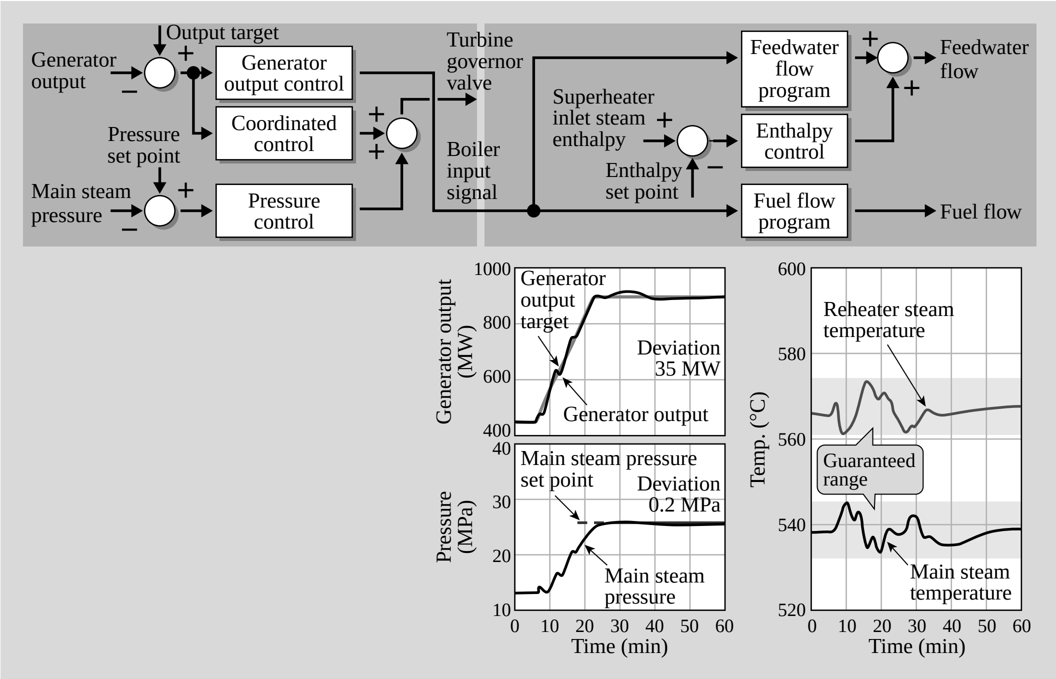

Fig. 6—Coordinated Control Scheme. Disadvantages of "boiler follow control" and "turbine follow control" are corrected by adding compensation to both the turbine and boiler contnrol based on the "turbine follow contnrol."

TABLE 1. Comparison of Master Control Schemes
Turbine follow control or coordinated control is effective for controlling main steam pressure and temperature.

Control scheme		Boiler follow control	Turbine follow control	Coordinated control
Generator output control		Turbine governor	Boiler input	Boiler input/ turbine governor
Main steam pressure control		Boiler input	Turbine governor	Turbine governor
Simulation results		NG	OK	OK
Control deviation	Main steam pressure	5.2/–5.2 MPa	0.0/–0.1 MPa	0.0/–0.2 MPa
	Main steam temperature	3.8/–5.6 °C	3.0/–1.4 °C	6.9/–4.6 °C
	Reheat steam temperature	3.3/–20.1 °C	3.0/–0.7 °C	7.6/–4.7 °C
	Generator output	24.4/–78.2 MW	5.5/–158.3 MW	24.4/–33.5 MW

are now ready to conduct actual trial operation adjustment tests.

Site Commissioning Results

In the actual control equipment for testing, we incorporated control circuitry for all of the control schemes that we considered in the simulation analysis so that we could freely select whatever scheme we wanted to test. The actual trial operations were done using the turbine follow control scheme that was shown

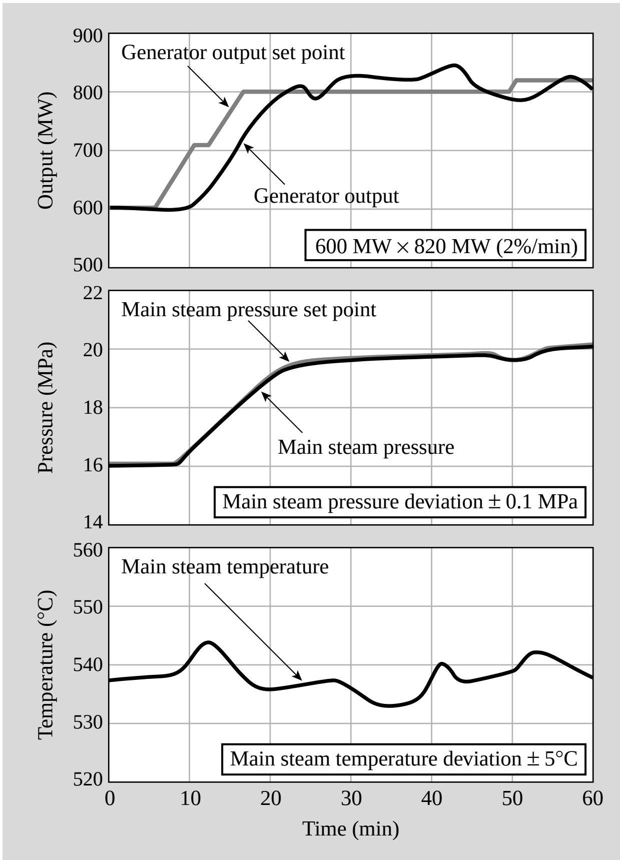

Fig. 7—Example Trial Operation Results.
Main steam pressure and temperature satisfy the control performance specifications as predicted by the simulation analysis.

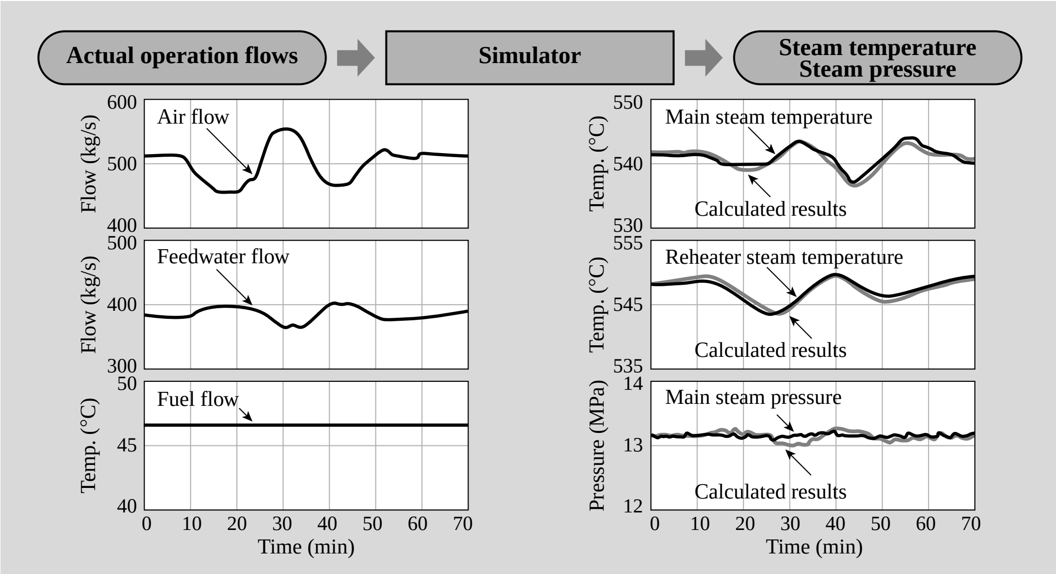

Fig. 8—Simulator Verification Using Site Commissioning.
Actual plant process behavior closely corresponds to the plant behavior predicted by developed simulator.

to be advantageous for controlling the main steam pressure and temperature. Fig. 7 shows an example of the trial operation results. Just as the simulation analysis predicted, the main steam pressure and temperature control performance guarantee specifications were satisfied.

In order to verify the suitability of the simulator, we compared data yielded by the simulator against actual measured data. Fig. 8 shows some of the results. One can see that the simulator developed for this Waigaoqiao project yields acceptably accurate results even with respect to dynamic behavior.

CONCLUSIONS

This article provided an overview of a new-generation integrated monitoring and control system that Hitachi supplied to Shanghai Municipal Electric Power Company's Waigaoqiao Power Station in Shanghai, China.

Present-day China is witnessing remarkable growth and demand for more information-intensive systems and electric power, and we can anticipate increased demand from the mainland for the type of system described here. Hitachi is well positioned to provide such systems based on reliability and experience to meet this demand.

Although we successfully met the challenge of more rigorous control performance specifications through the control technologies described here, we must redouble our efforts if we are to keep ahead of the competition and develop products that satisfy even more exacting control performance specifications in the years ahead.

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