Latest High-reliability Supervisory and Control Systems for Thermal Power Stations

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OVERVIEW: At thermal power stations that have been operating more than 10 years since the start of operations, there are cases in which plans are being made for the renovation of control equipment, from the point of view of preventive maintenance. These renovations do not simply mean replacing functions on existing equipment; in many cases, the goal is to improve upon existing functions through the application of the latest information systems technologies. From an economic standpoint as well, many users are actively promoting the rationalization of cable construction and control equipment through these renovations as a means of minimizing costs. In order to respond to these types of renovation plans, Hitachi developed a supervisory and control system and applied it to renovations in the control systems of a thermal power station. Through the adoption of four main elements — (1) CRT operations; (2) a shift to printed circuit board for relay circuits; (3) remote I/O (input and output); and (4) CAD-based software maintenance tools — this system ensures ease of maintenance, operability, and reliability, without sacrificing economy. Hitachi will apply these results in a broad range of areas, including the latest thermal power stations, while at the same time promoting downsizing and other activities aimed toward the construction of systems with even greater economy and reliability.

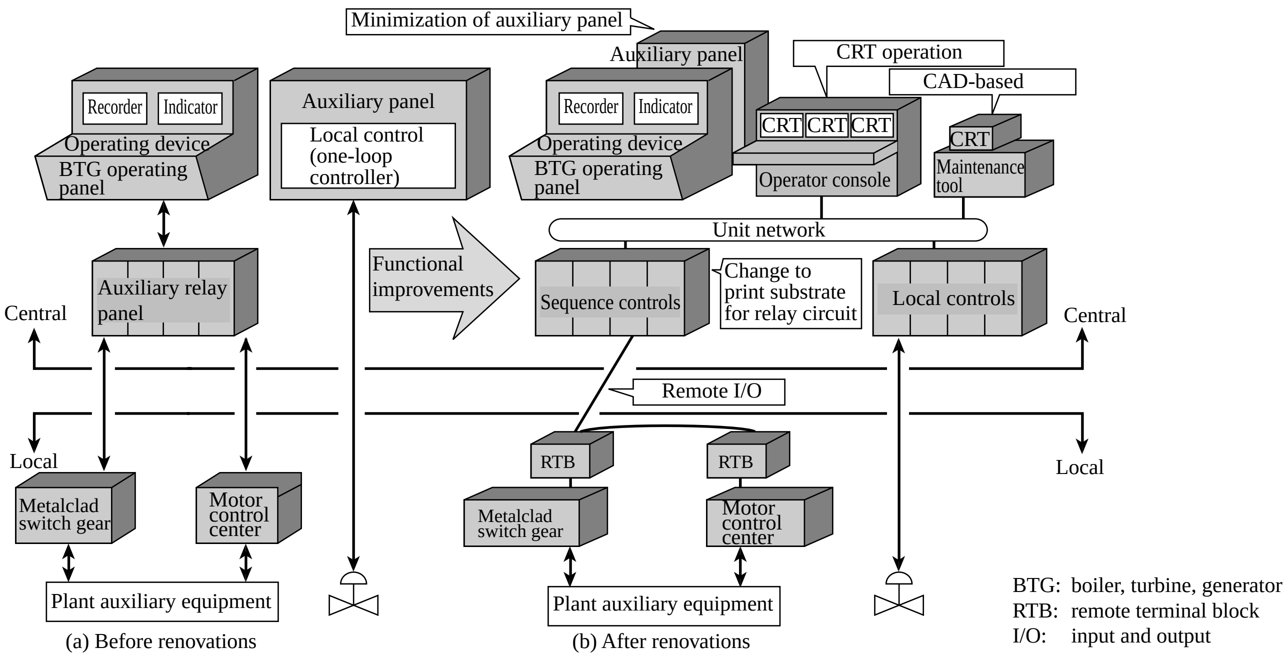

Fig. 1— Renovation of Control Systems at Tokyo Electric Power Co., Inc.'s Oi Thermal Power Station (No. 2 Generator), Applying 'HIACS-7000' — the Latest High-reliability Supervisory and Control System.
The renovation of supervisory and control equipment achieved such results as CRT operations, a shift to printed circuit board for relay circuits and remote I/O, successfully establishing ease of maintenance, operability, and reliability without sacrificing economy. This was accomplished through the adoption of the HIACS-7000, a highly reliable next-generation supervisory and control system.

INTRODUCTION

IN order to ensure a stable supply of electric power, there are cases in which plans are made for renovations of control equipment — once the facilities have been in operation for over ten years — from the standpoint of preventive maintenance. These renovations do not simply mean replacing functions on existing equipment; in many cases, plans are made to lessen the burden on operators through an expansion in the range of automation and a shift to more concentrated supervision. An additional issue is the reduction in the cost of equipment and installation work, aimed at bringing out the maximum effect with a minimum of capital investments.

In this backdrop, Hitachi, Ltd. is pursuing maximum economy while maintaining the high level of reliability that it has been cultivated over the years. At the same time, it has developed the ‘HIACS-7000’ (Hitachi Integrated Autonomic Control System 7000) — a supervisory and control system that can lessen the burden on operators and maintenance staff. The HIACS-7000 has already been put to use as a renovated system at a thermal power station.

Here, we will give an outline of applications at three Tokyo Electric Power Co. locations — the Oi Thermal Power Station (Unit No. 2), the Anegasaki Thermal Power Station (Unit No. 4), and the Futtsu Thermal Power Station (Group No. 2) — where the HIACS-7000 was applied as equipment for renovation of facilities.

RENOVATION OF SUPERVISORY AND CONTROL SYSTEMS AT THERMAL POWER PLANTS

Twenty-seven years have passed since the No. 2 generator at Tokyo Electric Power Co., Inc.’s Oi power station began operations, and plans are being made to renovate these facilities in order to increase the ease of supervisory operations. Specifically, plans call for a response to seemingly opposing requests for greater concentration of supervision and increased area of supervision through an expansion in the range of operation. This was accomplished through a change to a new system that allowed an expansion in the range of automation as well as more concentrated supervision by introducing sequence control functions and adopting CRT operation.

Fig. 2 shows the basic policies and countermeasures involved in the system renovation.

Shift to printed circuit boards for relay circuits

Up to now, interlocks that protect auxiliary equipment and other facilities have been comprised of relay circuits that allow interlock and protection functions to be secured even in the event of a controller trouble. For the HIACS-7000, Hitachi developed an intelligent PI/O (process input and output) intended to minimize the number of inspections and allow direct viewing of the circuit operation status. A CPU and ROM have been incorporated into the intelligent PI/O, while an interlock circuit and a protection circuit have been installed in the ROM, allowing independent functions even if the controller breaks down. The intelligent PI/O allows real-time supervision of the operation status using maintenance tools, and, in addition, allows reconstruction of interlock circuits by simply loading information from the maintenance tool.

We have adopted this intelligent PI/O to implement a shift to printed circuit boards for the existing relay board, in order to make the control equipment more compact. At the same time, we have achieved improved reliability and a rationalization of the

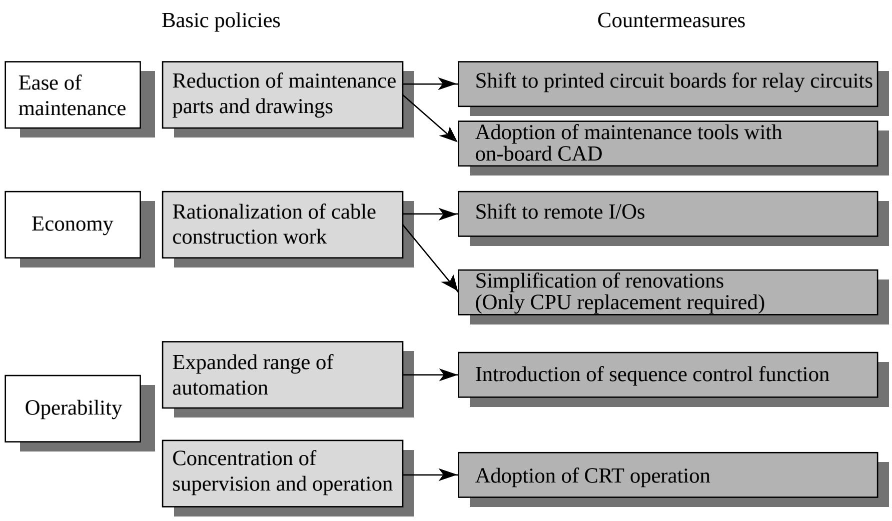

Fig. 2— Basic Policies and Countermeasures for Control System Renovations.
Countermeasures were decided in keeping with basic policies, from the standpoint of ease of maintenance, economy, and operability.

maintenance inspections.

In the past, when equipment renovations were carried out, it was necessary to take into account the time required for periodic inspection work, because of the major reconstruction that was required for the existing relay boards. This was true of the current application example. By applying the intelligent PI/O, however, the relay circuits used in the past will be changed to printed circuit boards, so that the reconstruction of the relay boards at the site will be reduced to minimum, and renovations will become possible within a short period of time.

Adoption of CAD-based Software Maintenance Tool

By incorporating CAD into the maintenance tools of the HIACS-7000, Hitachi has made it possible to unify the management of production drawings and software. In addition to on-line monitoring of CAD drawings, it is possible to display engineering values in real-time for the operation status within the intelligent PI/O. Then, by gathering trouble data for each controller from the maintenance tools via a network, the maintenance staff can quickly identify the location of the trouble, and implement correction measures in a short period of time.

Hitachi has also introduced a layered design method for the control circuits. In the layered design method, a group of functions are recorded as a single large macro, a combination of which forms the control circuit. This control circuit becomes a kind of ‘black box’ when functions are not required, and only when functions are required does a window open in the maintenance tool to allow viewing of the contents. This ties into a shift to software parts and standardization, which in turn helps to prevent human error. At the same time, it contributes substantially to the ease of understanding of drawings, and to a reduction in time required for inspection of non-conformity areas when trouble arises.

Aside from the merits described above, this system allows automatic management within the maintenance tool of such functions as address management, order of calculation management, and transmission management, which are absolutely necessary in digital control equipment. This automatic management within the maintenance tool results in increased software reliability and a substantial reduction in the number of software management drawings.

Shift to Remote I/O

We planned a switch to remote I/O between the control equipment and the local devices, in order to rationalize cable construction work and reduce the time required for this work. For the HIACS-7000, we developed an RTB that allows connections using intelligent PI/O and high-speed multiplexed field LANs. With this RTB, a repertory of functions has been created to respond to each of the various types of signals from the field (transmitter, thermocouple, resistance thermometer, etc.), and allow connections even with all of these types of signals coexisting. Furthermore, by adjusting the transmission speed, the user is able to select the appropriate intelligent PI/O based on the transmission distance.

By applying intelligent PI/O and RTB, we have succeeded in achieving the following (Fig. 3):
(1) Effective use of space in the control equipment room and rationalization of cable construction work through the installation of the RTB board local

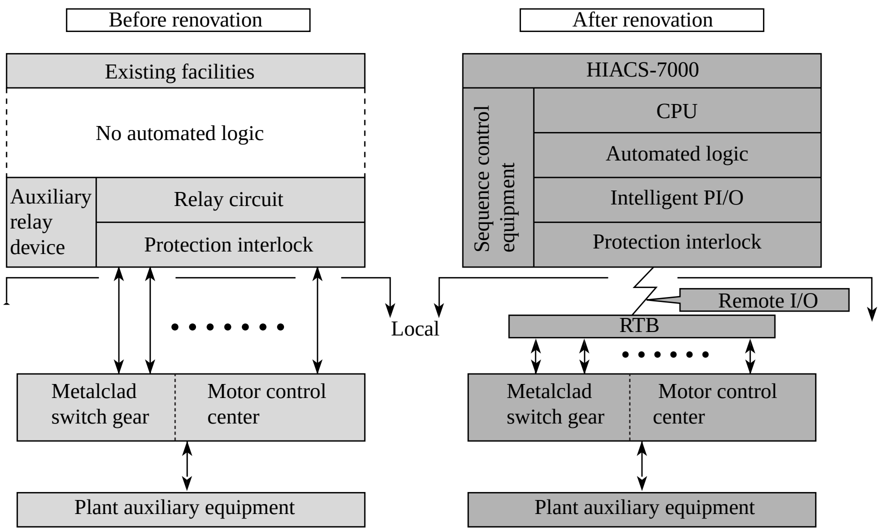

Fig. 3— Renovation Adopting Intelligent PI/O and RTB.

TABLE 1. Automation of Auxiliary Equipment and the Range of CRT Operation
Along with the renovation of equipment, we worked for automation and a shift to CRT operation in order to improve operability.

Item	Before renovations	After renovations
Sequence master	No master automation	7 masters
Boiler auxiliary	Manual operation	87 units (87 units with CRT operation)
Turbine auxiliary	Manual operation	88 units (86 units with CRT operation)

(2) Separation of low voltage electrical circuits from noise sources, through the separation of the controller and intelligent PI/O from the RTB board casing
(3) Simplification of renovations by allowing additional RTB connections to field LANs
(4) Preparatory start-up of cable construction work and reduction in time required for new construction work by allowing prior installation of the RTB board alone

The application range of this remote I/O corresponds mainly to the range between the control equipment and the switching/distribution equipment (metalclad switch gear and motor control center). The switching/distribution equipment has its device installations centralized at the site, and also has a large volume of cables. As a result, roughly 600 cables are connected to the RTB at the site, and with the adoption of the remote I/O, all control equipment that is downstream from the RTB can be handled by as few as 50 communication cables. In this way, we have achieved a reduction in the volume of cables, and a substantial rationalization of construction work.

Expanding the Range of Automation and Concentrating Supervision

Hitachi introduced sequence control equipment as a means of automating the start-up and stopping of auxiliary equipment, which in the past was a manual operation, in order to reduce the burden on operators. Also, local control in the vicinity of the boiler turbine had been controlled via a one-loop controller, but this has been updated with digital local control equipment, in order to allow centralized supervisory control in a central control device room as well as maintenance from the maintenance tools. At the same time, in reference to the operation supervision device — which is considered additional facilities — Hitachi has endeavored to minimize the size of the auxiliary panel through a shift to CRT operation (Table 1).

Hitachi has adopted a small ‘HF-W Series’ server for the CRT operation. This server offers superior operability and real-time operating functions. In addition to standard functions available in the past — including historical trend displays and manipulator calling from screens for manipulator and screens for drawing of control system— it also allows rapid response to logic stucks through sequence logic stuck supervisory functions, which were added to improve the concentration of supervision.

Simplification of Control Equipment Renovations

The HIACS-7000 also supports the process input and output equipment of previous systems (HIACS-3000 and 5000), and, with a replacement of the CPU, ensures equivalent ease of maintenance and control supervision operations (see. Fig. 4). In this way, it becomes possible to continue use of existing process input and output equipment, and by keeping down the

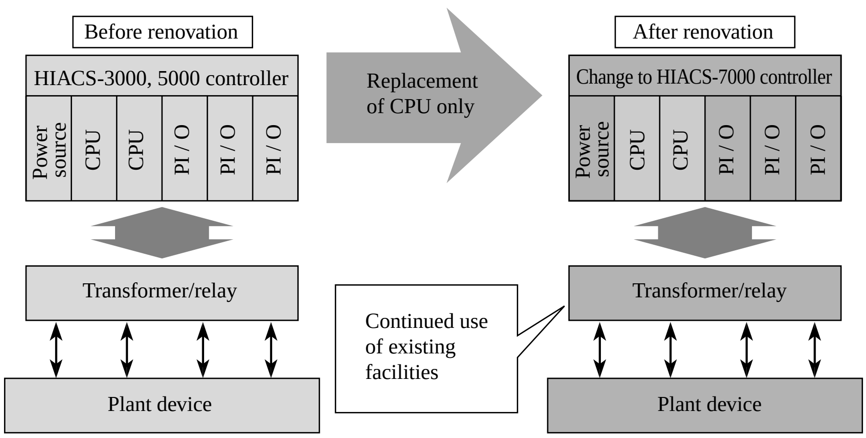

Fig. 4— Renovation Through Replacement of CPU only.
Hitachi made it possible to establish connections with the HIACS-7000 system after renovations by replacing only the CPU of the original system.

costs of equipment renovations and cable construction work, we have made it easier to carry out equipment renovations.

At the Tokyo Electric Power Co., Inc.'s Anegasaki Thermal Power Station (Unit No. 4), there were plans for facility renovations similar to those at the Oi Thermal Power Station (Unit No. 2). These renovations involved a switch to the HIACS-7000 system. In the process of these renovations, some of the equipment had already been replaced with the HIACS-3000 (the system currently running). In the case of this equipment, only the CPU was replaced; it was then connected to the equipment upgraded with the HIACS-7000 via a unit network. In this way, Hitachi made it possible to carry out maintenance of both equipment using the same CAD-based software maintenance tool.

RENOVATION OF SUPERVISORY AND CONTROL SYSTEMS FOR LARGE COMBINED CYCLE POWER PLANT

The advancement of supervisory and control systems for thermal power plants is progressing rapidly, supported by the development of electronics and transmission systems as well as multimedia technologies. The results of improvements such as rationalization and reduced power for operation, as well as increased reliability and ease of maintenance, are useful not only for newly constructed plants but also for renovations in supervisory and control systems for existing plants as well.

On this occasion, Hitachi carried out renovations of the supervisory and control systems at Tokyo Electric Power Co., Inc.'s Futtsu Thermal Power Station group No. 2 (7-stages configuration with 1,000 MW, LNG), taking advantage of the adoption of DLNC (Dry Low NO_x Combustor) there. Following is a description of the particularly notable technologies that were achieved as part of efforts to reduce both construction time and equipment space.

Customer Needs and Countermeasures

Following are the main points that were taken into consideration in the course of the recent renovation operations:

(1) Control equipment, which before renovations was a combination of analog and digital systems, was made entirely digital, such that maintenance can be carried out via a network from a central operation room, using a concentrated maintenance tool.

(2) Software configuration of protection and warning systems that had been made up of hardware, bringing about improved compactness and ease of maintenance.

(3) Protection has been made triple-redundant, resulting in even greater system reliability.

(4) Existing cables were put to use and remote I/Os were adopted over a broad range to reduce the need to lay new cables.

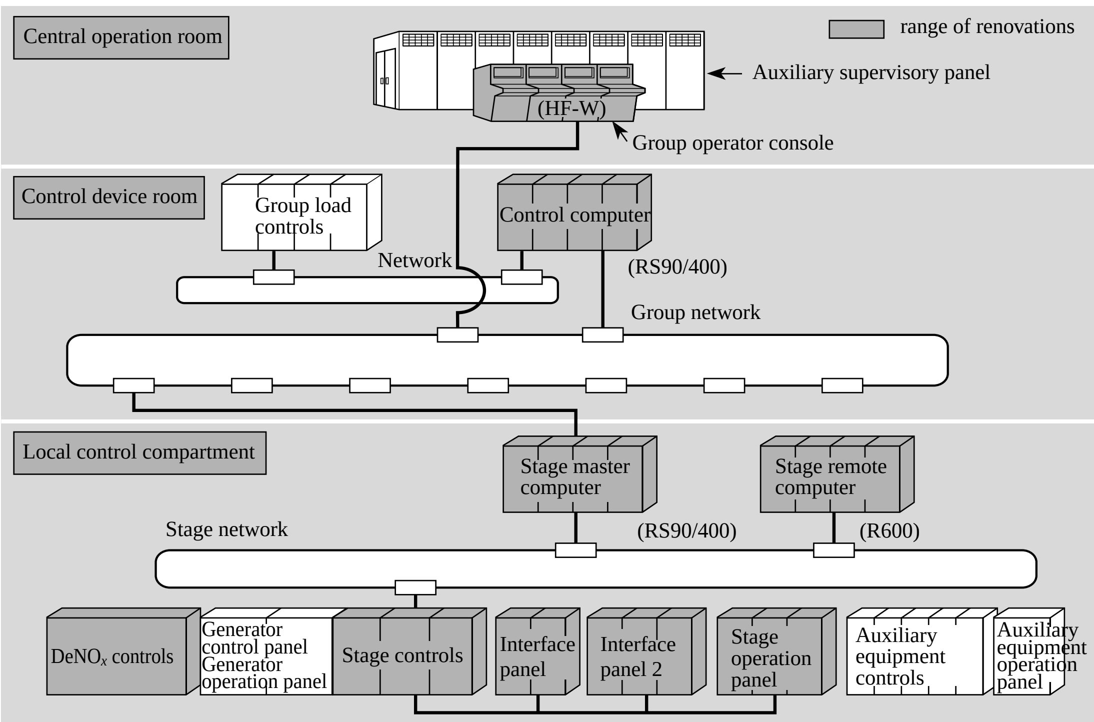

Fig. 5— Overall Configuration of Supervisory and Control Systems and Range of Renovations.
By adopting the HIACS-7000, Hitachi has ensured reliability and at the same time achieved the construction of an economical system and improved plant operability.

(5) A flat display was installed in the LCC (Local Control Compartment) in consideration of requirements for trial operation and repair work.

System Configuration

Fig. 5 illustrates the overall configuration of the supervisory and control systems and the range of renovations. The HIACS-7000 is at the core, and the rest of the system comprises the following elements: unit group control computer and stage master computer (RS90/400); human interface (HF-W); and unit group/ stage network ($\mu\Sigma$ Network-100).

By adopting the HIACS-7000, we have realized reliability that has been cultivated through years of experience, and at the same time achieved the construction of an economical system and improved plant operability.

Stage Control Panel

It was necessary to complete the equipment replacement and cable installation, as well as implement a test run, all within the specified inspection period for the stages (117 days). Hitachi was thus requested to eliminate the need for building reconstruction, and to use existing cables to the greatest extent possible. To accomplish this, we integrated the control and protection functions for the gas turbine, the steam turbine, and the heat recovery boiler, centralizing these into a unified stage control panel. At the same time, Hitachi used an RTB for input/ output, and installed this in the location of the existing panel.

The unified control panel comprises a large scale, high-speed controller and intelligent PI/O. The gas turbine and steam turbine controls and protection are triple-redundancy systems, and the HRSG (Heat Recovery Steam Generator) control is a dual-redundant system. A layered configuration has been adopted, such that a controller is used in the case of fuel flow instructions for the gas turbines and other functions for which comparatively slow calculation cycles are acceptable, while an intelligent PI/O is used in cases where high-speed calculations are required — for example, when controlling the degree of valve opening. The output from this intelligent PI/O is connected to an interface card that drives an electric hydraulic transformer; it is at this point that the median of output signals is selected.

The various triple-redundancy system controllers carry out calculations asynchronously, but over years of operation, changes and drift can result in slight changes to the calculation results. Because there are concerns that these changes may affect control stability, Hitachi has incorporated a forced tie-back function into the system.

Fig. 6 shows the external view and configuration of the stage controls.

In the configuration adopted, the gas turbine and steam turbine controls and protection are triple-redundancy systems, and the HRSG control is a double-redundant system. The calculation of the instruction values is carried out by the controller, while the closed loop control is carried out by the intelligent PI/O. The median for the instructions to the valve are selected at the IFTB (interface terminal board).

Configuration of the Protection System

It would be difficult to configure 43 trip items in a

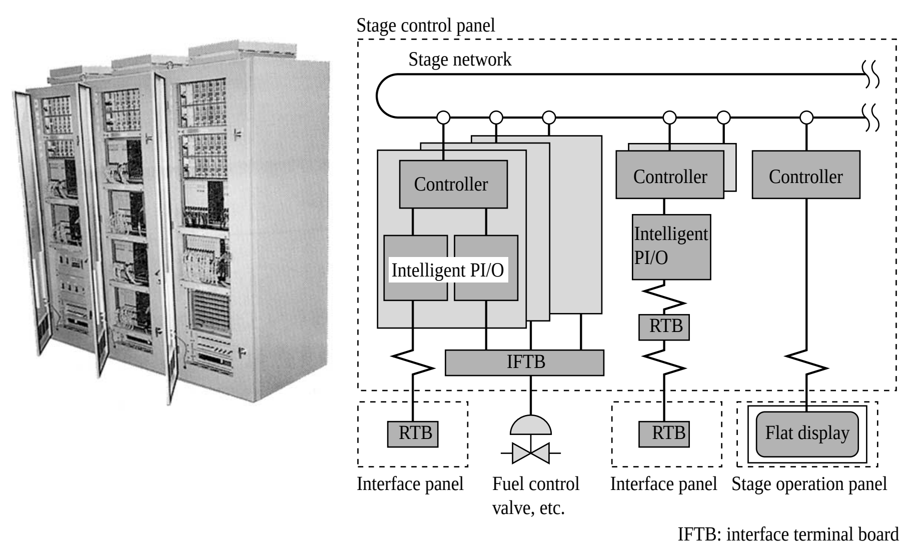

Fig. 6— External View and Configuration of Stage Control Panel.

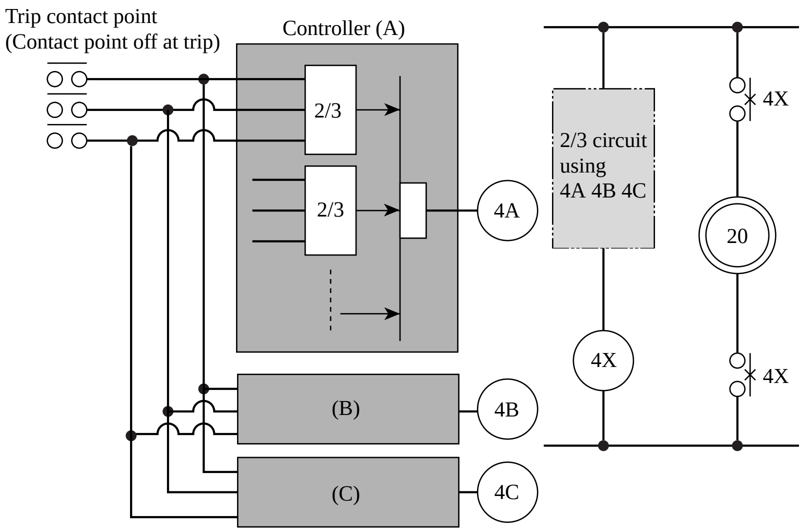

Fig. 7— Configuration of Protection System.
A continuous excitation method is employed, and the solenoid cutoff valve is in a continuously excited state. When a trip or a power loss occurs, the solenoid cutoff valve becomes non-excited, and the trip oil is cut off.

limited space using a hard-wired format, so we aimed for a complete software configuration, using the triple-redundancy controller of the unified control panel as the protection control as well. Hitachi decided to use a method in which a 1-point DO (digital output) is sent out after the trip items are concentrated; the stage trip is then carried out based on this signal. In addition, the double-redundancy controller detects malfunctions and ‘inoperable’ errors in each trip item. If two of the three redundancy systems cease to operate, it is considered a loss of protection function in the main unit, and the stage is tripped.

Using this configuration, Hitachi was able to put in place a protection system without having to install a specialized panel.

Fig. 7 illustrates this configuration.

Warning System

In order to efficiently process the increased number of warning items for DLNC in a limited amount of space, as in the case of the protection system, we took the following points into consideration:

(1) The system was made entirely digital. The double redundancy controller for stage controls was also used for the concentration of each of the warning logic and warning windows, along with the repeatable warning function.

(2) Warning windows and individual warning factors are displayed on the flat display adopted for the stage operation panel, thus reducing the number of warning windows.

(3) All warning information sent to the group control computer and the flat display is sent via a network.

Fig. 8— Example of Warning Display on Flat Display.
Aside from facilitating various types of displays, including operating data, warning windows, and individual warning factors, this display also has unconditional sequence master functions.

Using this type of configuration, we have eliminated the need for a specialized warning system panel. Fig. 8 shows a typical display example on the flat display.

Operation of the first stage began on December 15, 1998, and operation has been continuing without problem since that time. Up to now, three of the seven stages are operating for commercial use, and one stage is currently undergoing test operations. Test operations of all seven stages are expected to be completed by November 2000.

CONCLUSIONS

Here, we described an example of equipment renovation using the 'HIACS-7000' thermal power plant supervisory and control system, which maintains high reliability while pursuing economy, and at the same time lessens the burden on operators and maintenance staff.

Demands for economy and environmental protection with regard to power plants are expected to further intensify in the future. In order to respond to these demands, supervisory and control systems must have flexible system constructions that respond to a wide range of needs. We will continue making our efforts to create optimum supervisory and control systems that insure safe and efficient plant operation.

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