Advanced Supervisory and Control Systems for Nuclear Power Plants

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OVERVIEW: The supervisory and control system in a nuclear power plant is the "brain" that manages all monitoring and operation tasks. While placing top priority on reliability, such a system must ease the load on operators and improve maintainability. Recent supervisory and control systems, moreover, are totally digital, and are consequently expected to provide even more advanced maintenance functions and greater cost efficiency. Hitachi, Ltd. has adopted advanced digital and electronic technologies to improve operability and supervisory capabilities in nuclear power plants while maintaining sufficient reliability. In particular, Hitachi has recently completed a total-digital system through the development of the "NUCAMM-90" centralized supervisory and control system for advanced boiling water reactors (ABWR), and results from actual operation are already being obtained. At the same time, advances in general-purpose technologies like personal computers, networking, and information technology (IT) have been remarkable, and the possibility of applying such technologies to supervision and operation from the viewpoints of improving performance and reliability has arisen. Against this background, Hitachi has been using these technologies in the development of human-friendly supervisory and control systems and related products. The company is also moving forward on the development of next-generation elemental technologies using signal-processing technologies, multimedia, and other cutting-edge technologies. Testing and evaluation of these technologies are being completed using prototype and results are being applied to actual equipment.

INTRODUCTION

THE first requirement of a supervisory and control system in a nuclear power plant is reliability of operation. With this in mind, Hitachi has applied digital technologies and advanced human-interface technologies to the development of a new centralized supervisory and control system that raises both reliability and operability. This system, called "NUCAMM-90" (Nuclear Power Plant Control Complex with Advanced Man-Machine Interface 90), is already in operation and favorable results are being obtained. Also, in conjunction with deregulation of the electric-power industry, Hitachi is developing technologies to achieve further reductions in construction and operating costs and support technologies to make maintenance tasks during operation and periodic inspections more efficient and to raise the plant capacity factor.

In this paper, we describe Hitachi's latest supervisory and control systems for nuclear power plants.

EVOLUTION OF SUPERVISORY AND CONTROL TECHNOLOGIES

The evolution of supervisory and control technologies is shown in Fig. 1.

With the aim of improving operability, supervisory capabilities, and reliability, Hitachi has been making a step-by-step transition from analog control equipment to digital control equipment. It has also been increasing information capacity and easing the load on operators through system advancements like expanded use of networks and automation of plant operations.

For ABWR, Hitachi has expanded the use of digital technology throughout the plant including the reactor protection system and neutron monitoring system, and has completed the "NUCAMM-90" total-digital system.

Using the know-how gained with ABWR as well

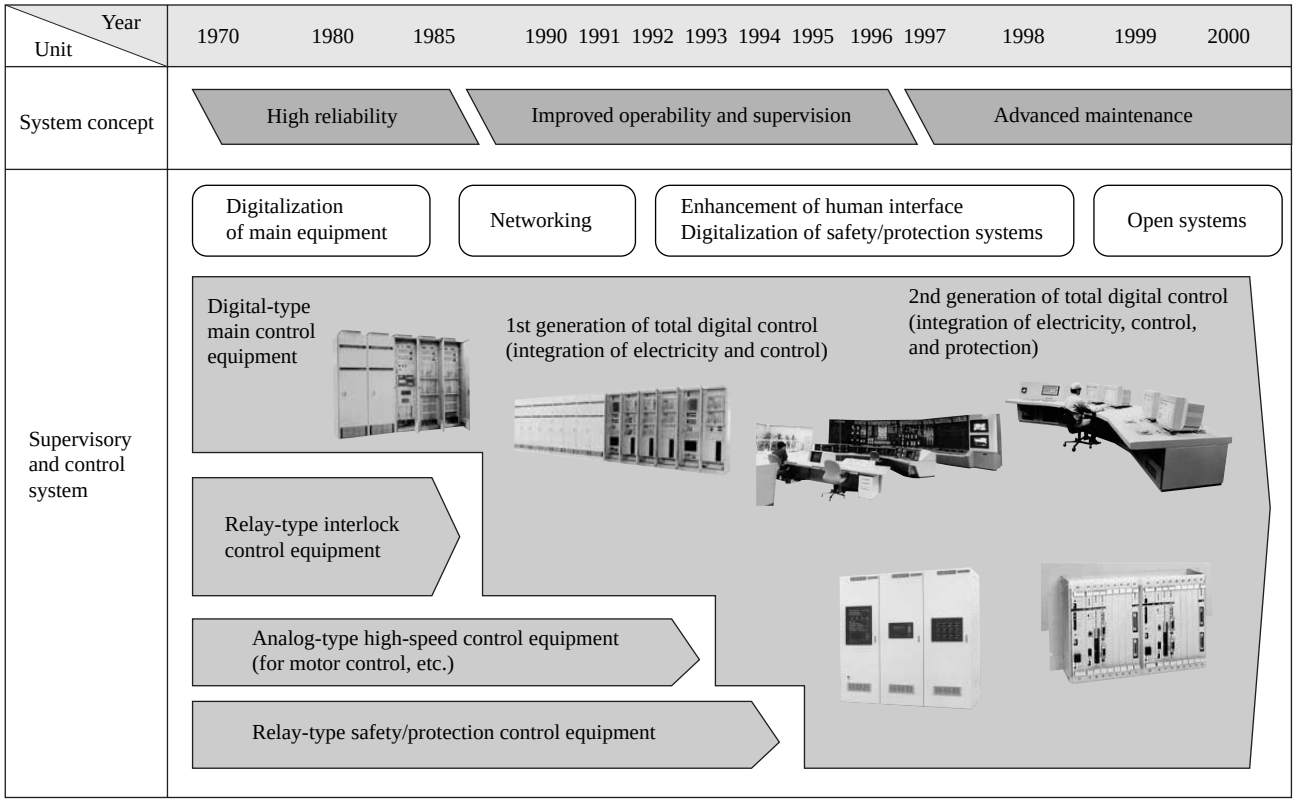

Fig. 1— Evolution of Supervisory and Control Technologies.
A total-digital system has evolved by expanding the use of digital control equipment in a step-by-step manner.

as new electronics and general-purpose technologies, Hitachi is developing supervisory and control systems excelling in operability and maintainability and applying them to new products. It is also planning to develop a rationalized and enhanced version of "NUCAMM-90" as a standard product.

LATEST SUPERVISORY AND CONTROL SYSTEMS

The expanded use of general-purpose technologies based on high-speed CPUs and large-capacity memories and the application of open networks has made it possible to achieve high-performance systems in compact configurations. In parallel with these advances, demands have been placed on recent supervisory and control systems to (1) ease the maintenance load and (2) improve supervisory capabilities and operability. In response to these requirements, Hitachi has applied open technologies to develop the following supervisory and control products that are human friendly in each phase of plant life, from its construction to operation and maintenance.

New Supervisory and Control System

The configuration of a new supervisory and control system consisting of a distributed process computer system and digital control system is shown in Fig. 2.

Distributed process computer system

Conventional process computer systems used in monitoring systems employed dedicated technologies. Rapid advances in general-purpose technologies, however, have made it possible to apply open technologies to the supervisory and control field in both hardware and software terms. Application of general-purpose technologies, moreover, has brought about an even stronger demand for improvements in cost efficiency and maintainability and for shortening of periodic inspection periods. Against this background, Hitachi has developed a distributed process computer system that applies general-purpose technologies while maintaining reliability.

In this system, control servers using general-purpose technologies are appropriately distributed and interconnected by a standard open network. Here, an optimal configuration that ensures reliability can be achieved by incorporating redundancy into each

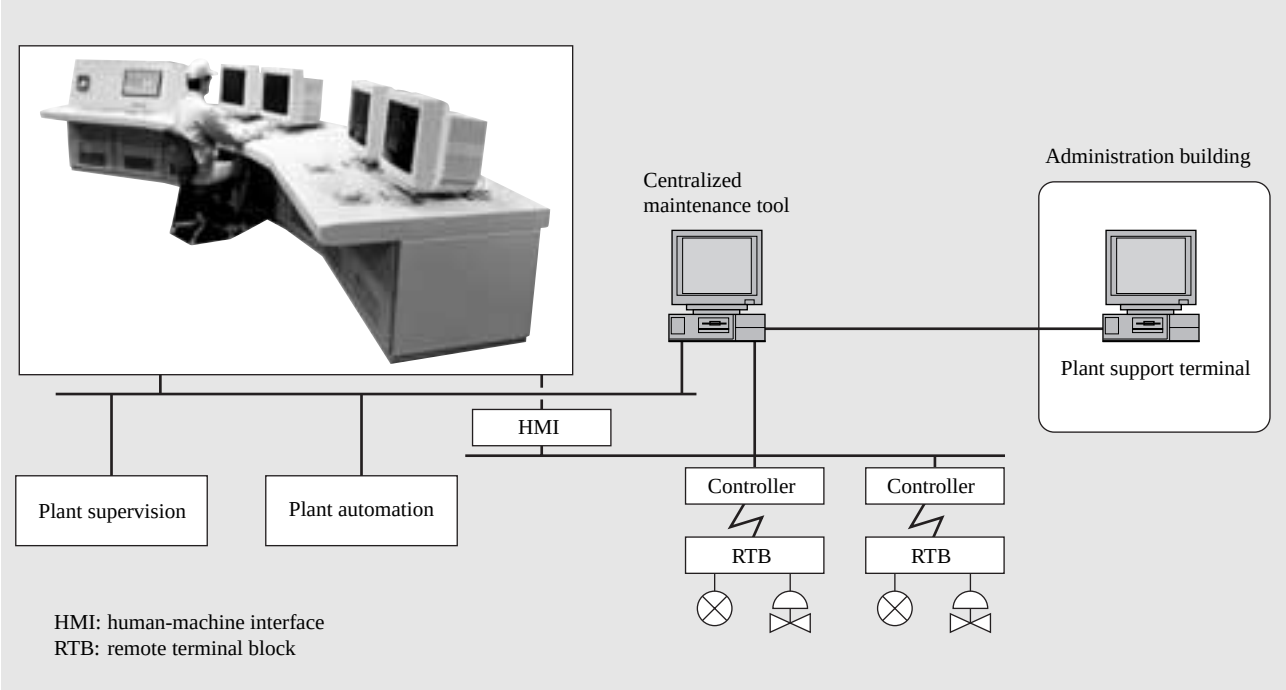

Fig. 2— Example of Configuring the New Supervisory and Control System.
A compact, human-friendly system can be configured by applying general-purpose technologies and open-network technologies.

control server according to reliability requirements. Extensive adoption of general-purpose technologies in this way enables system scale to be reduced by half compared to conventional systems. In addition, the extensibility of this distributed configuration enables architecture to be unified from a small-scale system to a large-scale system and allows a system to be easily upgraded in a step-by-step manner. It also allows maintenance and upgrading tasks to be divided up, which makes for shorter maintenance processes during periodic inspections and shorter equipment-replacement works. Furthermore, the appropriate adoption of commercially available software and the provision of multiwindows as a human interface while holding on to mature software architecture promotes an easy-to-understand and easy-to-use system (see Fig. 3).

This distributed process computer system was delivered to unit 2 at the Shimane Nuclear Power Station of Chugoku Electric Power Co., Inc., and replacement of the old system with this system was completed during a short periodic inspection.

Fig. 3— Screen Shot of Distributed Process Computer System.
Using multiwindows on one CRT, main parameters can be displayed and operations can be performed while monitoring the plant.

Digital control system

A new supervisory and control system called the "HIACS-7000" (Hitachi Integrated Autonomous Control System 7000) is employed for digital control equipment. The system on the whole adopts a layered configuration in its supervision/operation section and control section, and the inter-layer interfaces are simplified through connections made via human-machine-interface (HMI) servers.

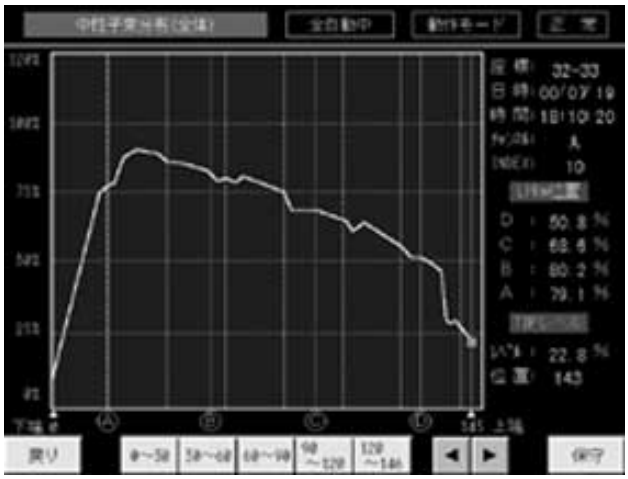

Fig. 4— Screen Shot of Traversing In-Core Probe System (TIP). Replacing the conventional X-Y recorder with a color flat display and digitizing data improves operability and simplifies the management of recorded data.

Here, a centralized maintenance tool features not only supervisory and maintenance software functions that are executed on the controller, but also computer-aided-design (CAD) functions for producing software. With the latter, displayed software becomes a drawing in the form shown, which can reduce the amount of work spent on managing software. The tool also has a software online monitoring function and a software isolation function that enable isolation of field equipment to be performed by software and maintenance to be conducted online.

This centralized maintenance tool can also be used to support maintenance operations remotely. Specifically, the tool can collect control data from each controller and plant data from process computers enabling supervisory functions to be performed from within the main administration building of the nuclear power station. This process is effective in determining the cause of an abnormal occurrence quickly and recovering from it in a short period of time.

Reactor Monitoring System

A reactor monitoring system is a particular feature of nuclear power plants, and comes in the form of a neutron monitoring system for measuring neutrons within the reactor and a radiation monitoring system for measuring radiation within the plant.

A neutron monitoring system is essential to core monitoring. To meet the need for improved maintainability and operability in existing plants, Hitachi has completed development of a new series of this system using a color flat display based on a new compact controller. This new series has laborsaving features like automatic gain calibration and a function for managing digital data of plateau characteristics by a personal-computer tool. Operability is also improved by using a flat display for the traversing in-core probe system (TIP) instead of an X-Y recorder, and digitizing measurement data simplifies data management (see Fig. 4).

A dust-radiation monitoring system monitors the amount of radioactivity in airborne dust in each area of the nuclear power plant[2], and improves the monitoring performance of artificial radioactivity by identifying natural radioactivity from the ratio of α-rays to β-rays in real time. In Hitachi's system, supervisory capabilities are improved by collectively managing measurement data from dust samplers installed in each building on a server and centrally displaying the data on flat displays in the main administration building and elsewhere using a general-purpose network. In addition, terminals in the security control room can access dust samplers remotely and make various kinds of settings.

These systems have been delivered to the Fukushima Daini Nuclear Power Station of Tokyo Electric Power Company.

Early Detection System of Anomalous Symptoms

To achieve stable plant operations, it is important that symptoms of anomalous be detected early and emerging trends understood.

With the aim of achieving early detection of anomalies within the primary containment vessel, Hitachi has developed temperature monitoring equipment using optical fiber technology (detection of Raman-scattering lights ratio). The idea is to perform detailed monitoring of temperature distribution and temperature change throughout the primary containment vessel so as to provide useful information for understanding system status and isolating the problem source.

Hitachi has also developed a high-sensitivity and continuous monitoring system of Off-Gas as part of the radiation monitoring system with the goal of measuring radiation in Off-Gas.

NEXT-GENERATION SUPERVISORY AND CONTROL TECHNOLOGIES

Hitachi is developing next-generation supervisory and control systems to provide comprehensive operation and maintenance support with the aim of

improving cost efficiency and easing maintenance load all the more. These efforts include the development of elemental technologies for detection and diagnosis of anomalies and provision of plant information[3].

For the detection and diagnosis of anomalies, Hitachi has developed technology for detecting symptoms of anomalies in a revolving body like a pump from vibration data by combining new signal-processing technologies like wavelet transform. The company has also developed technology for detecting symptoms of anomalies in processes through a neural network model. Furthermore, by using the results from these technologies in conjunction with ordinary plant data, Hitachi has developed technology for making comprehensive judgements on the cause of anomalies. This technology can also be used to monitor degradation of equipment characteristics with the objective of lengthening the operation cycle and extending plant lifetime.

Elemental technologies for providing plant information include techniques and methods for helping operators and maintenance personnel grasp plant status quickly. Examples are given below.

(1) Quick access to information using multimedia input such as speech and remote pointing onto the large-screen display using the pointer which emits a laser beam.

(2) Presentation of easy-to-understand information using multimedia, i.e. a combination of drawings, images, etc.

(3) Real-time information sharing between operators in the central control room and the local area using mobile computers.

Prototype systems incorporating the above elemental technologies have been developed, tested, and evaluated. Hitachi plans to apply these systems to actual plants.

Hitachi aims to apply new and open technologies to the development of supervisory and control systems for nuclear power plants of the 21st century that excel in cost efficiency and maintainability while placing priority on reliability.

CONCLUSIONS

This paper has described Hitachi's latest supervisory and control technologies for nuclear power plants.

With these technologies, Hitachi has been developing systems exhibiting excellent cost efficiency and maintainability while achieving high reliability, and has been deploying these systems in actual equipment. Hitachi is also in the process of researching and developing elemental technologies to support next-generation supervisory and control systems.

For the future, Hitachi is looking to develop even more human-friendly supervisory and control systems with even higher levels of reliability.

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