The Technological Trend of Computerized Control Systems –The Upgrade of Instrumentation and Control Systems, and Application for New Plants–

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For the stable operation of nuclear power plants, it is essential to have a highly reliable instrumentation and control (I&C) system with ease of operation. Installation of I&C system soft-operation main control board and computerized plant protection and control system is a global trend. Mitsubishi Heavy Industries (MHI) has installed the digital I&C system for digital upgrade and new plants. This paper reports our experience to improve operability, maintainability, and reliability through use of the I&C system.

1. Introduction

The I&C system in nuclear power plants consists of the main control board to operate, monitor and control the plant along with the protection and control system for monitoring and controlling equipment such as pumps and valves. Unlike the conventional plant protection and control system which consists of analog and relay circuits and other hardware devices that are connected via numerous cables, our current digitalized I&C system provides the following digital technologies and benefits (**Figure 1**):

- Soft-operation main control board (Improved operability and reduction in operator workload)
- Digital protection and control system (Savings in maintenance workload through the use of software without drift and early detection of failures by self-diagnostics)
- Use of data communication for connection between systems (Reduction in the amount of cables)

2. Soft-operation main control board

The soft-operation main control board is designed to improve operability and reduce the operator workload, and thereby allow single-person operation. This main control board consists of (1) the operator console which integrates and centralizes the functions of the conventional hard-wired main control board and allows monitoring and control from a seated position; (2) the large display panel which provides the operator an overview of the plant status; and (3) the supervisor console through which the shift supervisor monitors operations.

(1) Operator console

The operator console is a compact console designed to enable centralized monitoring and control by integrating the conventional main control board equipped with hard-wired monitoring devices (e.g., indicators, recorders, indicator lamps, etc.) and controllers. The operator console consists of the operational visual display unit (VDU) which is used for plant monitoring and control during normal operation, the alarm VDU which indicates alarms according to significance and control during normal operation, the alarm VDU which indicates alarms according to significance and priority and the safety VDU which is used for the monitoring and control of safety-related equipment.

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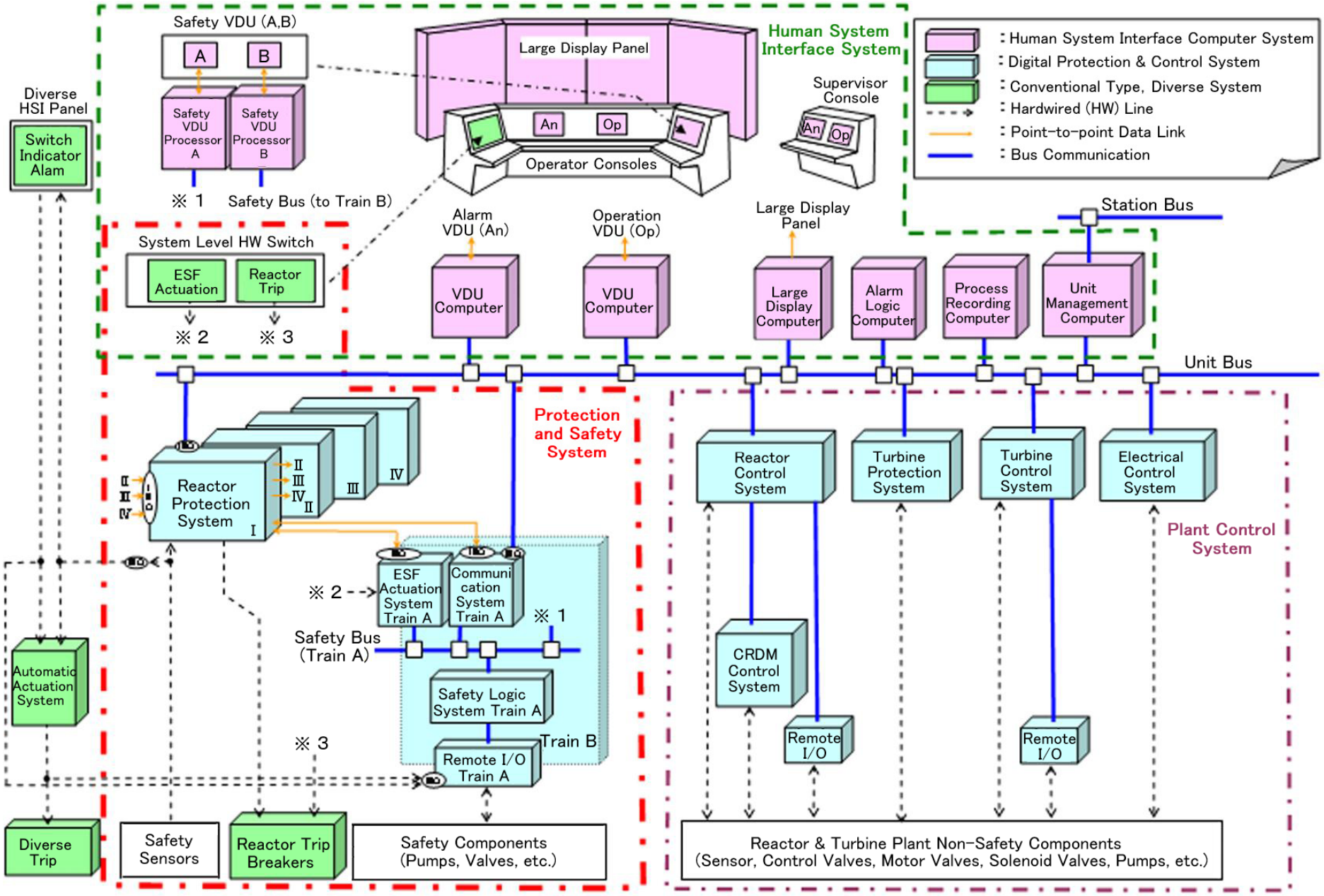

Figure 1 The overall architecture of the digital I&C system

Figure 2 shows conventional monitoring and control instruments of the software-based operational VDU.

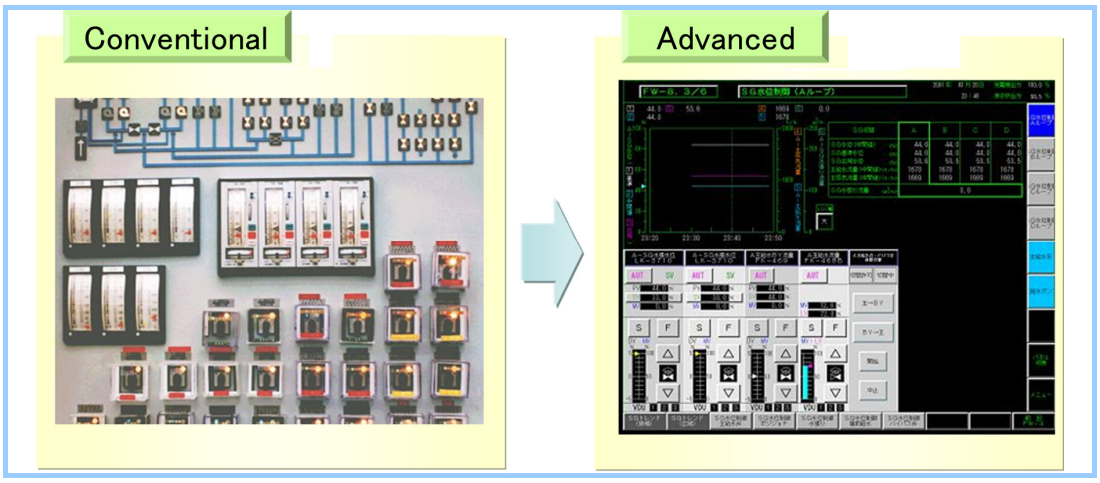

Figure 2 Conventional monitoring and control instruments of the software-based operational VDU

(2) Large display panel

The large display panel (LDP) shows parameters that require continuous monitoring and integrated alarms so that operators can share an overview of the plant information. Of the four screens on the LDP, three have fixed views to show system parameters and alarms which allow operators to continuously monitor the system and alarm status of the plant. The remaining one screen provides a variable view. Operators can choose a desired view from plant operation monitoring views available on the operation VDU. **Figure 3** shows screen shots of the large display panel.

(3) Supervisor console

This console has a capability to display the same screen as the operator console. The shift supervisor can monitor the same information viewed by the operator in order to direct and supervise the operation crew, as part of his or her responsibility.

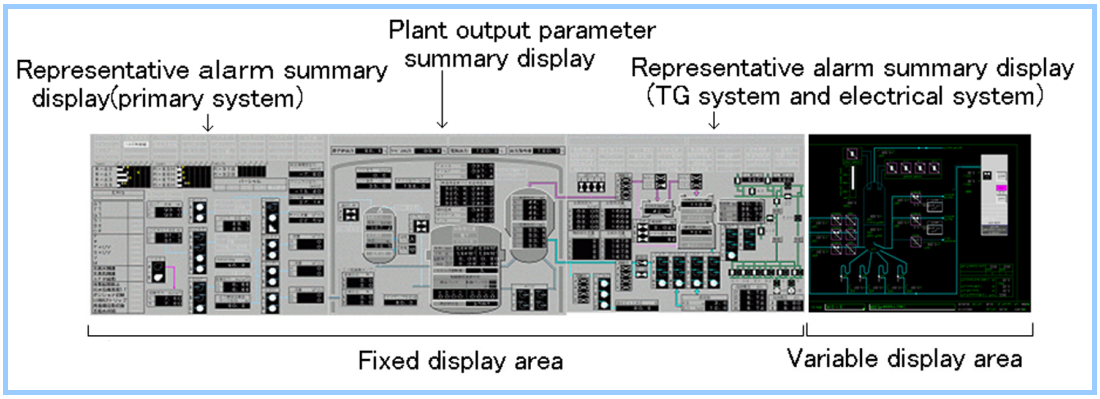

Figure 3 Large display panel images

3. Computerized Protection System

MHI has much experience in applying digital technology to the plant control system by means of the plant I&C system for PWRs in Japan. Based on this experience, the digital technology is being applied to the protection system which requires higher safety and reliability. The key features of our digital protection system are outlined below.

(1) Redundancy and independence

The protection system is configured to have two or four train redundancy for the event of failure or the removal of a single system to maintain safety functions.

Redundant divisions are physically and electrically isolated from each other in order to prevent the loss of safety functions. In addition, data communication between these divisions applies optical communications which enable electrical isolation and communication memory which prevents anomalies in the processor function from affecting other systems.

(2) Isolation from the plant control system

When signals are acquired from the protection system to the plant control system, the systems are configured to allow for physical and electrical isolation between them so that failure in the plant control system would not have an impact on the protection system. In addition, data communication between these divisions applies optical interfaces which enable electrical isolation and communication memory, which prevents anomalies in the plant control system from affecting the protection system.

(3) Self-diagnostics function

The protection system is equipped with self-diagnostics that are constantly active. When the self-diagnostics function detects a failure, they send an alarm to the main control room so that operators can be notified of the failure in a timely manner. The self-diagnostics function is also designed to maintain the "fail-safe" state in case of a failure that causes loss of function of the safety system.

(4) Simple software

Software applied to the protection system has the following features:

(a) To ensure the ease of software verification, software is simply configured with fixed-cycle processing and single-task structure.

(b) During the design and production phases of programs, visualization language is used for visualizing software in the same form as block or logic diagrams. This clarifies the source of the processing, and makes it easier for the third party to understand.

(5) Verification and validation

During the process of design, manufacture and test, verification and validation is performed in accordance with the "Guidelines for Verification and Validation of Digital Safety Protection System of Nuclear Power Plants" (JEAG4609-2008), we ensure that the functions required for safety protection are properly implemented in the software.

(6) Improved maintainability

Application of digital technology helps in reducing maintenance work.

(a) The use of software-based arithmetic circuits eliminates the need for calibration of ranges, spans, set points and so forth, which are necessary in conventional analog circuits.
For example, there are about 100 circuits with safety-related set points per unit, but their calibration is no longer needed.

(b) The application of the automatic calibration function to the field sensor signal input circuits eliminates the need for calibration that is necessary in conventional analog circuits.
For example, there are about 100 safety-related process parameters per unit, but the calibration of their input circuits are no longer needed.

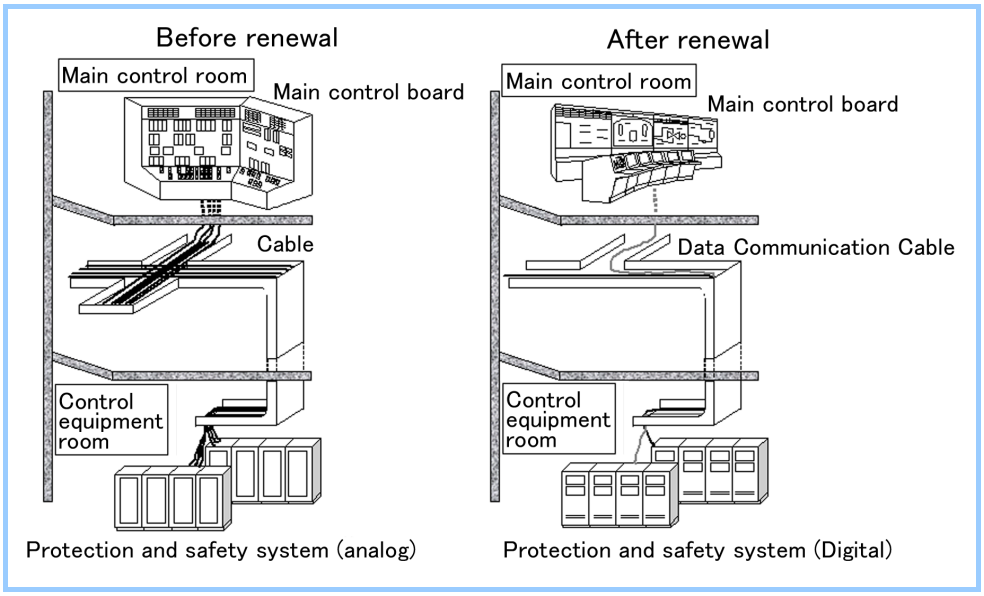

Figure 4 Example of renewal at existing domestic plants

4. Examples of application to existing and new plants

Digital upgrade of the I&C system has taken place at the Ikata Nuclear Power Station Units 1 and 2 of Shikoku Electric Power Co., Inc. The new systems are currently in commercial operation.

In terms of the new plant, digital I&C systems have been installed in Tomari Nuclear Power Station Unit 3 of Hokkaido Electric Power Co., Inc. The system is now in the inspection and testing phase. There are also plans to install the digital I&C system in new plants to be constructed in the future.

5. Conclusion

MHI continues to improve the safety and reliability of the I&C system and is ever more contentious in their design to enhance operability and maintainability. MHI aims to further improve technology in order to facilitate upgrades and new plant designs for the I&C system in Japan and abroad.