Rod Control System Oriented for Improving Operational Capability of BWR Plants

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OVERVIEW: An RMCS (reactor manual control system) and RPIS (rod position information system), which are next-generation products, were developed to assist in stable operation of existing BWR (boiling water reactor) plants. Installation tests of these systems were completed at The Tokyo Electric Power Company Incorporated, Kashiwazaki Kariwa Nuclear Power Station Unit 4, and The Chugoku Electric Power Co., Inc., Shimane Nuclear Power Station Unit 2. The new systems started operation at both of plants in June 2005. The basic concept of these systems is to improve performance [avoidance of LCO (limiting condition of operation)] by maintaining compatibility with existing facilities and by utilizing the functions of a redundant decentralized system. It is a system that monitors the positions of control rods while operating them manually in the BWR plants. A soft logic method was created by adopting the latest controller and optical data transmissions that use the latest IC (CMOS: complementary metal-oxide semiconductor). This method is used in place of the logic method, which uses IC technology (TTL: transistor-transistor logic).

INTRODUCTION

HITACHI has been developing systems for BWR (boiling water reactor) plants based on systems developed about 30 years ago. The systems have contributed to plant operations for a long time. Hitachi, however, developed next-generation products to further improve its operation system availability, based on great leitmotifs of existing systems. The company made these replacements for its next-generation system in BWR plants. This report describes the development background, content, and features of next-generation products and also replacements in the plants (see Fig. 1).

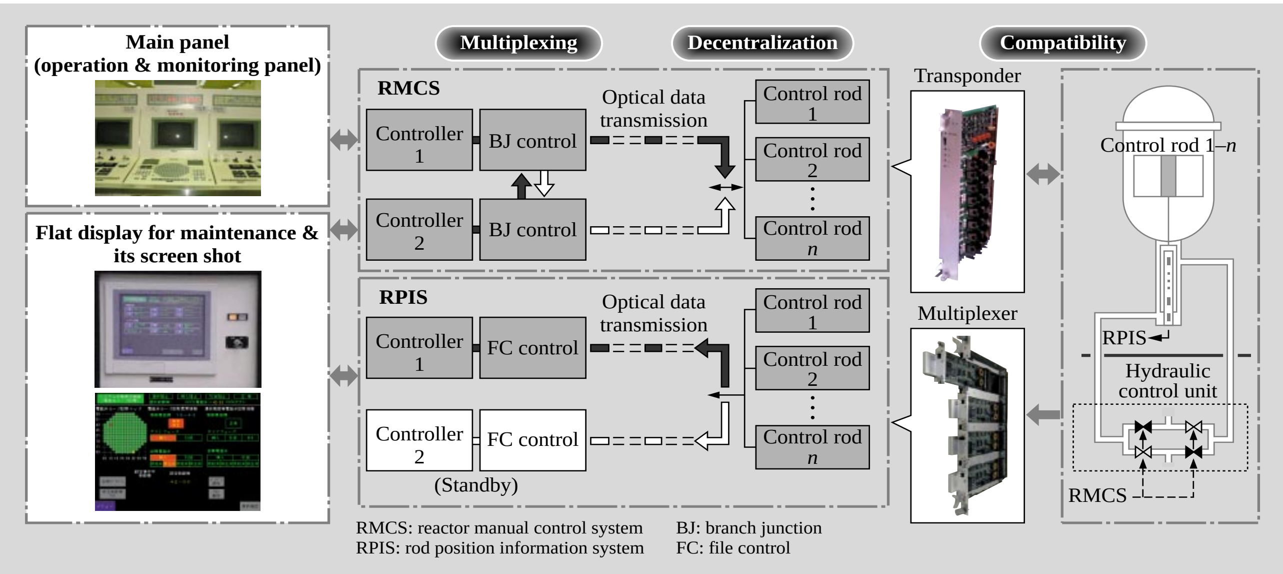
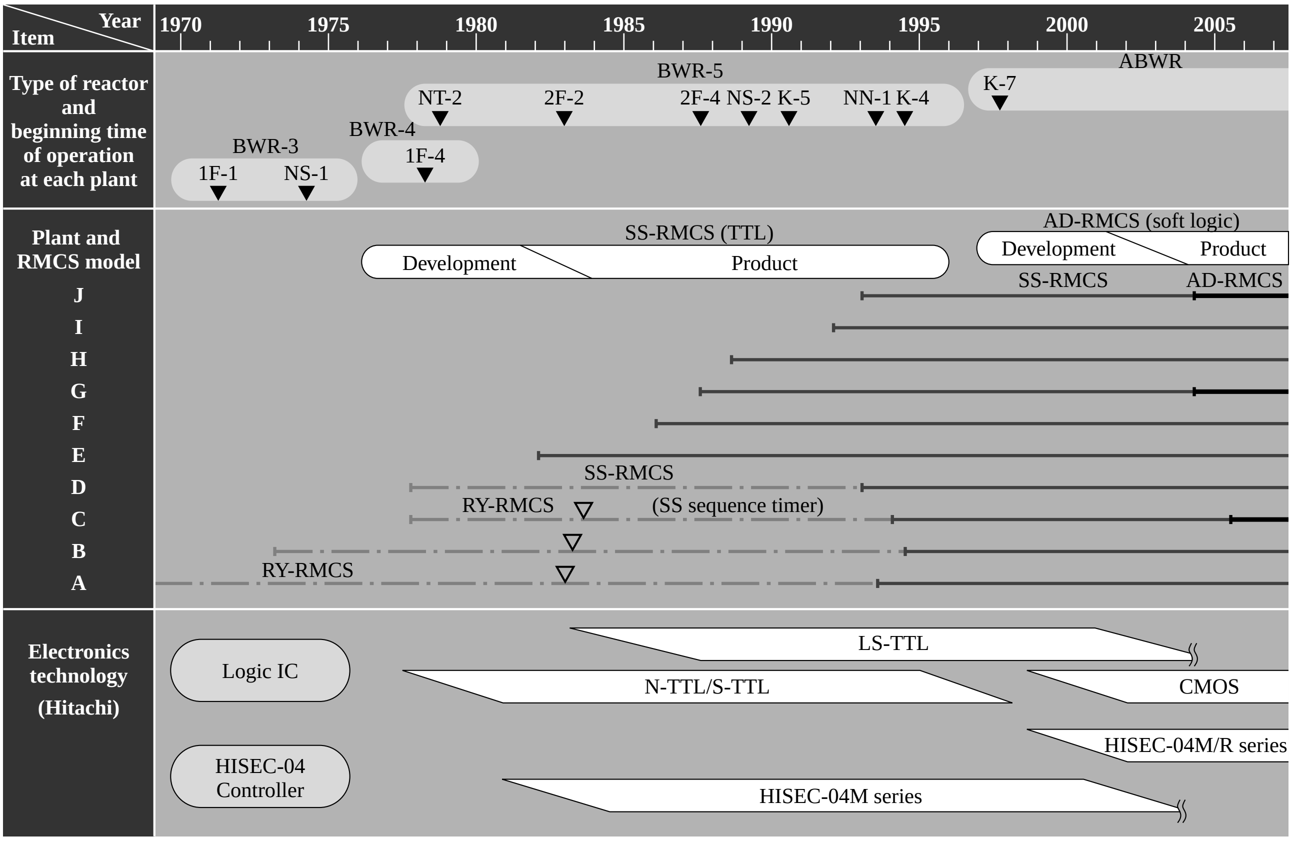


Fig. 1—Outlined Configuration of Control System with Control Rod for Existing BWR.
I/O (input/output) card of field panel, which is an interface with mechanical equipment, duplicates circuits of the existing system and conducts hot swapping for each control rod.



ABWR: advanced BWR RMCS: reactor manual control system SS-RMCS: solid state type RMCS
AD-RMCS: advanced digital type RMCS RY-RMCS: relay type RMCS SL: low power Schottky diode
TTL: transistor-transistor logic N: normal S: Schottky diode CMOS: complementary metal-oxide semiconductor

Fig. 2—RMCS in BWR Plants and Transitions of Related Technologies.
RMCS, a control system of nuclear power plants and reactors, has been steadily improved as part of an evolution in electronic technology, and it is now an important part of next-generation products.

TECHNOLOGY TRENDS AND TRANSITIONS

I&C (instrumentation & control) technology around the BWR plants has been improved, increasing the number of applications to Japanese domestic plants. Also, the important control systems of a reactor, RMCS (reactor manual control system) and RPIS (rod position information system), have been shifted from a relay RMCS to a solid-state RMCS through a sequence timer in a relay circuit (see Fig. 2).

Remarkable progress has also been made in electronics technology over the last 30 years. For example, we have achieved high integration, performance, and upgradability in ICs, which in turn have enabled improvements in controllers. These controllers are a key component of an I&C system (see Fig. 2). The latest technology has been introduced in stages into the field of nuclear power.

The control system of the control rod for BWR plants, which was developed and supplied by Hitachi will be the solution for tomorrow's replacement plans, and it will meet the latest requirements for the next generation of products (see Figs. 1 and 2).

NEW RMCS AND RPIS

Development Leitmotif

We incorporated our new RMCS and RPIS in the following architecture based on the basic leitmotif in order to improve existing systems and to create solutions for easy replacement in them.

(1) Maintaining compatibility with existing facilities

The architecture minimized changes in our existing facilities and interfaces to replace systems to achieve superior cost performance with high reliability. No changes were made on the interface in circuits inputted by machinery equipment (hydrolytic control unit) and electric signals.

(2) Improving performance capability using redundant/decentralized system

The systems created did not conflict with regulations by single failure concerning plant operation [avoidance of LCO (limiting condition of operation)]. I/O (input and output) parts were dispersed by control

TABLE 1. Product Specifications and Features
A flexible system is used, one that can select the hardware configuration and optional functions.

Item		Content	Note
Application		Replacement for BWR-3/4/5	
System specification	Use	Hydraulic drive control rod	The same as existing system
	Control method	Sequence time drive by manual operation	The same as existing system
	Interlock	Rod-block, etc.	The same as existing system
Equipment specification	Configuration (with options)	(1) Central control cabinet (replacement) + field cabinet (replacement) (2) Central control cabinet (replacement) + field cabinet (existing system)	
	Controller (with options)	(1) HISEC-04M/R600 (2) HISEC-04M/600CH	
	RMCS	Central control rod: duplicated AND logic Field: decentralized cards by control rods/duplicated circuits	With manual bypass function Capable of hot swapping
	RPIS	Central control rod: duplex system (master and standby) Field: decentralized cards by control rods	Capable of hot swapping
	Interface (with options)	(1) Analog neutron monitor system: dedicated transmission (2) Digital neutron monitor system: standard transmission	
	4-rod display	Response: less than 20 ms	
	Functions of flat display	Maintenance data. Position of all control rods	
	Maintenance functions	Diagnosis of solenoid valve loop, diagnosis of PIP	With maintenance PC
	Accessory functions (with options)	Core cell status monitor system Scram timing recorder	

PIP: position indication probe

rods (bypass unit) and circuits were duplicated based on the premise that controllers in RMCS adhered AND logic (with manual bypass function). Also, the controllers of the RPIS were changed to a duplex system: master, standby (the existing system is a master only).

Developments and Results

The following are descriptions of major items that were developed, along with the development results:
(1) We developed a system architecture in which the latest component was applied, and we conducted element development of optical data transmission cards and I/O cards applied to the latest IC (CMOS: complementary metal-oxide semiconductor);
(2) We developed a mock-up (model) system and conducted performance tests (completed in August 2002).

PRODUCT FEATURES AND OPERATION STATUS

Product Specifications and Features

The product specifications and features are summarized in Table 1. The following are descriptions of them.
(1) System specifications, such as an interlock, are the same as in existing systems, but the following improvements were made in the design.
(a) The response time of a rod block was analyzed and evaluated while considering the replacement for the RMCS/RPIS and digital power range neutron monitor in BWR plants.
(b) The interlock block diagram was represented graphically for superior maintainability.
(2) A flexible hardware configuration, which can asynchronously replace the central control panel composed of controllers with a field panel composed of I/O parts, was created by adopting the following technologies into the system architecture.
(a) It was composed of an HDLC (high-level data link control) protocol between a controller BJ (branch junction) control card and field panel, electrical data transmissions (based on the existing system method) between I/O cards (transponder card) in the field panel, and an optical data transmission card (optical BJ card) that achieves a gateway function.
(b) The RPIS was built in the same way as the RMCS [FC (file control) card, optical FC card, etc.].

These features facilitate replacing equipment of the existing BWR even if implementation on the field is performed differently.
(3) Redundant controllers achieved maintenance and accessory functions by dividing the controllers into each major function [RMCS, RPIS, HMI (human-machine interface)].

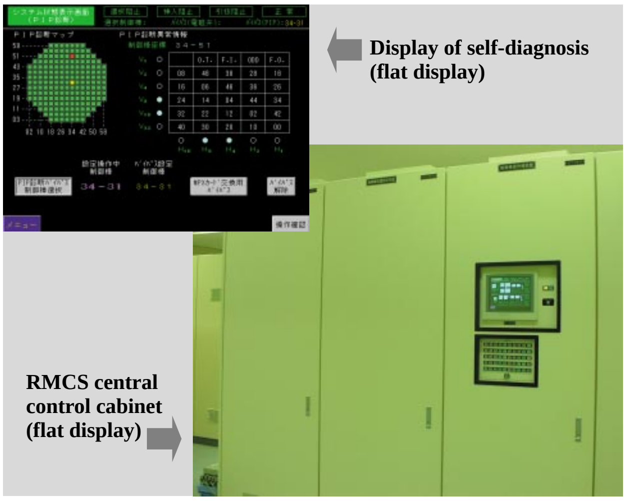


Fig. 3—Conditions after Replacement in Tokyo Electronic Power Company, Incorporated, Kashiwazaki Kariwa Nuclear Power Station Unit 4.
Maintenance data has been shifted so that it is integrated and displayed on a color screen (self-diagnosis data, positions of all control rods, etc.) from a lamp display of a special panel.

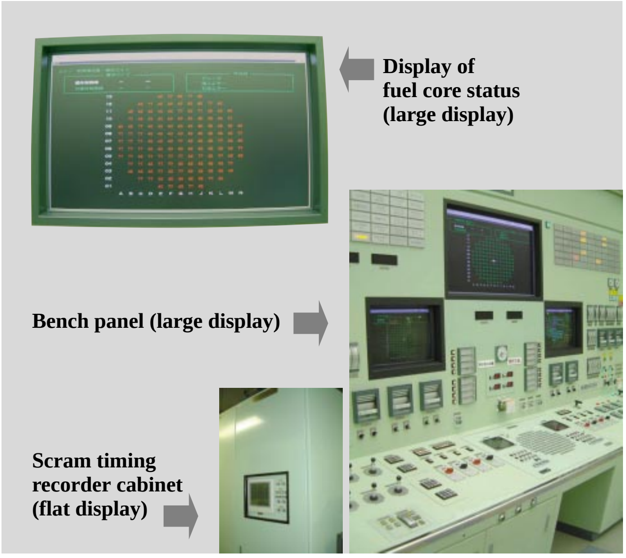


Fig. 4—Conditions after Replacement in Chugoku Electronic Power Co., Inc., Shimane Nuclear Power Station Unit 2.
Changed to an integrated display with a large color screen.

(4) A fast response was achieved in the position display of four rod of the RPIS for manual operation in the RMCS.
(5) Consolidated and summarized data is shown in a flat display instead of the existing special display of self-diagnosis information. The data is recorded with maintenance PCs.

Responses to New Functions

A core cell status monitor system is being implemented during an annual inspection plant outage for operations related to core internals in annual inspections so as to achieve superior reliability and efficiency. The RPIS in this system possesses functions to achieve operation combined with a core cell status monitor system during an annual inspection plant outage (option).

Replacement Status at Plant

Replacements for this system will be made during annual inspections; the test duration will be approximately 30 days, when all fuel is taken out. The following replacements were made.
(1) The Tokyo Electric Power Company, Incorporated, Kashiwazaki Kariwa Nuclear Power Station Unit 4 finished installation tests and started operation of systems in March 2005. Fig. 3 shows the conditions after the replacement.
(2) Systems for The Chugoku Electric Power Co., Inc., Shimane Nuclear Power Station Unit 2, including scram timing recorder in a replacement range, finished installation tests at the plant and started operation in February 2005. Fig. 4 shows the conditions after the replacement.
(3) System design for The Tokyo Electric Power Company, Incorporated, Fukushima Daiichi Nuclear Power Station is now in commissioning (As of October 2005).

CONCLUSIONS

This report described a control system for a control rod as part of a next-generation product for BWR.

Hitachi is going to provide solutions that meet electric companies' needs for nuclear power plants around the world through its experience in replacing and maintaining BWR plants, promoting replacement proposals for I&C systems, as well as through this new RMCS and RPIS.

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