FURTHER IMPROVEMENT OF HUMAN-MACHINE INTERFACE FOR ABWR MAIN CONTROL ROOM

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Abstract

Tokyo Electric Power Company (TEPCO) has developed main control room panels based on progress in C & I technology. ABWR type main control room panels (ABWR MCR PNLs) are categorized as 3rd generation type domestic BWR MCR, that is, they are were developed step by step based on operating experience with the 1st and the 2nd generation BWR.

ABWR type main control room panels were applied to Kashiwazaki-Kariwa Nuclear Power Station Units No. 6 and 7 (K-6/7) for the first time. K-6/7 are the first advanced BWR (ABWR), which started commercial operation in November 1996 and July 1997, respectively.

The concept of ABWR MCR design was verified through wooden mock-up panels, start-up tests and commercial operation. Though the K-6/7 design has borne fruit, we are planning to refine and standardize the design based on the following concepts.

- to maintain the plant operation and monitoring style of ABWR MCR PNLs
- to introduce brand-new HMI technology and devices
- to incorporate operators' advice in the design

This paper outlines the features and improvements of the K6/7 MCR PNLs design.

Introduction

The main control rooms of Japanese BWRs were originally designed to concentrate in one place control of all information required for plant operation. This design concept has been applied to all BWR units up to now, with the introduction of the latest HMI technology and the modification of the arrangement of the panels.

In addition to the 2nd generation type MCR design, ABWR MCR PNLs were developed as 3rd generation ones, based on the following essential concepts.

- to prevent human-errors during accidents
- to enhance plant operability

ABWR MCR PNLs design were examined through the verification of functions by using prototype panels and review by operators of life-size wooden mock-up panels made by TEPCO.Requirements accumulated through start-up tests were recorded. In accordance with some of them, slight design changes were made in a timely manner, such as to CRT screen design and modification of logic.

Although the basic concepts were realized as expected, several required improvements were identified by engineers and operators in TEPCO. Thus, we decided to incorporate them into the ABWR MCR PNLs design and establish the standard domestic design.

- to apply 18-inch colored LCD
- to enhance information on plant automation
- to rearrange the roles of FDs and CRTs
- to improve the method of managing software isolation during outages
- to introduce distributed computer systems to process computers

ABWR Type Main Control Room Design

Main Control Room

ABWR MCR PNLs are composed of large display panels and compact control consoles. They are designed so that operators can monitor major plant parameters and start up and shut down while seated. Therefore, the width of the main control console was decreased to around 5 meters, as compared with the 2nd generation one (11 meters). Figure-1 shows a photograph of the K-6/7 main control room panels.

On the main control console are located 7 CRTs, 17 FDs and conventional switches. FD is 10-inch TFT LCD that is directly driven by a distributed digital controller. FDs are applied to every system group, such as SSLC, BOP, NSS, in order to minimize the risk against random failures and to back up CRTs driven by the process computers, though the screen size and performance of FDs are inferior to those of CRTs.

Hardwired switches and software switches through CRTs and FDs are available for plant operation. Normally, hardware switches are used for fast initiation of ECCS and for mode switches to initiate sequential routine operations during normal operation. On the other hand, software switches are used for the operation of individual pieces of equipment, such as pumps and valves during periodic tests.

A large display panel has a total width of around 12 meters. That includes essential alarm windows, large mimics and a large screen. It is designed to be able to provide almost all information required for plant operation. Symbols and characters on large display panels are large enough for a shift supervisor to see from afar while seated. Thus, major plant information is easy for operation crews to access simultaneously.

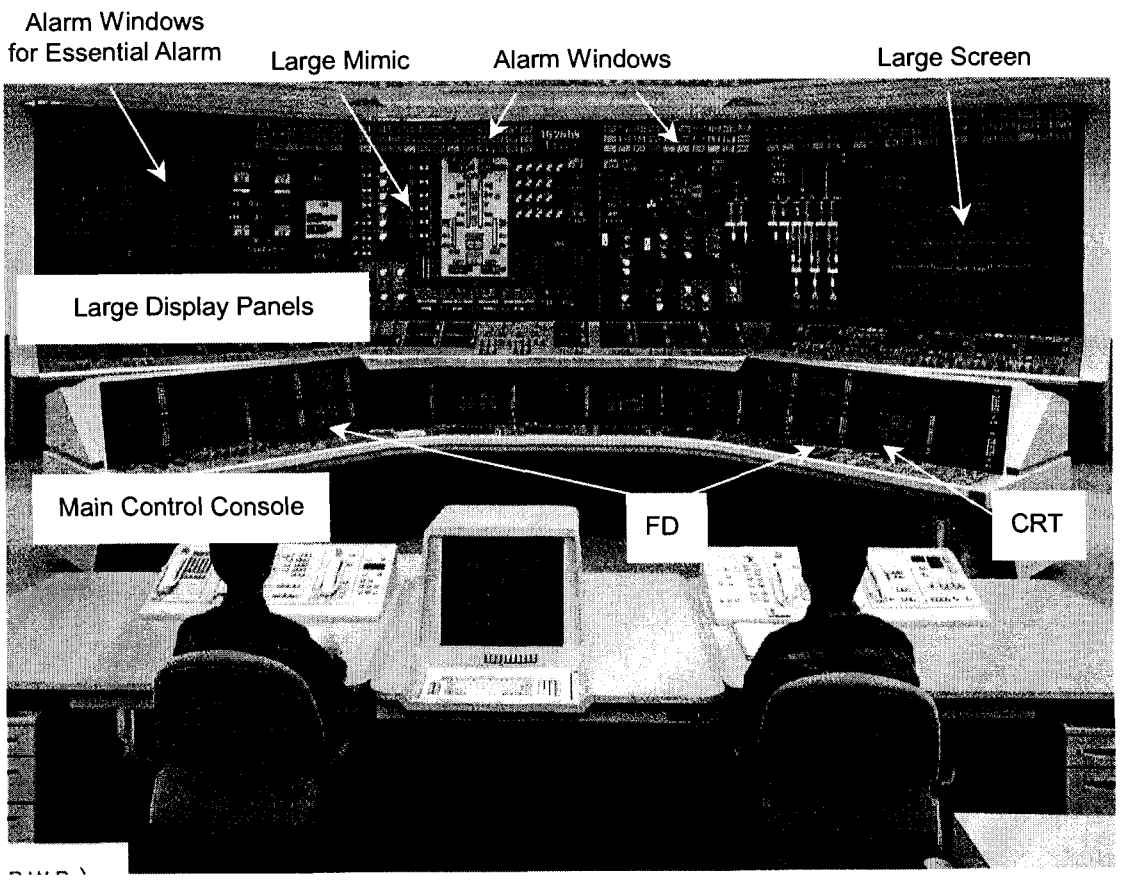

Figure-1: Photograph of ABWR Main Control Room Panels

Automated Plant Operation

In TEPCO, automation of routine operations has been applied gradually. In ABWR, the scope of automated plant operation has been enlarged to post-scram and CR operation based on workload analysis of previous plants as follows.

- After a scram, several sequential routine operation is required.
- CR operation take much time during start-up and shut-off.

Table-1 shows a history of automated plant operation comparing to the 2nd generation type with ABWR one.

Table-1: Comparison of Automated Operation

	Major Operation		2nd Generation	ABWR
Start-up	Reactor System	Switching of Reactor Mode SW	OG+M	OG+M
		Reactor Re-aeration	OG+M	OG+M/S
		Withdrawal of Control Rods	M	A/F
	Turbine System	Start-up Turbine Gland Seal Steam	OG+M	OG+M/S
		Start-up Air Extractor and Off-gas System	OG+M	OG+M/S
		Start-up Feedwater and Condenser Pump	OG+M	OG+M/S
	Main Turbine/ Generator	Warming of Control Valves	A/F	A/F
		Increase of Turbine Speed	A/F	A/F
		Generator Synchronization	A/F	A/F
Surveillance Test		Emergency Core Cooling System	OG+M	OG+M
Immediately After Scram		Switching of Reactor Mode SW	M	M
		Main Turbine Trip	M	A/L
		Turbine-driven Reactor Feedwater Pump Trip	M	A/L
		Switching of Turbine Gland Seal Steam	M	M/S
Emergency		Scram and Start-up of ECCS	A/F	A/L
		Start-up of Containment Cooling System	M	M/S
		Mode Switching of Residual Heat Removing System	M	M/S

M: Manual, M/S: Sequential Manual, OG: Operation Guide
A/F: Auto by Feedback Control , A/L: Auto by Logic Control

Configuration of C & I System

Figure-2 shows a system configuration of ABWR C & I. The design of ABWR MCR PNLs is based on a plant-wide digital network, to which FDs, controllers and process computers connect.

Others

In addition to the above items, we stratified alarms, which used to number more than 1,500 alarm windows, and categorized them into 3 levels: plant level, system level and component level. Owing to the alarm hierarchy, it is easy for an operator to recognize plant status correctly.

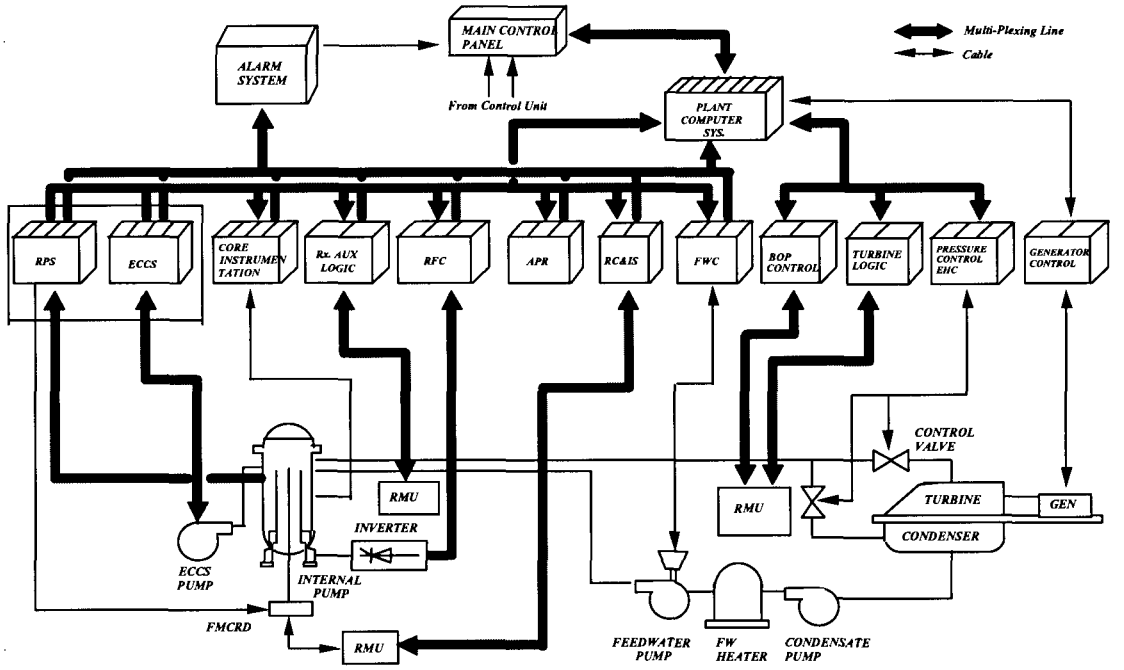

Figure-2: Configuration of C & I System for ABWR

Collection of Items

Slight design changes and modifications were made before starting commercial operation, in accordance with field requests. However, if an improvement had an effect on overhaul plant design and/or required much time, we made it a rule to record and incorporate them into the following plant design.

Thus we collected all requests from the field and categorized them into the following 3 groups:

Group 1: items to be applied in basic HMI design
Group 2: items to be applied to equipment design and/or device design
Group 3: items to be considered in detailed design

Items categorized group 1 are as follows:

- to enhance information of plant automation
- to improve the method of managing software isolation during outage

Moreover, for the purpose of enhancing operability, reliability and availability, and reducing initial costs, we are planning to introduce the latest digital technology.

- to apply 18-inch colored LCDs
- to apply distributed computer systems to process computers

Further Improvement of HMI for ABWR

Concept of Further Improvement

TEPCO made it a basic policy to improve and standardize design without extra cost for reviewing:

- to follow the plant operation and monitoring style of K-6/7 MCR, basically
- to avoid reexamination of seismic design and safety design
- to establish a domestic standard as a common reference for Japanese BWR owners

Support System for Automated Operation

Generally, automation of a sequential routine operation is effective for decreasing start-up time. When there is trouble with the automation, we are forced to waste much time referring to software logic diagrams trying to recover the automation. Thus, we recognized the necessity of having more information to recover the automation and decided to provide more information on automation logic and current status to support operators through temporary HMI devices.

Application of Distributed Computer System for Process Computers

The process computers for an ABWR provide many functions, such as operation guidance, plant status indication, performance calculation, diagnosis of equipment and so on. Therefore, we decided to use large-scale, real-time custom computers supplied by plant providers.

Though some parts of the process computers at K-6/7 are redundant, process computers are stopped completely and undergo maintenance for 2 weeks during every outage in order to prevent them from causing problems during plant operation.

For improved standard ABWR MCR PNLs, process computers will be designed to be fully redundant, except for shared memory, so as to provide enough plant information during not only plant operation but also outages.

Application of 18-inch Colored LCD

In K-6/7, 10-inch colored LCDs and CRTs were applied. Recently, remarkable development have been achieved in the field of HMI devices, and 18-inch colored LCDs are a major devices now. Thus, we will replace both FDs and CRTs with them.

By unifying HMI devices, it will be possible to rationalize screen design as follows.

- In K-6/7, the screen design of CRTs and FDs was performed independently, but under the improved standard ABWR MCR PNLs, CRT screen design will be applied to FDs directly.
- Operation of valves and pumps can be performed completely through devices driven by controllers.

Application of Isolation Management System

TEPCO has made it a rule to control work permission sheets and isolation tags corresponding to maintenance work in order to ensure plant safety during maintenance. In ABWR, software switches for FDs and CRTs were introduced in place of conventional ones, and thus, isolated equipment are monitored as follows.

- to display symbols standing for isolation on screens of FDs
- to keep tags corresponding with every screen in special boxes

Figure-3 shows an outline of an isolation management system.

In this method, the information on screens is less than isolation tags; therefore, we plan to introduce a dedicated "isolation management system" in order to supervise the isolated equipment more precisely and effectively.

The design concept of an isolation management system is as follows.

- to maintain electrical independence from the safety system.
- to control isolation effectively and conveniently using a database on equipment.
- to be able to communicate with the existing maintenance management system.

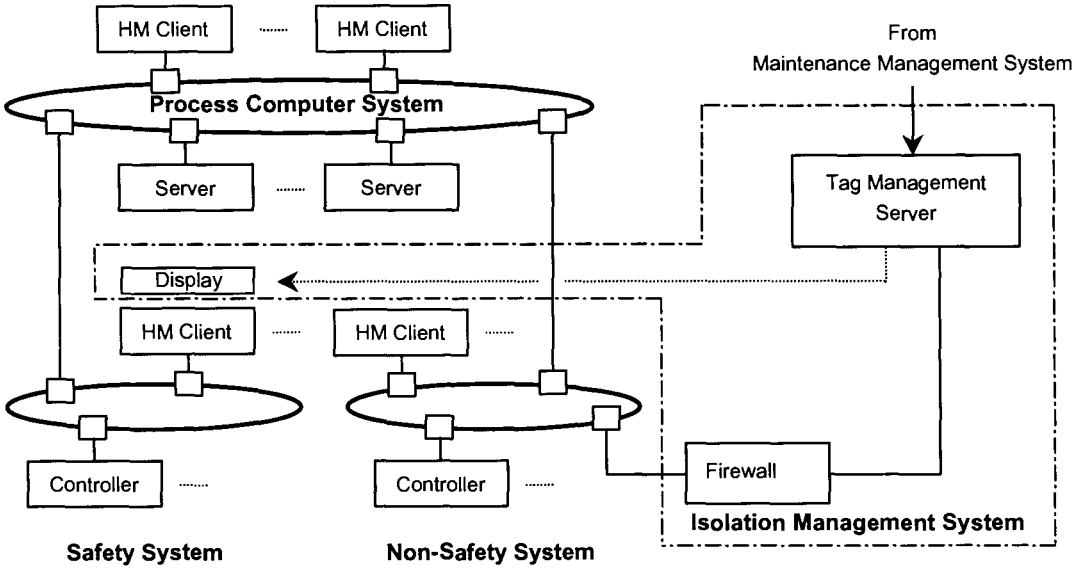

Figure-3: Outline for Isolation Management System

Outline of Standard ABWR MCR Panels

Figure-4 shows the improved standard ABWR MCR PNLs design compared with that of K-6/7.

Conclusion

The improved standard ABWR MCR PNL is designed with the following features:

- to incorporate operators; advice into the design
- to introduce the latest HMI technology so that operators can monitor and operate the plant more effectively
- to supervise isolated equipment more precisely and effectively by means of introducing an isolation management system

All activities to improve the design of ABWR MCR PNLs have been examined by Japanese BWR owners, and thus, we expect it to be the domestic standard design and for the initial costs to be reduced.

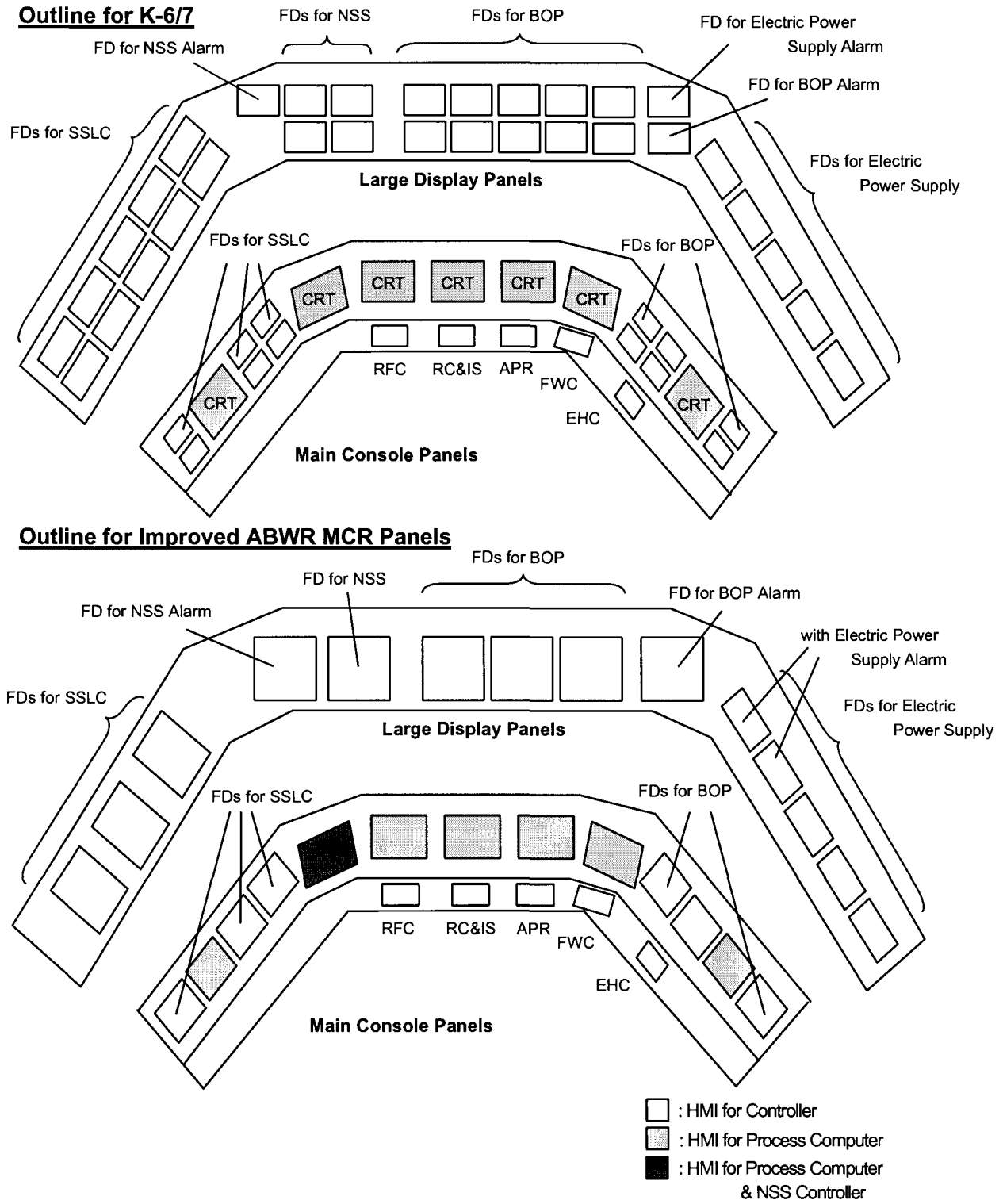

Figure-4: Outline of Improved ABWR MCR Panels compared with that of K-6/7

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