Digital Upgrade of Main Control Panels

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***Abstract*— The main control panels, which are installed in the main control room, play a crucial role in monitoring and controlling the plant. Various modifications and improvements in the PWR main control panel in terms of human-machine interface have been pursued on a continuous basis while the items to be monitored and controlled by the main control panel have been increasing due to the enhancement of safety-related systems. Considering that the production of many instruments and controllers on the main control panels at these 3 plants have been already discontinued, it was decided to replace the whole main control panels with advanced digital panels to improve the maintainability.**

Keywords—main control panel; digital update; human-machine interface

I. INTRODUCTION

Kansai Electric Power's Takahama 1, 2 and Mihama 3 are the pressurized water reactor (PWR) which have been operating for more than 40 years. After obtaining approval for extended plant operation, Mihama unit 3 has resumed operation and Takahama units 1 and 2 are currently working on the preparation for full-scale operation.

Considering that the production of many instruments and controllers on the main control panels at these 3 plants have been already discontinued, it was decided to replace the whole main control panels with advanced digital panels. This paper introduces Kansai's efforts to replace the main control panels with new ones conducted as part of the safety enhancement work toward long-term operation beyond 40 years.

II. BACKGROUND LEADING O MAIN CONTROL PANEL REPLACEMENT

The main control panels, which are installed in the main control room, play a crucial role in monitoring and controlling the plant. Various modifications and improvements in the PWR main control panel in terms of human-machine interface have been pursued on a continuous basis while the items to be monitored and controlled by the main control panel have been increasing due to the enhancement of safety-related systems.

The main control panel design for PWR plants in Japan has been changed according to the generation as descried below:

(1) 1970's

The main control panel was basically built on the U.S. design of the time, with an integrated three-dimensional operation benchboard and a large number of conventional monitoring and operating instruments, such as indicators and recorders lined up on the panel.

(2) 1980's

Domestically produced central control panels were introduced incorporating many ergonomic improvements in response to the TMI accident. The size of the panel was optimized by lowering the height of the panel to make it easier to see the instruments on the top. In addition, the shape of the operating switch handles was differentiated according to their functions (pumps, valves, etc.), the accident monitoring instruments were identified by their frame colors, the alarm windows were color-coded according to their importance, and the arrangement of switches and instruments was optimized. The main control panel was integrated with a three-dimensional operation benchboard, and a color CRT was introduced in addition to conventional monitoring equipment to improve the monitoring performance by enabling the centralized display of information.

(3) 1990's

An improved main control panel was developed with a wide range of human factor improvements, such as reducing the workload of operators, while further pursuing ergonomic improvements in monitoring operability. The main features are as follows:

(a) Main panel and auxiliary panel configuration

The conventional integrated panel is divided into a console-type main panel for seated operation and a benchboard-type auxiliary panel for standing operation (reactor auxiliary panel and turbine generator auxiliary panel) corresponding to the operation modes. In the past, the arrangement of instruments on the panel was determined by the system, but in this generation, instruments that are frequently monitored and operated during normal operation are concentrated on the main panel to reduce the distance the operator has to travel. The auxiliary panel contains instruments with less frequencies of being monitored and operated that are used only during start-up and shutdown, and during accidents.

(b) CRT-based monitoring

Thanks to the improvement of computer technology, the application of ergonomics to CRTs, and the accumulation of know-how on how to operate CRTs, CRTs have become the primary means of operation monitoring in this generation, and conventional instruments are secondary. Monitoring for normal operation by the main panel can be on performed almost exclusively by means of CRT owing to the advancement of technologies.

(c) Improved Alarm Display System

In the domestically produced main control panels, a "static" method was used, in which alarm windows were placed according to a predetermined level of importance and fixed color coding was used. The main control panel in this generation adopts a variable display structure, capable of identifying and displaying status change with the color of the alarm window, "Operation response required: red", "Confirmation required: yellow", and "Status indication: green".

(4) 2000's

In the improved main control panel of the 1990s, the application of CRT as a monitoring device made it possible to consolidate the information necessary for monitoring on a screen, which greatly reduced the walking distance in a series of monitoring operations. In addition, the human-machine interface has been improved to reduce potential human errors. However, the operator still used hard controllers, so seated operation throughout all operation modes was not feasible.

In this generation, as the instrumentation and control system becomes more digitalized, an advanced main control panel with touch operation is designed to (i) integrate the display of monitoring and operating information, (ii) reduce the size of the main control panel (seated operation), and (iii) automatically check the confirmation action by the computer, thereby reducing the potential human error and physical workload as well as mental workload.

III. Development and Verification Process of the Advanced Main Control Panel

In developing the advanced main control panel, verification models were fabricated at each of the development stages shown below, and linked with a simulator to create plant conditions equivalent to those of an actual plant, and operation verification was conducted by operators of an actual plant. The reason why we have conducted the operation verification by linking with the simulator is that the evaluation of the operability of the main control panel needs to be conducted under time-constrained conditions such as abnormalities, accidents, or complicated monitoring operations during normal operation.

(i) Stage of conceptual design

(a) study of conceptual design （Step1）

(b) verification of feasibility of advance main control panels（Step2）

(ii) Stage of practical design

(a) verification and validation (static)（Step1）

(b) verification and validation (active)（Step2）

IV. Software Operation Type Main Control Panel

The new main control panel is designed to be a compact console-type main control panel that can be operated in a seated position. It consists of an operation console for monitoring and operating the plant, a large display device for general monitoring of the plant, and an operation command console for the shift manager.

(1) Operation console

The operation console is a compact console-type panel that allows the operator to monitor and operate the plant from a seated position by reducing the width of the panel significantly through the use of software (touch operation). In addition, a touch panel (visual display unit (VDU)) has been adopted to integrate the monitoring and operating functions so that a series of monitoring and operations can be performed on the same screen.

(2) Alarm system

The significance of alarms is displayed in three different colors, alarm (red), warning (yellow), and status display (green), according to the progress of the plant status so that the operability can be enhanced by indicating the alarm according to the significance and priority.

(3) Large display system

The plant main parameters and representative alarms are displayed on a large display unit at all times to support the sharing of overall plant information and information that should be commonly recognized by operators.

(4) Operator support system（EOSS）

This system is designed to diagnose abnormalities and accidents related to plant safety, which place a high psychological burden on operators and have a significant impact when human errors occur, by using a computer based on operation manuals, and to display messages, operation guides, and other support information on large displays, operation consoles, and other devices, as well as to provide audio announcements for the purpose of providing operational support to the operators.

In line with digitalization of the main control panel, a severe accident (SA) monitoring and operation panel is installed to meet the new regulatory requirements. The SA monitoring and operation panel is installed in the main control room as a VDU independent of the operation console for operator visibility and operability, and is dedicated to monitoring operation parameters and operating equipment that are used only in the event of a severe accident.

V. Status of Replacement of Main Control Panels

The work to replace the entire main control panel with a new digital main control panel is being carried out in the following steps. At Mihama unit 3, the new main control panel has been put into operation on a full-scale after all the steps were completed.

(1) Steps in replacement of the main control panel

(a) Installation of temporary control panels

(b) Start of operation of temporary control panels

(c) Removal of existing control panels and installation of new control panels

(d) Functional test

(e) Start of operation of new main control panel

VI. AFTERWORD

The replacement of the main control panels at Takahama units 1 and 2 and Mihama unit 3 is the first construction work that has been carried out after obtaining the permit of Reactor Installation Changes and the approval of Construction Plans following the enforcement of the new regulatory requirements. We would like to continue to place the highest priority on safety in restarting our nuclear power plants while asking for your kind understanding and cooperation.