Development and design guideline for computerized human-machine interface in the main control rooms of nuclear power plants

MISHIMA Takaki[1], NISHI Hiroaki[2], TAMURA Yoshiaki[3], and NAKAGAWA Yasushi[1]

1. Tokyo Electric Power Company, Tokyo, Japan (mishima.takaki@tepco.co.jp, nakagawa.yasushi@tepco.co.jp)
2. Kansai Electric Power Company, Kansai, Japan (nishi.hiroaki@c3.kepco.co.jp)
3. Japan Electric Association, Tokyo, Japan (y-tamura@denki.or.jp)

Abstract: In the development of the new main control room (MCR) for constructing nuclear power plants (NPPs) and modernization of existing NPPs, the new interface technologies have been adopted in Japan. Therefore, functional requirements and design requirements for the human-machine interface (HMI) in the MCR were expected to clarify as design guideline in Japan. According to this need, we started to investigate domestic and foreign standards, and design and operating experiences of modern NPP. Based on the results of these investigations we specified functional and design requirements for the HMI and procedures for development and design of the computerized HMI in the MCR, and established JEAG4617 as a new HMI guideline. JEAG 4617 was reviewed by the Nuclear Standard Committee of Japan Electric Association and was issued in June 2005. On July 16 2007, the Niigata-Chuetsu-Oki earthquake occurred in Kashiwazaki area, Niigata. Then there weren't any operating trouble in Kashiwazaki-Kariwa NPP unit No.6 and 7, the ABWRs, during and after earthquake.
Keyword: human-machine interface, main control room, earthquake

1 Introduction

Since TMI-II accident in 1979, the researches in the field of human factor have been advanced in order to prevent operators misjudging and operating error in the MCR(main control room) of NPPs(nuclear power plants). The results of these researches and other efforts such as classification of alarms and indicators have applied to the HMI(human-machine interface) in the MCR to enhance the reliability of monitoring and operating. In addition, remarkable progresses in electronics technologies and previous operating experiences have been reflected in the HMI designs of the MCR.

Under these conditions, in the development of the new MCR for constructing NPPs and modernization of existing NPPs, new interface technologies such as touch-operation and large display panel have been adopted in addition to the computer technologies such as compact main console, hierarchic arrangement of alarm display, and expansion of the scope of automatic operation. Therefore, functional requirements and design requirements for the HMI in the MCR were expected to clarify as design guideline in Japan.[1-2]

According to this need, we started to investigate domestic and foreign standards[3-4], and design and operating experiences of modern NPP such as the ABWR plant from 2001. Based on the results of these investigations, we specified procedures for development and design of the computerized HMI in the MCR and established JEAG4617 as a new HMI guideline.

2 Position of JEAG4617 in the Japanese safety regulations

The contents of the Japanese safety regulations are classified into the following four levels as shown in Fig.1.

- Level 1: Goal
- Level 2: Functional requirements
- Level 3: Performance requirements
- Level 4: Acceptable implementation method

JEAG4617 corresponds to the Level 4 that means the basis of upper level.

Received date: June 2, 2010
(Revised date: June 7, 2010)

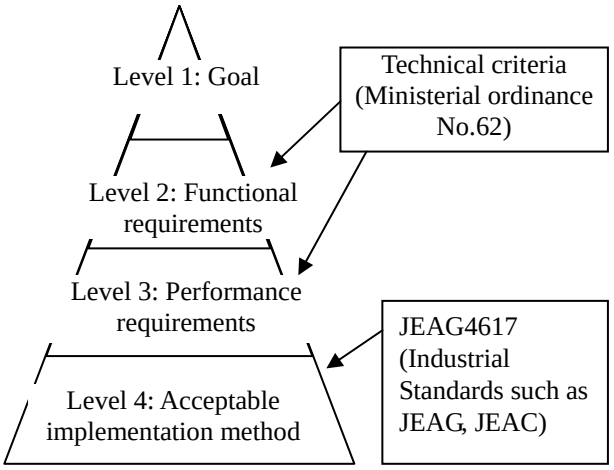

Fig.1 Position of the guideline and technical criteria in the Japanese safety regulations.

3 Scope of application

JEAG4617 is intended for application to:

- functional and design requirement for the computerized HMI;
- procedure for development and design of the computerized HMI.

In JEAG4617, the computerized HMI includes information systems, display elements, controls, alarm systems, large display, operator support systems, layout, configuration and devices as shown in Fig.2

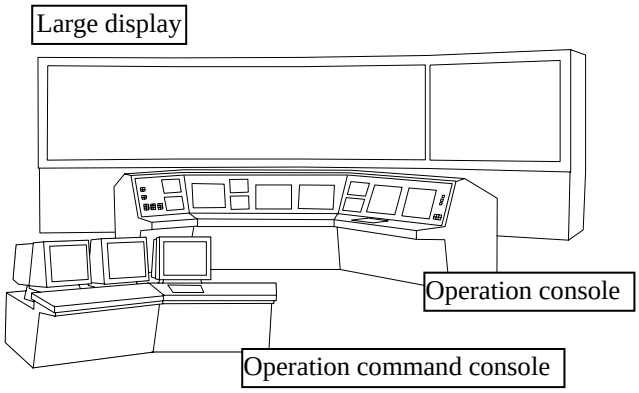

Fig.2 Computerized HMI of ABWR type MCR

4 Organization of the guidelines

JEAG4617 consists of "Functional and design requirements" and "Development and design processes".

"Functional and design requirements" provides requirements for function and design of the computerized HMI.

"Development and design processes" provides the standard processes to develop the design concept and design details.

The details of each guideline are described in next chapter.

5 Contents of the guideline

5.1 Functional and design requirements

5.1.1 Functional requirements

The function of the HMI should be determined in consideration to:

- maintaining function to monitor and operate at all plant condition;
- selecting information to monitor and equipments to operate in order to maintain safety function;
- ensuring enough time to switch automatic to manual operations in order to maintain safety function;
- designing system redundancy
- alarming operator when the HMI is failure.

5.1.2 Design requirements

The HMI should be designed in consideration to following aspects.

a) Information systems
   - Monitoring and operating systems;
   - Information navigation system.

b) Display elements
   - Legibility and distinguishable;
   - Display format;
   - Display devices.

c) Controls
   - Arrangement;
   - Grouping;
   - Selected Action;
   - Touch operation.

d) Alarm systems
   - Hierarchic arrangement;
   - Processing;
   - Display;
   - Reliability.

e) Large display

f) Operator support systems

g) Layout and configuration
   - Lauout of MCR;
   - Layout of console;
   - Configuration of console;

- Lighting.

h) Devices

6.2 Development and design processes

Figure 3 shows the standard development and design process for the HMI.

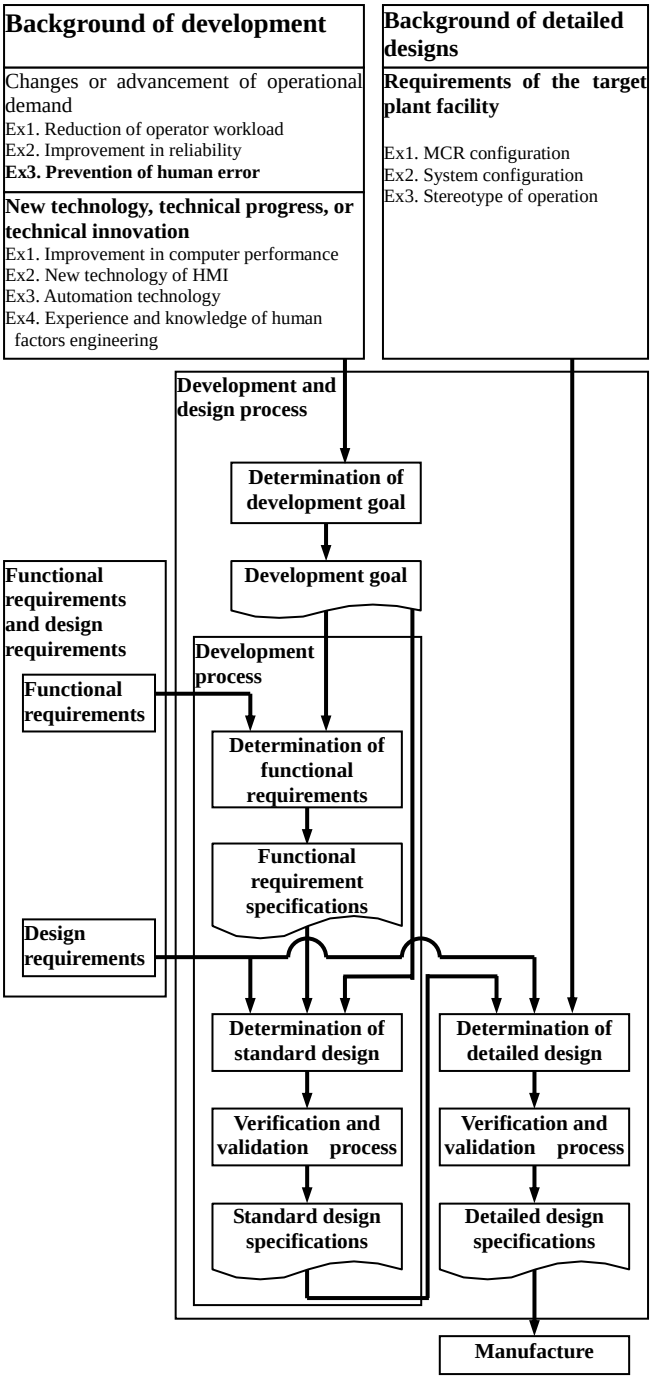

Fig. 3 Standard development and design process.

In developing the new HMI and modifying functional requirement specifications or standard design specifications that have already been developed, the designer should follow the development process.

In the development process, in order to satisfy the development goal and functional requirements the designer should:

- make the functional requirement specifications.

Next, in order to satisfy functional requirement specifications, development goal and design requirements the designer should:

- determine the standard design;
- verify and validate the standard design;
- make the standard design specifications.

In applying the standard design specifications to the manufacturing design, the designer should follow the design process.

In the design process, in order to satisfy standard design specifications, requirements of the target plant facility and design requirements, the designer should:

- determine the detailed design;
- verify and validate the detailed design;
- make the detailed design specifications.

5.3 Commentary

For easy understanding of contents in the body text, reference information is described in JEAG4617, such as symbols and color.

Table 1 Example of display color on the screen

Display elements	Color typically used	
State of the equipment	Run	Red/Hollow White
	Stop	Green/White
	Open	Red/Hollow White
	Close	Green/White
	Input mismatch	White/Yellow
	Input failure	White/Yellow
Fixed element	Green/Cyan	
Background	Black	
Variable characters	Normal	Green/White
	Abnormal	Red
	Input failure	White/Yellow
Controls	Normal	Green/Grey
	Selecting	Magenta /(Hollow) Grey
	Feedback	Yellow/Magenta
Abnormal state	Red/Yellow/Green	

Table 2 Example of Display symbols for pump/fan

Display			Remarks
Symbol	Color	Contents	
	White	Input mismatch	Four types are available as follows. Facing right Facing left Facing up Facing down
	Green	Shut-down	
	Red	Start-up	

6 Present status of the guideline

JEAG4617 was reviewed by the Nuclear Standard Committee of Japan Electric Association and was issued in June 2005.

7 Computerized HMI in the MCR of NPPs in Japan

In Japan the four ABWR plants have been operating since Kashiwazaki-Kariwa NPP unit No.6, the first ABWR, started commercial operation on 1996. The computerized HMI was adopted in the MCR of these ABWR plant. The ABWR type MCR was designed and manufactured to meet requirements and procedures in JEAG4617 though JEAG4617 was not issued at that time. As a results, any serious troubles attributed to the computerized HMI in the ABWR type MCR haven't been experienced to the present.

8 Operation in ABWR type MCR at the occurrence of the Niigata-Chuetsu-Oki Earthquake

Kashiwazaki-Kariwa NPP unit No.7 was in power operation and unit No.6 was in planned outage shutdown when Niigata-Chuetsu-Oki earthquake occurred on July 16 2007. Unit No.7 immediately automatic scrammed. Then any troubles of the computerized HMI in unit No.6 and 7 were not reported during and after earthquake.

In order to verify the effectiveness and validity of JEAG4617, we interviewed with the operators on duty when the earthquake had occurred.

We confirm from their answers that they could shutdown the plants safely with the use of computerized HMI.

Their answers were that:

- they could promptly identify the plant condition from large display and operator support systems;
- they could operate communicating with the other operators.

9 Conclusions

JEAG4617 provides functional and design requirements for the HMI and procedures for development and design of the computerized HMI in the MCR.

The ABWR type MCR was designed and manufactured to meet requirements and procedures in JEAG4617. Any serious troubles of the HMI in the ABWR type MCR haven't occurred yet.

On July 16 2007, the Niigata-Chuetsu-Oki earthquake occurred in Kashiwazaki area, Niigata. Then there weren't any operating troubles in Kashiwazaki-Kariwa NPP unit No.6 and 7, the ABWRs, during and after earthquake.

We have started to revise JEAG4617 to reflect the latest operating experience, domestic regulatory positions and referenced domestic/foreign standards since April 2010.

References

[1] MASUDA, N., IMAI, K., HIRATA, K.: Guidelines for human-machine interface designs for the computerized main control rooms of nuclear power plants, The 6th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety, 2004.

[2] JEAG 4617-2005 Guide for development and design of computerized human-machine interfaces in the main control room of nuclear power plants, Japan Electric Association, 2005.

[3] IEC 60964:1989, Design for control rooms of nuclear power plants, International Electrotechnical Commission, 1989.

[4] NUREG-0700 rev.2, Human-system interface design review guidelines, U.S. Nuclear Regulatory Commission, 2002.