The influence on the performance of operators along with the introduction of the advanced main control board

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Abstract: This paper describes an influence on the performance of operators along with the introduction of the advanced main control board (MCB). The influence on the performance of operators is considered based on the operating procedure, the requirements for operators and the operator training. The operating procedure is the document which puts forward the way that the designer has thought in advance for the operators and describes the performance of operators. The introduction of the advanced MCB seems to be bringing a change of the operating procedure. The requirements for operators are the knowledge, skills and attitude, and crew resource management (CRM) skill. CRM skill makes use of the knowledge, skills and attitude and improves the team performance. The advanced MCB seems to induce a change of CRM skill i.e. the communication, decision making or problem solving, team building, situation awareness, and workload management of different shift teams. The operator training is the best way to verify the change of the operating procedure and CRM skill.

Keyword: performance of operators, advanced main control board

1 Introduction

The advanced main control board (MCB) which utilizes digital control technology to be composed of compact operation console and large-sized display is developed and introduced in each country around the world as shown in Table 1. The advanced MCB of PWR is applied to the construction of new nuclear power plant Tomari unit 3 and the modernization of nuclear power plant Ikata units 1 &2, in Japan.

Table 1 Advanced MCB in the world

Country	Type	Nuclear Power Plant
Japan	APWR/PWR	Tsuruga-3&4, Tomari-3, Ikata-1&2
	ABWR	Kashiwazaki-Kariwa-6&7, Hamaoka-5
French	N4(PWR)	Chooz-1&2, Civaux-1&2
Europe	EPR	Olkiluoto-3, Flamanville-3
Korea	APR1400	Shin-Kori-3&4
Canada	CANDU-6	

In the 1970's, a lot of indicatory instruments and switches which have the same form and the same color setup were placed in a perfect array on the MCB of nuclear power plant. But it became obvious that the perfect array is not effectively functional to reduce the operator workload and human error. After TMI accident, the MCB design was revamped and improved, for example: the alarm prioritization system, the CRT, the coding (mimic) and so on. Since then, the advanced MCB which has totally new general idea is developed in order to decrease the operator workload and the human error potential in addition to the increase of the reliability of nuclear power plant. On the other hand, the change of the MCB specification has exerted a change on the system of the shift team setup and the performance of operators at the same time. This paper tries verification from the viewpoint of operators in order to influence the performance of operators along with the introduction of the advanced MCB.

MCB is the most important Human System Interface (HSI) which cannot be mistaken by the operator of the nuclear power plant with respect to safely. The operating procedure is the document which puts forward the way that the designer has thought for the operators and describes the performance of various operations. The operating procedure is the point of contact between the plant system and the operators. The operating procedure is also the HSI. The requirements for operators are the knowledge, skills, attitude and CRM skills. The requirements for operators are the standard which monitor and evaluate the performance of operators. In this paper, the

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operating procedure and the requirements for operators are reviewed before discussions of its influence on the performance of operators, along with the introduction of the advanced MCB.

2 Operating procedure

The operating procedure is the document which puts forward the way that the designer has thought for the operators and describes the performance of operators. If operators do not comply with the operating procedures, it is impossible to change the plant condition as they had intended. Furthermore, the safety of the nuclear power plant may be placed in danger. Also, the operating procedure is the document which prescribes the responsibility of operators. It is necessary to reflect the knowledge that is gained from the operating experiences too. In order for the thought of designers and the experience of operators to be well balanced and reflected in the operating procedure, it is highly necessary to cooperate between designers and operators.

2.1 Corresponding with plant condition

The operating procedure is classified into General Operating Procedure (GOP), Abnormal Operating Procedure (AOP) and Emergency Operating Procedure (EOP) in corresponding with the plant condition.

GOP is used for the routine start-up, shutting-down and the change of power of plant. The method of monitoring, and various control methods are described according to the order of the operations. It should easily reflect what the designers are thinking of, and incorporate the operating experiences in GOP, because the operation sequence has to be planned and discussed in advance. Therefore, operators may comply with GOP easily.

AOP is used in situation when equipment breaks down or the system deviates from the normal condition. The procedures for switching breakdown equipment to the back-up or returning it to the normal condition is described according to the order of the operation. It is comparatively easy to reflect the operating experiences in AOP, because the operation sequence is based on available equipments and expected plant response. However, operators may waver over selecting the operating procedure when two or three systems deviates from the normal conditions, at the same time.

EOP is used when the plant falls to the accident condition. The automatic sequence of reactor trip and Emergency Core Cooling System (ECCS) actuation, and the way of monitoring and controlling are described according to the time series and the operation sequence. There may be little room which reflects operating experiences into EOP, because EOP is based on the process of design and safety analysis i.e. Design Basis Accident (DBA). Operators should comply with the operating procedure which is required in safety analysis. However, the accident which occurs at the actual power plant is different from DBA. Sometimes, the equipment which is not assumed in DBA breaks down and/or the equipment which is assumed unavailable can be used. Operators are required to have the application ability to select more than one EOP in addition to EOP handed over from designers.

2.2 Two kinds of EOP

All EOP toward DBA are event based. In 1980's, EOP toward beyond DBA was added to existing EOP as a lesson learned from TMI accident and Chernobyl accident. Since then, two kinds of EOP, the event bases and the symptom based ones are used.

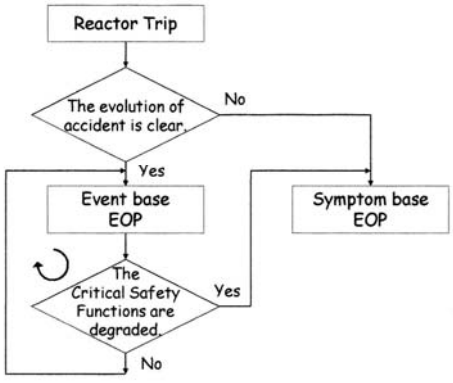

Fig. 1 Two Kind of EOP

The event based EOP is the one to have assumed the evolution scenario of the accident. The event base EOP has the merit that compatible operation after that becomes clear, if it can diagnose the event. If operators miss the accident scenario and/or find the

degradation of the critical safety functions, they change the event base EOP with the symptom base one immediately as shown in Fig.1.

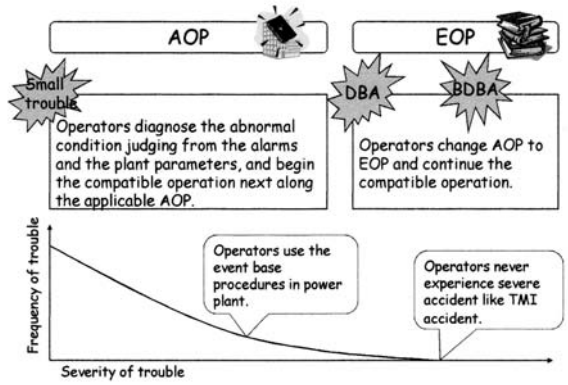

Fig. 2 Use of Operating Procedure

Majority of incidents/accidents are triggered by small minor trouble. Operators diagnose the abnormal condition, judging from the alarms and the plant parameters and begin compatible operation along the applicable AOP. If the reactor trip occurs, operators change AOP to EOP and continue the compatible operation. Today, plant reliability is higher and frequency of plant trip is low. Operators may experience minor trouble sometimes, but have little or no experience of reactor trip in their term. Operators never experience a severe accident like TMI accident. Operators use the event base procedures in actual power plant. They pick up the symptom base EOP once or twice a year at training center as shown in Fig.2.

Moreover, operators reassure themselves by thinking that they know how the trouble evolutes in the future. If the evolution of event is clear, it is possible to say that the way of thinking to follow the event base procedure is rational. Therefore, it is reasonable that operators prefer the event base procedure to symptom base.

2.3 Computerizing operating procedure

In comparison to before, when all operating procedures were paper based, today the development of computer technology and the digitalization of the plants are bringing crucial changes to the operating procedures. The electronic procedure and the computer-based procedure and so on are constantly proposed.

In Japan, MHI developed the Emergency Operation Support System (EOSS) for the advanced MCB and adapted it for the new construction plant. EOSS is electronic procedure with navigational links. Also, as for the EDF, it adopts the computer-based procedure KIC which covers GOP, AOP and EOP at the N4 plant. KIC has links with control aids information, but each operating step is performed manually. Both EOSS and KIC-EOP are basically the symptom base procedure. It seems that the symptom base is suitable for the computerized procedure.

However, some operators show resistance for computerization of operating procedure. In other words, well-trained operators usually give priority to their knowledge and experiences when they decide on the conducts of the operation. It seems that they think to compete with the computer as well as master of the game like “Chess”.

As for complying with operating procedure, there is a difference in degree with each country. Operating procedure is applied, selected for the actual power plant condition with flexibility in Japan; meanwhile operating procedures are strictly applied in the USA. The responsibility of shift teams, the number of operators, roles of the operators and so on is different in each country.

3 Requirements for operators

3.1 Knowledge, skills and attitude

The knowledge and skills for operators to perform their duties is listed up in accordance with JEAG-4802 “Guidelines for Education and Training of Nuclear Power Plant Operators” in Japan. For example:

- Knowledge: A basis such as the limitation value and standard value can be explained in accordance with technical specifications:

- Skills: Reactor criticality can be checked and confirmed using by standard operating procedures.

Operators are trained to acquire these knowledge and skills along the well-planned training programs.

Moreover, requirements for operators are not simply knowledge and skills. The attitude which tries to comply with the measures of good safety is also

essential, the law and the work conducted are necessary too. Operators should have an attitude which is suitable for their duty and carry out their tasks.

3.2 CRM skill

There is a thing which is still short of even if operators have the sufficient knowledge and skills and maintain the high level attitude. It is necessary to manage operators as a member of shift team. The only managed shift team can get a high performance. The procedures for managing operators are called Crew Resource Management (CRM) skill. CRM skill makes use of the knowledge, skills and attitude and improves the team performance. CRM skill is the ability demanded for not only supervisor but all shift team members.

CRM skill is roughly classified into:

- Communication
- Decision making or problem solving
- Team building
- Situation awareness
- Workload management

The knowledge, skills, attitude and CRM skill which is looked for operators is universal. The catalogue of the knowledge and skills for operator license is published in USA [1, 2]. CRM skill is common idea with the characteristics of excellent team referred in the guideline of INPO [3].

The knowledge, skills, attitude and CRM skill should be respected even if the advanced MCB is introduced. The influence on the knowledge, skills, attitude and CRM skill along with the introduction of the advanced MCB is reviewed by two methodologies i.e. comparing MCB and observing operator training.

4 Comparison of MCB

As for the two cases of the existing MCB and the advanced MCB, the knowledge, skills, attitude and CRM skill of operators changes, and what is invariable is investigated using reactor trip as an example.

4.1 Existing MCB

Operators monitor the plant condition through the alarms, meters, indication lamps, CRT screens and so on, and carry out necessary operation using the switches and the controllers on the control board. Supervisor manages the operators' behavior directly, and monitors the plant condition by himself/herself. It is possible that the abnormal condition of the plant is recognized promptly through the conventional alarm windows. Operators and the supervisor can know what happened easily by the flicker pattern of the alarm window.

The flow chart of operator's action after reactor trip in case of existing MCB is shown in Fig. 3. Operators acknowledge the flicker of alarm window and confirm "Reactor Breaker Open", "All Rod In", "Neutron Flux Decrease", "Turbine and Generator trip" and so on by conventional lamp, instruments or recorder If necessary, they control the water level of steam generator by conventional controllers and switches on control board.

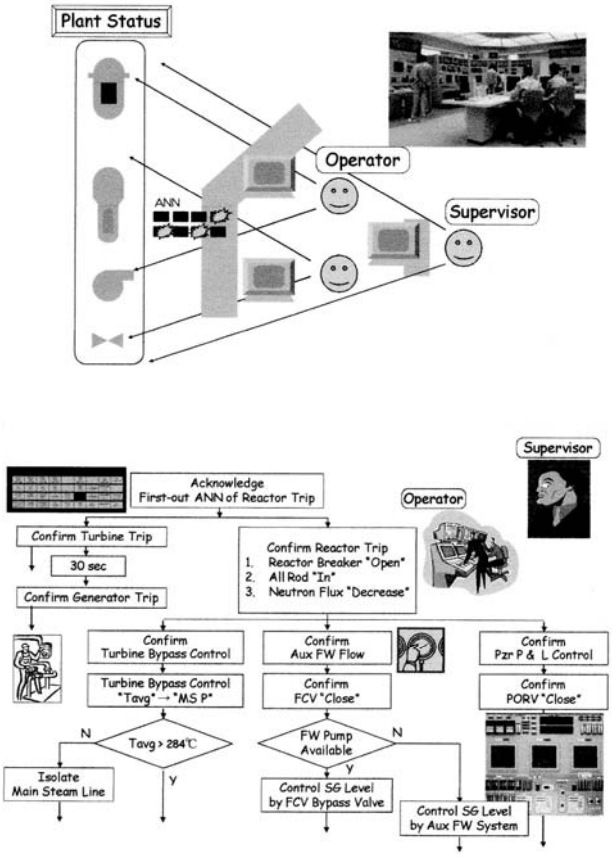

Fig. 3 Operator Action in existing MCB

4.2 Advanced MCB

Operators monitor the plant condition and make

necessary operation by the VDUs on operator console. Supervisor can manage the operator's action by the VDU of supervisor console. Operators acknowledge the blinked message of alarm screen. At this step, operators and supervisor can use the large display panel as a common source of information in order to exclude "the key-hole effect".

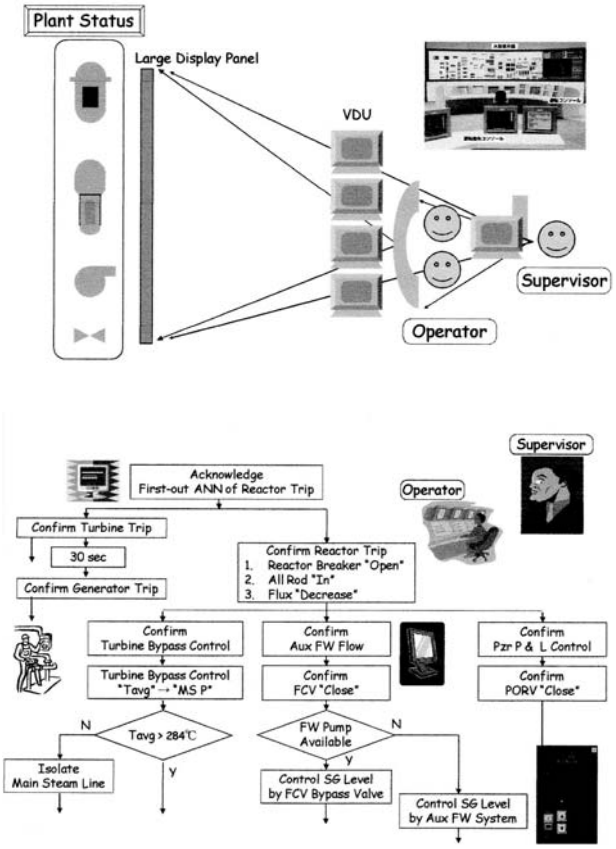

Fig. 4 Operator Action in advanced MCB

The flow chart of operators' action after reactor trip in case of the advanced MCB is shown in Fig. 4. Operators diagnose what kind of abnormal condition has occurred in the plant from several messages on the alarm screen and confirms "Reactor Breaker Open", All Rod In", "Neutron Flux Decrease", "Turbine and Generator trip" and so on by trip status screen which is automatically displayed on VDUs. And then, operators control the auxiliary feed water flow and the other plant parameters by selected screens.

The result of comparison of the two cases of the existing MCB and the advanced MCB derives the tentative conclusion as follows.

- The plant parameters which operators should monitor and control are the same.
- The devices which operators use to monitor and control the plant parameters are obviously different.
- The knowledge, skills and attitude may be almost the same.
- Communication, decision making or problem solving, team building, situation awareness, and workload management i.e. CRM skill seem to be different.

5 Operator training

Operator Training is the best way to verify the tentative conclusion derived from comparing MCB. Nuclear Power Training Center Ltd. (NTC) carries out the training of about 500 operators and about 200 shift teams every year for over 30 years. NTC has a lot of operator training records. These training records are utilized to evaluate the performance of operators and improve their knowledge, skills, attitude and CRM skill. The new simulator which has two reference plants (Tomari unit 3 and Ikata unit 2) was introduced and operator training by the advanced MCB was started at November 2008 as shown in Fig. 5.

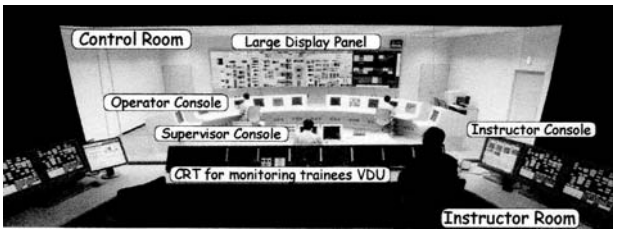

Fig. 5 Simulator Training at NTC

Operator Training by the advanced MCB has already been carried out at BWR Training Center Corp. (BTC) in Japan and training centers of EDF in France. Operator training at BTC and EDF are also reviewed to compare the influence caused by the difference in the design of the advanced MCB and the operating management system.

5.1 Training at NTC

The trainees from Tomari unit 3 and Ikata unit 1&2 are well trained about the plant system and operating procedure, because they used to work long time at the existing plant. Therefore, the training by the advanced MCB is focused on two main points.

- The screen selection of VDU could be carried out smoothly.

• The large display panel could be used effectively to share the plant information and diagnose plant status.

The observation from the simulator training suggests the followings.

• Instructors intend to prepare and use the training scenarios which are applied for the existing MCB, because they think that the kind and the frequency of the incidents/accidents occurred at the actual power plant are unchanged before and after the introduction of the advanced MCB.

• Operators face the simulator training in the same way and the same thinking exists for the MCB, because the numbers of each shift team crew, the responsibility and the roles of operators are unchanged before and after the introduction of the advanced MCB.

• Operators are strongly required for their independence in order to carry out their duties, because they can monitor, diagnose and respond to the plants condition by their VDUs. As a result, and to roughly speak the performance of the shift team depends on the capability of the individual operators.

• Operators can alter the selection of VDU screen with short training, because they are familiar with PC. Operators intend to grasp the plant status use by both the VDU and large display panel, and monitor all related parameters more than the integrated information and try to piece it all together.

• Supervisor intends to diagnose the plant status independently using by VDU for himself/herself. However, his/her workload management becomes more important than the existing MCB, because sharing the screen information of VDUs makes it easier than that of an operator assist the other operator.

Supervisor suggests the followings.

• It is easy to judge what operators monitor or try to operate from the operator's standing point of view and behavior without a report from operators in case of the existing MCB. However, in case of the advanced MCB, it is necessary to monitor the screen linked to operator's screen all of the time, because operators frequently select the various screen of VDUs at the same position.

• It is necessary to do all kinds of procedures to enforce the communication inside the shift team, because operators monitor and control the plant parameters on the screen of VDU with the uttermost concentration and attention.

• It is not easy for supervisor to memorize which screen is displayed and what matter needs attention, though young operators can select and perform with the screen of VDU smoothly.

5.2 Training at BTC

Simulator Training of ABWR at BTC has been carried out since June 1994. Training was based on the following characteristics of ABWR.

• The difference in the man-machine interface (MMI).

• The expansion of the automatic control system

Familiarization program was as follows:

• Classroom training of the knowledge and its basis of MMI

• Part simulator training of the changeover from the screen and touch operations which are actually interlinked with the simulator used.

• Total simulator training of the skills and the choices that the operation of the suitable screen that needs to be met in correspondence to the situation of the plant in the actual training scenario.

These conversion training was smoothly finalized. There is no need for any kind of trouble that was caused by the advanced MCB in the training experience of more than ten years at BTC. As for operators, the advanced MCB is the same as the existing MCB, if they are familiar with the selection screen and touch operation. The conservative design concept (basically, the existing indicatory instruments, switches and annuciators on the control board are transferred to the CRT/VDU or the large display panel) seems to contribute to this results.

5.3 Training at EDF

Conversion training of EDF was planned as following, because the eighty percent of N4 operators were moved from existing plant.

• Classroom training regarding the difference between N4 and existing plant.

• Simulator training is comparative to initial training course (Normal operation 17days, transient operation 13 days and accident operation 30 days).

These conversion training was also completed without

any troubles.

The system of shift team in EDF is a unique one. Supervisor works from being based at his office usually, and moves to the control room in case of abnormal condition or a call summons him. Operators diagnose the plant status and execute the necessary operation in accordance with computer-based procedure, even without the supervisor's direction.

The operator training by the advanced MCB at each training center is being carried out without any trouble, as well as by the existing MCB. As for the operators, most of them are converted from the existing plant and are often trained on only how to use the new devices, the VDUs and large display panel. Therefore, operators feel that it is easy to use the advanced MCB if it gets accustomed. Supervisor feels that the communications, the role of shift crews are different from the existing plant.

6 Summary

This paper summarizes the influence on the performance of operators along with the advanced MCB as follows.

First, the operating procedure is the document which conveys and reflects the thought of the designers into the actions of the operators and describes the performance of operators. The introduction of the advanced MCB seems to be bringing a change of the operating procedure. On the other hand, well-trained operators intend to give priority to their knowledge and experiences when they decide the methods of the operation.

Second, the requirement for operators is the knowledge, skill and attitude, and CRM skill. CRM skill makes use of the knowledge, skill and attitude and improves the team performance. The advanced MCB seems to induce a change of CRM skill i.e. the communication, decision making or problem solving, team building, situation awareness, and workload management of the shift team.

Third, the operator training is the best way to verify the change of the operating procedure and CRM skill. NTC starts the initial training course by the advanced MCB approach since February 2010. Initial training course is covered with the normal operation to the emergency operation. A wide range of trainees participate in this training course. And the continuous training course is prepared for operators to take two week simulator training every year. A lot of operators participate in the simulator training for the advanced MCB. A variety of training scenario is used at training center compared to the place of the verification of the advanced MCB. In addition, in the duration of training, operators and instructors reflect their mind and thoughts with each other about the operator's action, thinking, expressing their feeling and so on. Therefore, it is strongly required to continue the investigation of the influence of the advanced MCB on the performance of operators through the observation of the operator training.

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