Design of the Cognitive Information Display for Water Level Control of the Steam Generator in Korean Nuclear Power Reactor

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Abstract. This paper introduces a design of the cognitive information display using EID (Ecological Interface Design) for the water level control of steam generator in Korean advance nuclear power reactor. The concept of conventional display method in NPPs (Nuclear Power Plants) mainly relies on the SSSI (Single Sensor Single Indicator) design criteria; therefore, the conventional information display method employed a method based on the type of P&ID (Piping & Instrumentation Diagram). Due to the lack or excess of the information, the operators in NPPs could not understand the overall relationship between the objective and operator's control; it leads to be a human's cognitive decision burden and human error. In this paper, we propose the design method that applies the EID to the water level control of steam generator in advanced nuclear power reactor. This design method consists of the cognitive task analysis, the selection of the example task, the design of the example task, the feasibility evaluation. Proposed design method shows the effectiveness when developing the cognitive information display in NPPs. Also, this paper shows the further study points not only for applying the EID to real NPPs, but also for applying the EID to ubiquitous maintenance applications in real NPPs to overcome the lack of the information due to small screen.

Keywords: Cognitive Information Display; Ecological Interface Design; Advanced Power Reactor; Ubiquitous maintenance; Nuclear Power Plants

1 Introduction

An advanced digital MCR (Main Control Room) and I&C system are being applied to Korean advanced power reactor as digital techniques have improved. Also, in order to enhance the safety and human reliability in NPPs (Nuclear Power Plants), advance MMI (Man Machine Interface) based on the human's awareness has been widely studied. The MMI display for the APR1400(Advanced Power Reactor 1400MWe) MCR only relies on physical design basis such as the SSSI (Single Sensor Single Indicator) design criteria as shown in Fig. 1; therefore, the conventional information display method employed a method based on the type of P&ID (Piping & Instrumentation Diagram) on which sensor values directly indicated. In the case that the operators reach at the lack of information in the conventional personnel workstation; it leads to be a human error due to operator's poor understanding of the overall relationship between the objective and operator's control. Also, in the case of excess of the information in the LDP (Large Display Panel), it is difficult for the operator to find the proper information; it leads to the operator's burden[1]. Because the operator cannot get the insight from the conventional display and directly indicated values, integration of the information and decision could be an operator's cognitive burden. EID (Ecological Interface Design) is used to represent the internal process of human brain; therefore, it could be a method to reduce the operator's cognitive burden and human error. In this paper, we propose the design method that applies the EID to the steam generator and pressurizer water level control in advanced power reactor. This design method consists of the cognitive task analysis, the selection of the example task, the design of the example task and the feasibility evaluation.

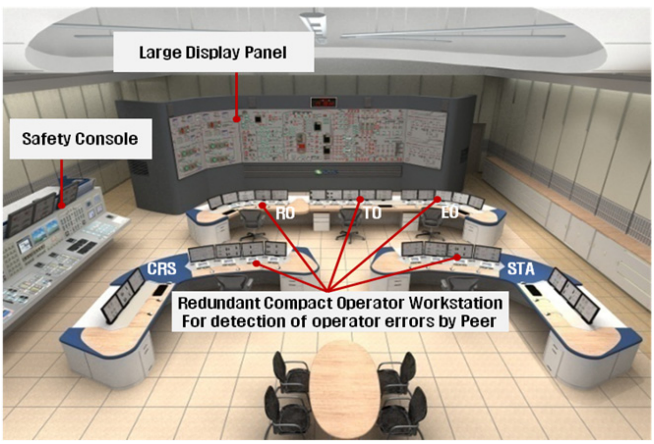

Fig. 1. Information display in APR1400 MCR

Also, this paper shows the further study points not only for applying the EID to real NPPs, but also for applying EID to ubiquitous maintenance applications in real NPPs to overcome the lack of the information due to small screen.

2 Related Work

The EID concept and its formalized approach, which is SRK taxonomy (: Skill-based, Rule-based, Knowledge-based) and AH (Abstraction Hierarchy), originated in a systematic form for the interface design of large and complex system [2]. When the abstracted information which represents on the AH gives visually to the operator, it could be an operational effectiveness at diagnosing and controlling the plant system [3]. In [4, Burns], the experiment for the information display by EID on the nuclear plant simulator shows the better situation awareness performance than the one of conventional information display [4].

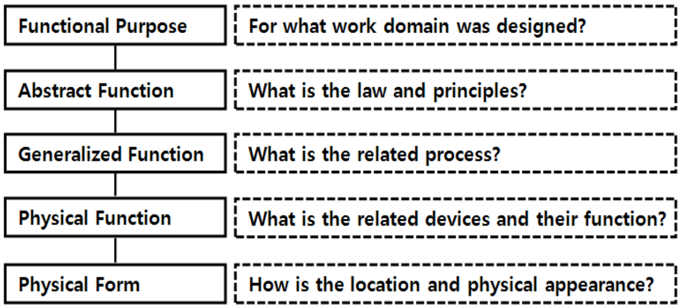

Fig. 2. Five level of abstraction hierarchy

We surveyed the application examples using EID. Most application examples have focused on the simulation and feasibility evaluation; it means that EID is rarely implemented in the real system beyond the simulator. The reasons why it is difficult to implement in the real field are that (1) the information display form is not established, (2) new EID information display design have the burden to retrain up the operator[1]. After designing the information display by EID, the feasibility evaluation is the most important to raise the performance of the information display. As shown in Figure 3, FIP (Functional Information Profile) was used to evaluate the EID design of pasteurizer [5].

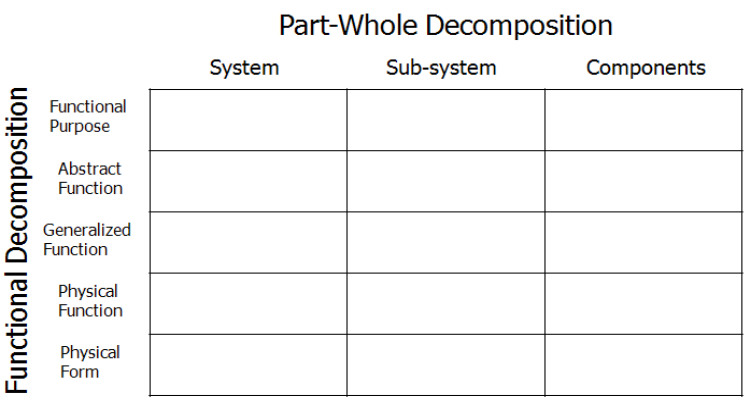

Fig. 3. Composition of the FIP

Burns (2002) validate the work domain model by training scenario [5] and Marmaras (2004) used the work-through method based on the scenario [6].

3 Proposed Design Method

The overall procedure of the proposed design method is shown in Table. 1, which consists of 5 steps (: Task selection, Cognitive task analysis, Scenario analysis, Design and evaluation of examples and Establishment of information display standard).

Table 1. Overall procedure of the proposed design method

Step	Activity	Details
1	Task selection	-
2	Cognitive task analysis	• Work domain analysis • Task analysis
3	Scenario analysis	• Procedure analysis • Expert consultant, Accident analysis
4	Design and evaluation of exam ples	• Display object analysis • Design of examples • Feasibility evaluation of examples
5	Establishment of information display standard	• Design of group verbal communication method • Style guide

3.1 Cognitive task analysis

The purpose of cognitive task analysis is to review the cognitive structure and process. In this paper, we conduct the cognitive task analysis (: work domain analysis, task analysis). The work domain analysis is conducted to decompose the task regarding steam generator control as shown in Fig. 4-6.

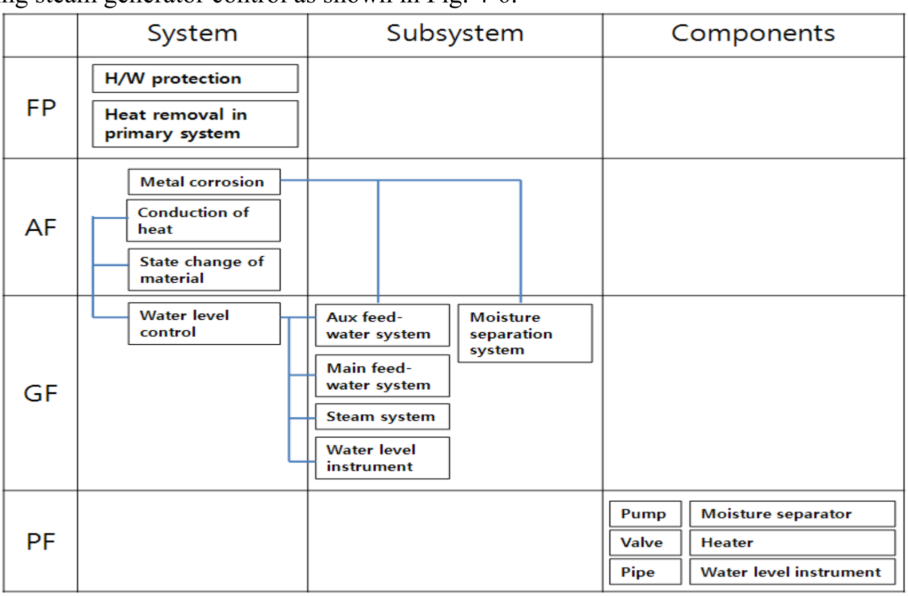

Fig. 4. FIP decomposition for water level control process of the steam generator

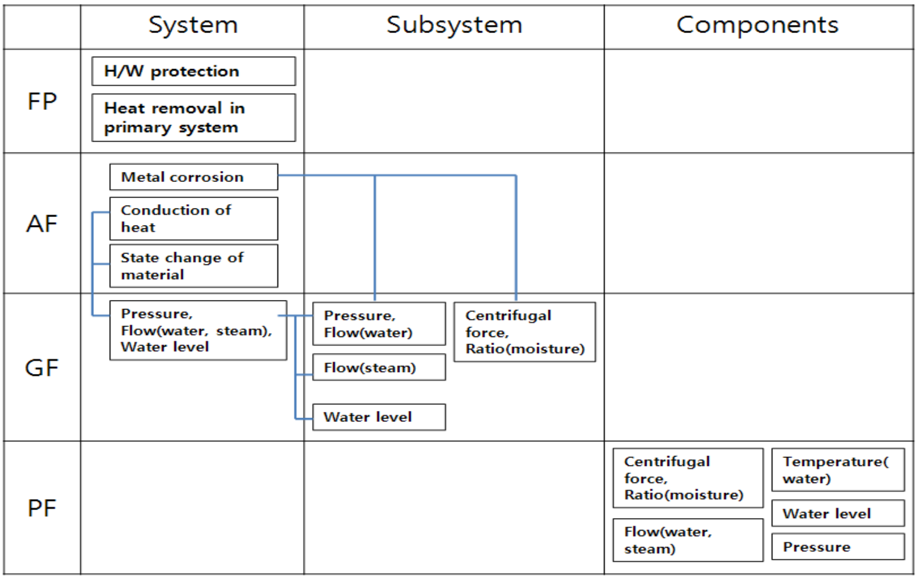

Fig. 5. Requirement driven from steam generator FIP

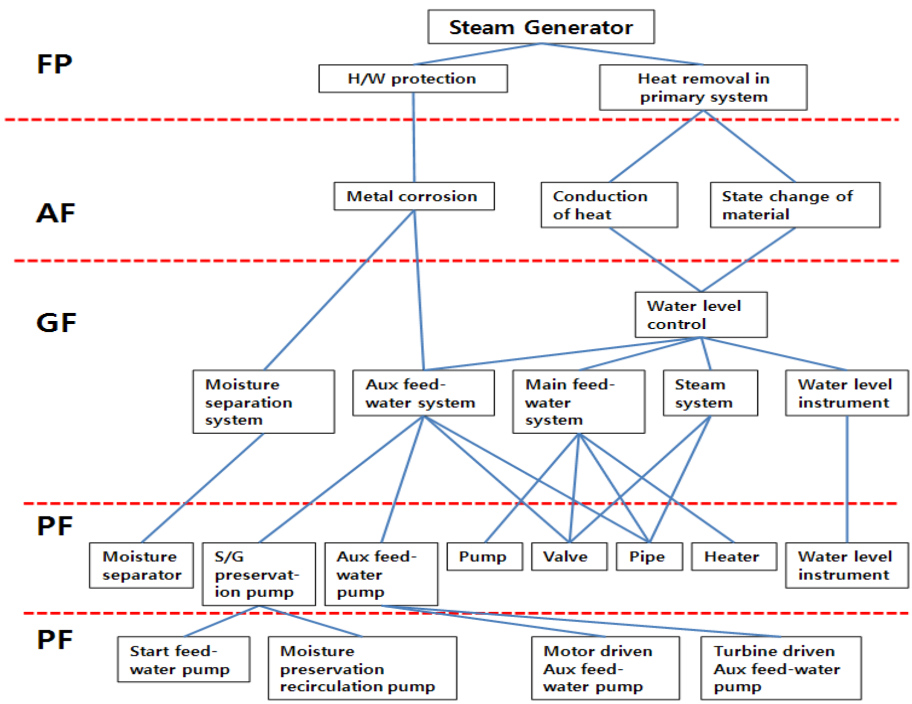

Fig. 6. Abstraction hierarchy for water level control of the steam generator

Also, we conduct the three-type task analysis on the basis of Younggwang NPP unit #5 & 6 EOP(Emergency Operating Procedure). The result of task analysis for Reactor Trip, LOCA(Loss of Coolant Accident) and SGTR(Steam Generator Tube Rupture) shows the similarity to the result of cognitive task analysis.

3.2 Scenario analysis

The purpose of scenario analysis is to establish the information requirement. We conduct the procedure analysis on the basis of Uljin NPP unit #5 & 6 EOP, AOP(Abnormal Operating Procedure) and SOP (System Operating Procedure). Also, the expert consultant is implemented for the operation of the steam generator control as follows,

- the possibility of reactor trip from the water control of steam generator
- the task change according to automatic control of the steam generator
- the system variables for the operator during manual control
- the role of auxiliary feed water system on the task of water control of the steam generator

The accident analysis is conducted using the accident data which was taken from Korean NPPs from 2002 to 2011. Three accidents, which are related to the human error of water control, were reviewed.

3.3 Design of example

In the conventional information display in Fig. 7, the flow vales of main feed water and main steam are indicated on the P&ID display. The operator's control means for the water control of steam generator are down-comer valve, economizer valve and the velocity of main feed water pump. In order to control by those, operator should clicks the object to load the soft control display.

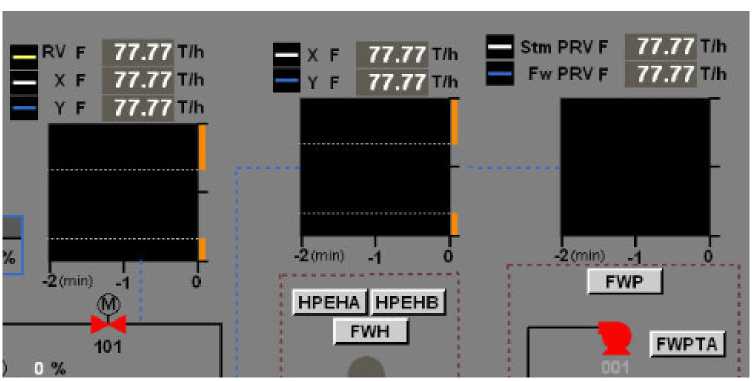

Fig. 7. Information display example of main feed water based on the P&ID

Fig. 8 shows not only the own values of feed water/steam, but also the difference/direction between the feed water flow and steam flow. The difference or direction is the abstract information not acquired from sensor; the operator can predict the water level of steam generator. The left bar means the feed water flow and the right bar means the steam flow. The direction of the arrow means that the water level of steam generator will be lower, and difference means the amount of change. The reference point means the idle point, which is an equilibrium level at which the two flows are the same, requested by the control system. The reference point can give the effect to reduce the operator's cognitive burden. Also, the left bar represents the economizer flow and down-comer flow respectively; the operator can confirm the distribution of the feed water flow according to the reactor power.

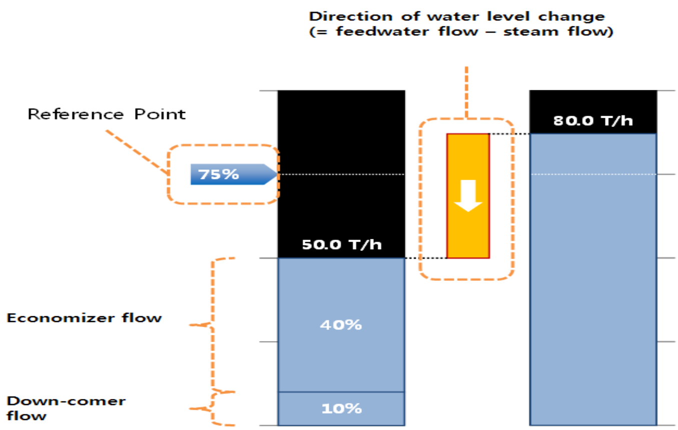

Fig. 8. Graph example of feed water and steam based on EID

Fig. 9 shows the soft controller in the VDU(Visual Display Unit) based on conventional P&ID. Due to the parallel disposition of conventional soft-controller display and the lack of plant information, it could not give the intuitive sight and overall relationship between objective and operator's control. The conventional soft controller shows the SP(Set point), PV(Process value), OP(Output demand) respectively.

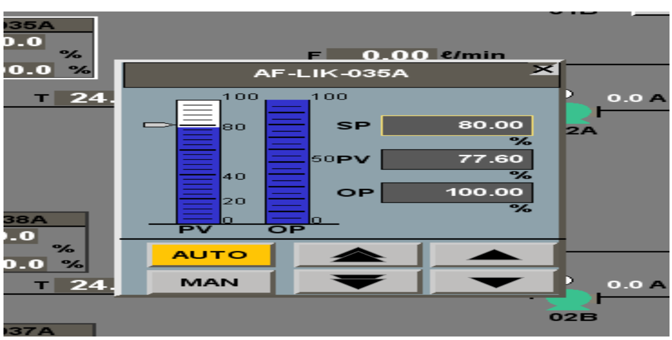

Fig. 9. Soft controller example based on conventional P&ID

Fig. 10 shows the soft controller example based on EID, and includes not only SP, PV(: feed water flow), OP(: valve open rate) respectively but also the relationship between above three values. While there are only up/down buttons in conventional soft controller, the sliding icon is employed to control the input more intuitively.

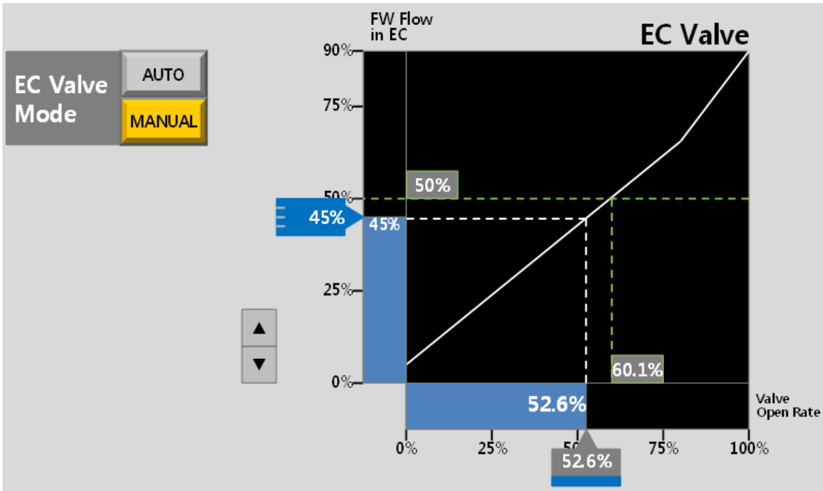

Fig. 10. Soft controller example based on EID

3.4 Consideration for applying EID to ubiquitous maintenance applications

In the industrial field as well as NPPs, there are many studies to apply ubiquitous techniques to the area of maintenance, e.g., logging, status checking, control, etc. The mobility from ubiquitous environment is the best advantage specially in the wide area such as NPPs. When maintained the complex systems in NPPs, the understanding of the overall relationship is the most important factor to maintain systems by ubiquitous devices; moreover, the device identification should be added to the display of the ubiquitous device. Considering the small screen of ubiquitous devices, we should consider further study points as shown below.

- Identification method for the proper target system for maintaining
- Design method of ubiquitous display considering portability and small screen
- Integration of P&ID display and EID to overcome the mode error(: integration method might be useful in the maintenance area of complex system)

4 Conclusion

In this paper, we introduce a design method of the cognitive information display for the water level control of steam generator, which is made up of the task selection, the cognitive task analysis, the design and evaluation of examples, the establishment of information display standard for applying the EID to real NPPs in Korea. The evaluation of the examples and the evaluation of information display standard will be carried out after the design of examples is completed. Though design experience for the cognitive information display in NPPs, we have found improvement points for a further study as summarized below.

- Feasibility evaluation of the designed example by operation expert,
- Design to consist of the monitoring function without cognitive burden, quick and accurate control function during manual operation,
- Design to reduce the mode error (e.g., proper composition of cognitive and physical information display).

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