Development of Information Displays based on Severe Accident Management Guidelines and R.G 1.97 rev.5

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1. Introduction

Public concerns and worries about severe accidents of nuclear power plants (NPPs) have been relighted since the Fukushima nuclear accident in 2011. One of the reasons the Fukushima nuclear accident cannot not be prevented is that the human operators were not able to obtain the appropriate accident mitigation information due to the loss of vital power which results in the instrumentation and control (I&C) systems inoperable.

To this end, new I&C system called nuclear black box that can be survived in extreme environments (i.e., high temperature, high radiation, flooding, and so on) has been developed by KAERI to overcome the vulnerabilities of existing I&C systems. Moreover, the associated information displays that provide monitoring and control information acquired from the nuclear black box have been also developed.

In this paper, the development process and result of the information displays based on the severe accident management guidelines (SAMGs) and regulatory guide (R.G) 1.97 rev.5 are explained.

2. Information Displays based on SAMGs and R.G 1.97 rev.5

The information displays developed in this study are considered following aspects:

- HSI Inventory Analysis for the SAMGs
- Information Display Structure based on the SAMGs
- Information Display for Type F variables in the R.G 1.97 rev.5
- Multi-unit Monitoring Strategies

2.1 HSI Inventory Analysis for SAMGs

The SAMGs consists of the following guidelines as shown in Table 1 [1].

Table 1: Categories of SAMGs

Doc. No.	Title
Emergency-01	Severe Accident MCR Guide
Control-01	Diagnostic Flow Chart
Mitigation-01	Inject into SG
Mitigation-02	Depressurize RCS
Mitigation-03	Inject into RCS
Mitigation-04	Inject into Cavity
Mitigation-05	Reduce Fission Product Release
Mitigation-06	Control Containment Conditions
Mitigation-07	Reduce Containment Hydrogen
Monitoring-01	Long-term Monitoring
Termination-01	Termination of SAMG

In order to develop the information displays based on the SAMGs, Control and Mitigation guidelines were selected as the target guidelines. All HSI inventories described in the Control-01 and Mitigation-01 to 07 were analyzed. The example of HSI inventory analysis for Mitiation-03 (Inject into RCS) is shown in Table 2.

Table 2: HSI Inventory for Mitigarion-03 (Inject into RCS)

Inventory	Inform.	Control
SI-PP02A		v
SI-PP02B		v
SI-PP01A		v
SI-PP01B		v
CS-PP01A		v
CS-PP01B		v
RWST level	v	
SUMP level	v	
RC-PP01A		v
RC-PP01B		v
RC-PP02A		v
RC-PP02B		v
SG level	v	
CV-PP01		v
CV-PP02		v
CV-PP03		v
VCT level	v	
CTMT H_2 Con.	v	
RCS pressure	v	
CET	v	
RCS Temp.	v	
RV level	v	
Neutron flux	v	
CTMT level	v	
CV-V531		v
CV-V530		v
SI-V675		v
SI-V676		v
CV-V536		v
CV-V534		v
CV-V501		v
CV-V504		v
Etc.	-	-

The results of HSI inventory analysis for the SAMGs were utilized as the input data for the information display development. For example, what kinds of information and what kinds of controllers are essential

to perform each mitigation guideline were defined in this development phase. However, the number of information displays does not need to be same as the number of mitigation guidelines. Detailed information display structure is explained in Section 2.2.

2.2 Information Display Structure based on SAMGs

Basically, the information display structure is designed to monitor and control multi-unit NPPs. In order to monitor and control multi-unit NPPs, the navigation display which is not presented in the normal plant condition is provided as shown in the upper part of Fig. 1. In this study, the information display structure consists of the following displays.

- Navigation display
- Overall status display for multi-unit NPPs,
- Main screen for each unit,
- Detailed system display for each unit,
- Type F variable information display for each unit

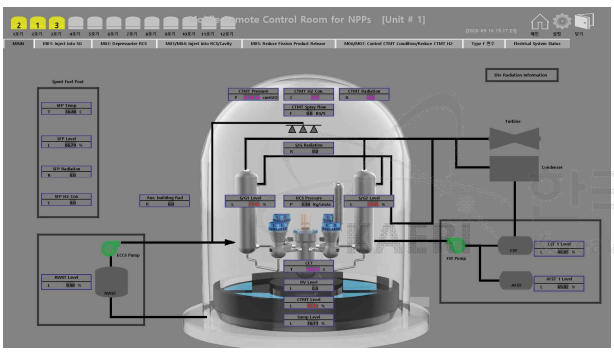

Fig. 1. Main display of information displays based on SAMGs

Among the many displays, detailed system displays for each unit are developed based on the HSI inventory analysis explained in Section 2.1 and the associated P&IDs. Fig.2 and 3 shows two detailed system displays based on HSI inventory analysis of Mitigation-01 and 02, respectively

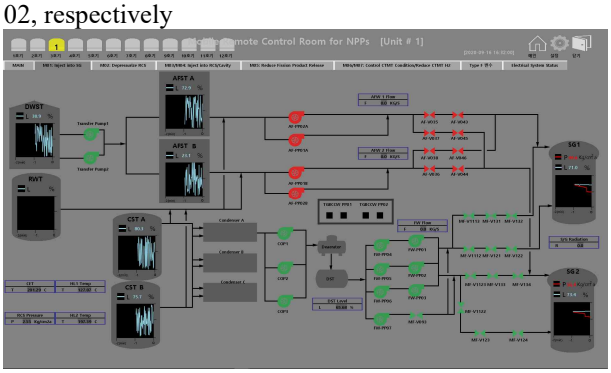

Fig. 2. Detailed system display for Mitigation-01

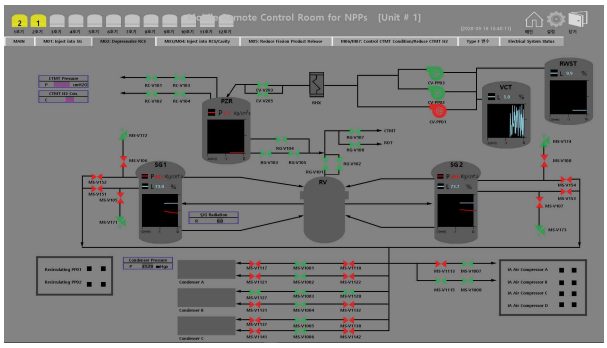

Fig. 3. Detailed system display for Mitigation-02

For the detailed system display for each unit, total 5 displays are developed as follows

- M01: Inject into SG
- M02: Depressurize RCS
- M03/04: Inject into CTMT/Cavity
- M05: Reduce Fission Product Release
- M06/07: Control CTMT Condition/Reduce CTMT H2

2.3 Information Display for Type F variables in R.G 1.97 rev.5

In the R.G 1.97 rev.5 [2], it is required that Type F variables should be provide information on fuel damage and the effects of fuel damage under severe accident conditions. Moreover, in IEEE 497-2016 [3], Type F variables are defined as “variables that provide primary information to accident management personnel to indicate fuel damage and the effects of fuel damage” and the selection of Type F variables should be “the selection of these variables represents a minimum set of plant variables that provides the most direct indication of the parameters needed to execute the SAMGs and/or variables needed to mitigate those accidents postulated in a plants severe accident analysis.”

Although there is no domestic Korean NPPs that endorse R.G 1.97 rev.5 resulting that Type F variables have not been defined yet, according the above definition and selection criteria, Type F variables would be defined as the sub-set of the variables in the SAMGs. In this study, therefore, the space for type F variable display is only designed so far as show in Fig. 4.

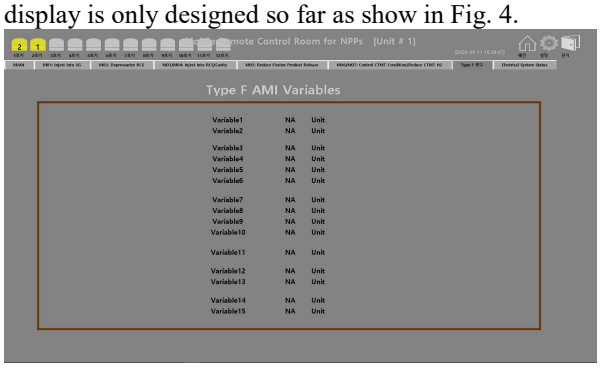

Fig. 4. Information Display for Type F variables

2.4 Multi-unit Monitoring Strategies

There are several process parameters more important than the others in the SAMG such as the parameters to confirm the diagnosis of severe accident status. These important parameters are provided to the human operators in the spatially dedicated position with their importance/severity to monitor multi-unit simultaneously. The severity of these monitoring parameters is defined using the setpoints described in the SAMGs. Fig. 5 shows the important parameter monitoring display for multi-unit monitoring with application of their severity criteria referred by SAMGs.

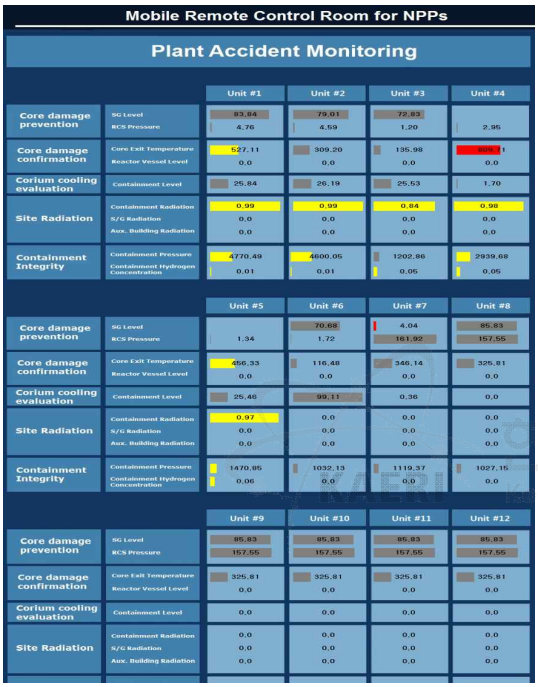

Fig. 5. Important parameter monitoring display

In addition, most of the information displays in this study were designed for multi-unit control and monitoring. In order to efficiently control and monitoring the multi-unit NPPs under severe accident condition, it is necessary for the operators to prioritize multi-unit as the important order. In this light, the priority unit selection logic was provided using specific monitoring parameters and their setpoints in the SAMGs. Basic rules for the priority unit selection logic are based on the general accident phenomena. Table 3 shows the suggested priority unit selection logic.

Table 3: Priority unit selection logic

	Parameter	Criteria	Decision
1	CET	CET1>371.1	
2	CET	CET2>648.9	
3	Site Radiation	Site Rad. = Y/N Site Rad.= 0 or 1	In case, more than 2 units are over CET2, Apply this criteria
4	Containment	CP1>1336cmH	In case, more than
	Pressure (CP) Containment Hydrogen Concentration (CH)	2O & CH2>5%	2 units are over CET2 criteria, and Site Rad criteria Apply this criteria
5	Containment Pressure (CP) Containment Hydrogen Concentration (CH)	CP2>8577.5cm H2O & CH2>5%	In case, more than 2 units are over CET2 criteria, Site Rad criteria, and CP1 criteria Apply this criteria
6	CET	CET value	In case, more than 2 units are over CET2, CP, CH, Site Rad criteria, Apply this criteria

Based on the priority unit selection logic, navigation display provides the priority order of multi-unit automatically as shown in the upper part of Fig. 1. (Priority number with yellow coding indications)

3. Discussion and Conclusion

The information displays in this study were developed based on the SAMGs considering the multi-unit monitoring and R.G 1.97 rev.5. Since the emergency preparedness and response in emergency operations facility (EOF) during the severe accident are still performed using the information of information processing system (IPS), the severe accident specific information displays developed in this study possibly contribute the severe accident management. However, there are several things that should be resolved to finalize information display development in this study.

- Type F variable selection with corresponding professional group.
- Full scope human factors verification and validation
- Interface with I&C systems

REFERENCES

[1] Severe Accident Management Guidelines
[2] Criteria for Accident Monitoring Instrumentation for Nuclear Power Plant, Regulatory Guide 1.97 Rev.5, 2019.
[3] IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations, IEEE Standard 497, 2016