Human Performance Evaluation when using Human System Interface applying Priority Unit Selection Logic for Responding Multi-Unit Severe Accidents

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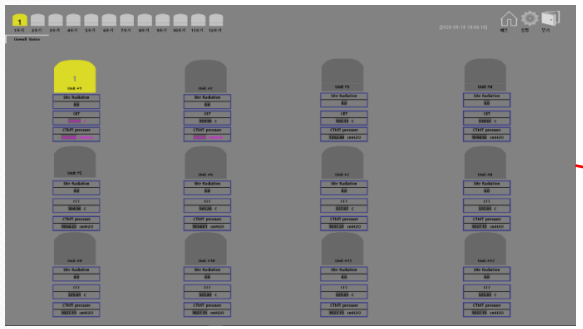
CONTENTS

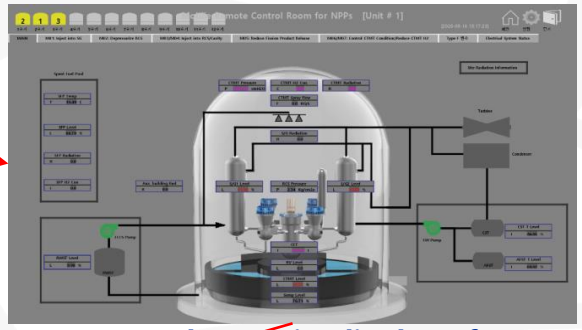
01 Introduction

Previous Works

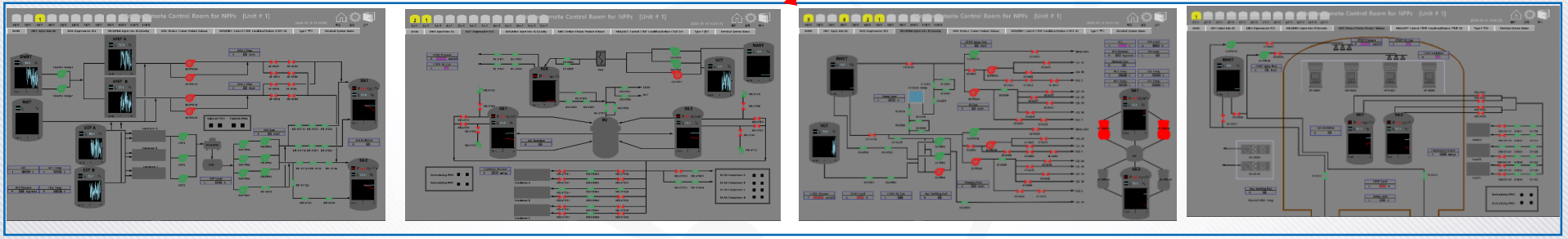
- In order to mitigate multi-unit severe accidents efficiently, Korea Atomic Energy Research Institute (KAERI) has developed the information displays based on task analysis results of severe accident management guidelines (SAMGs).



<Level 1: Overall status display for multi-unit NPPs>



<Level 2: Main displays for each unit>



<Level 3: System based displays>

01 Introduction

Previous Works

- During the development phase for the information displays, a priority unit selection logic for responding multi-unit severe accidents was applied as one of the multi-unit monitoring strategies.
  - Priority Unit Selection Logic: the priority unit selection logic automatically selects the units that have to be monitored and controlled as an important order.

- In addition, using the various simulated instrumentation signal, the implementation of the priority unit selection logic on the information displays was verified.

- However, the improvement of human performance when using the human system interface (HSI) applying the priority unit selection logic has not been validated yet.

01 Introduction

Objective of this Study

- ① Investigation of deviation of the human performance with and without applying the priority unit selection logic
  - The situation awareness scores are measured when the human system interface (HSI) applying the priority unit selection logic is provided and not provided.

- ② Human performance evaluation for new human system interface (HSI)
  - (Using the results of activity ①) Human performance is evaluated when using the information displays applying the priority unit selection logic for responding multi-unit severe accidents in order to validate the priority unit selection logic has positive effects on improving the human performance.

02 Priority Unit Selection Logic

Priority Unit Selection Logic

- The priority unit selection logic applied to the information displays is based on the specific monitoring parameters and their setpoints from the SAMGs.
- The priority unit selection logic automatically selects the units that have to be monitored and controlled as an important order.

<Priority Unit Selection Logic>

Priority	Variable	Criteria	Priority Decision
1	CET	CET1 > 371.1°C	Priority is given to the unit exceeding the setpoint of CET1
2	CET	CET2 > 648.9°C	When two or more units exceed the setpoint of CET1, priority is given to the unit exceeding the setpoint of CET2
3	Site Rad (CTMT Rad.)	Site Rad = Y/N (Site Rad = 0 or 1)	When two or more units exceed the setpoint of CET2, priority is given to the unit exceeding the setpoint of Site Rad (CTMT Rad.)
4	CTMT Pressure (CP)	CP1 > 1336cmH_2O	When two or more units exceed the setpoint of CET2 and Sit Rad, priority is given to the unit exceeding the setpoint of CP1
5	CTMT Pressure (CP)	CP2 > 8577.5cmH_2O	When two or more units exceed the setpoint of CET2, Sit Rad, and CP1, priority is given to the unit exceeding the setpoint of CP2
6	CET	CET value	When two or more units exceed the setpoint of CET2, Sit Rad, CP1, and CP2, priority is given to the unit having the highest CET value

02 Priority Unit Selection Logic

Principle of Priority Unit Selection Logic

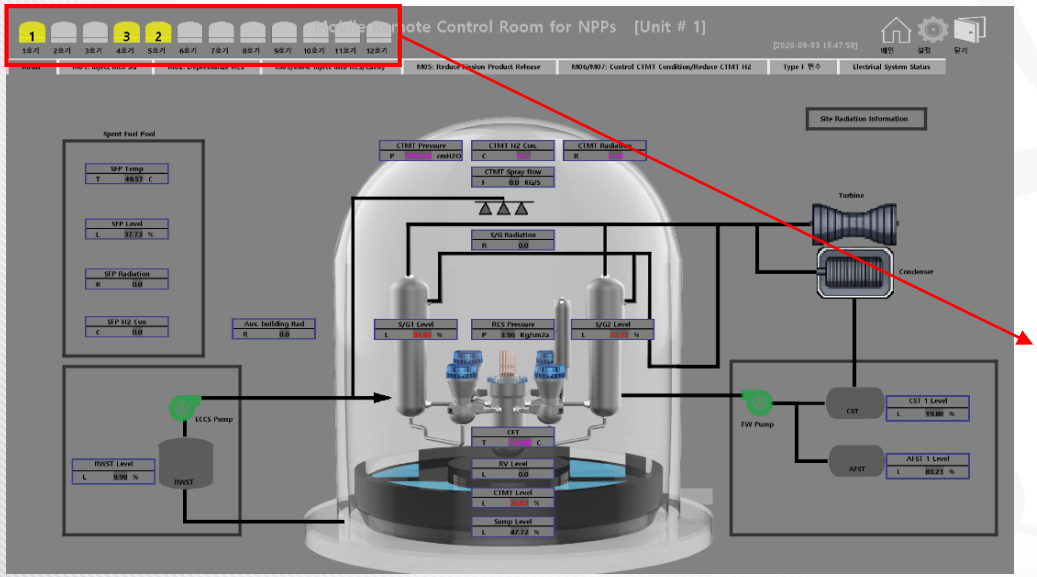
- As shown in Table of previous slide, the priority unit is selected based on three process parameters such as core exit temperature (CET), containment radiation (CTMT Rad.), and containment pressure (CTMT pressure).

- With those three parameters, six priority selection criteria based on the key setpoint of each parameter in SAMGs are suggested.
  - In case that, any unit exceeds 371.1°C of CET, the priority is given to this unit.
  - In case that, more than two units exceed 371.1°C of CET, the next priority criteria (648.9°C of CET) is applied to the associated units.
  - In case that, more than two units exceed 648.9°C of CET, the third priority criteria (whether or not the containment radiation is appeared) is applied to the associated units.
  - In case that, more than two units exceed the five priority criteria from the first to fifth criteria, the unit that has the highest CET is determined as the unit that has to be monitored first.

03 Information Displays applying Priority Unit Selection Logic

Information Displays applying Priority Unit Selection Logic

- The suggested priority unit selection logic is applied to the information displays using the color and numeric coding.
  - In case that, any unit exceeds the setpoint of criteria, the color coding (yellow warning) is provided to the associated units as shown in upper part of Figure below.
  - In addition, if two or more units exceed the identical setpoint, the units that have to be monitored as the important order (numeric coding in Figure below) are selected using the priority unit selection logic as explained in the previous slides.



<Examples>

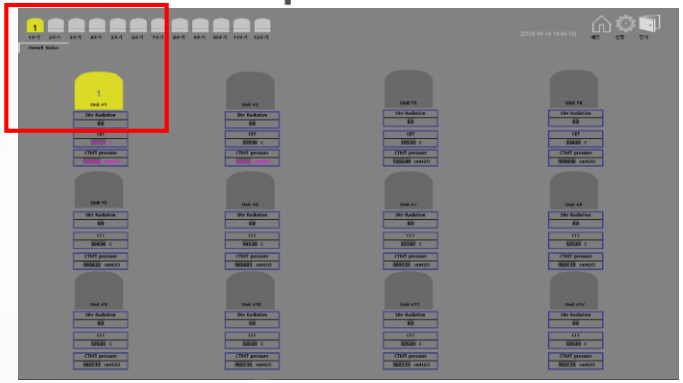
Alarm provision: any unit that exceeds the predetermined setpoint of CET is alerted using color coding.

Prioritization: in case of two or more units exceed the CET setpoint, the prioritization logic provides numeric coding for units that need to be monitored first.

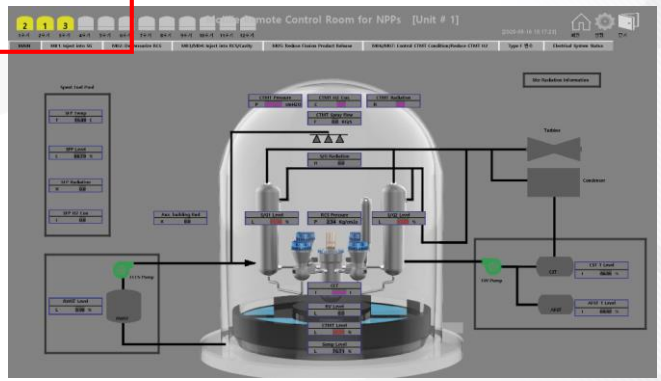
03 Information Displays applying Priority Unit Selection Logic

Information Displays applying Priority Unit Selection Logic

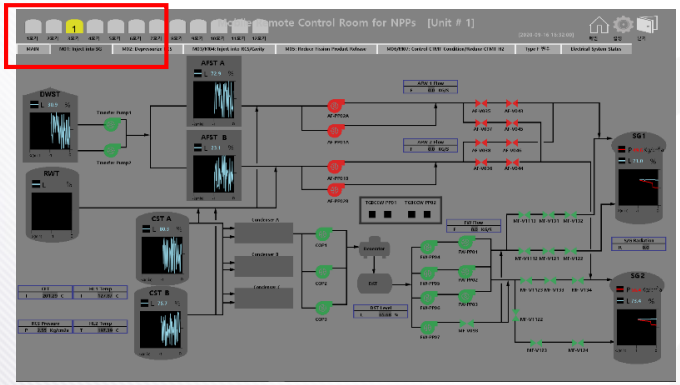
- The priority unit selection logic is applied to the all information displays regardless of the level of information displays.
  - The human operators are able to confirm the result of priority unit selection on any displays.



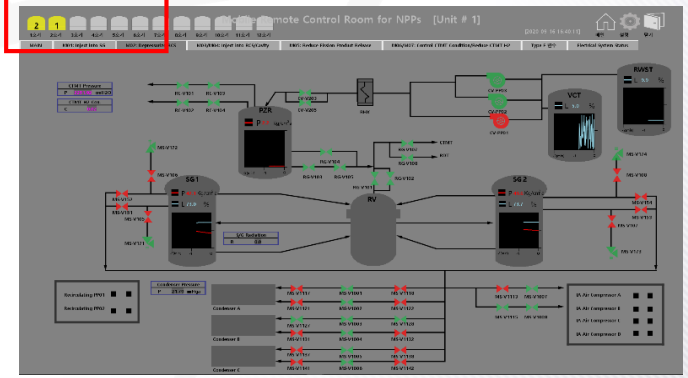
<Level 1: Overall status display for multi-unit NPPs>



<Level 2: Main displays for each unit>



<Level 3: Inject into SG>



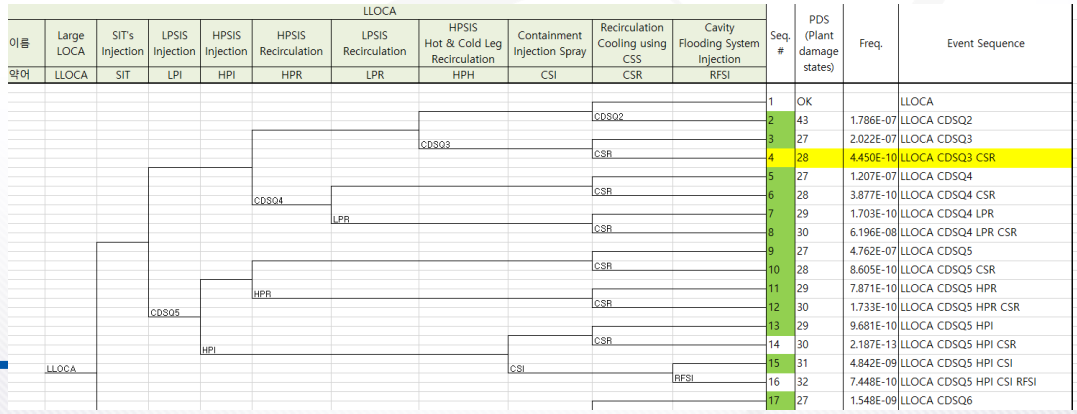
<Level 3: RCS depressurization>

04 Human Performance Evaluation

Experiment Scenario

■ Simulation of Multi-Unit Severe Accidents

- It was assumed that the severe accidents occurs at seven nuclear power plants (NPPs) independently to simulate the multi-unit severe accidents, satisfying with the experiment scenarios of human performance evaluation in this study (even though the probability of independent severe accidents is very low)
- The initial events of these severe accidents consist of
  - large loss of coolant accident (LOCA), medium LOCA, small LOCA
  - loss of off-site power (LOOP), station blackout (SBO)
  - steam generator tube rupture (SGTR),
  - loss of all feedwater (LOAF)
- In case of large LOCA, the fourth sequence in Figure below is considered as one of the severe accidents.



이름	Large LOCA	SIT's Injection	LPSIS Injection	HPSIS Injection	HPSIS Recirculation	LPSIS Recirculation	HPSIS Hot & Cold Leg Recirculation	Containment Injection Spray	Recirculation Cooling using CSS	Cavity Flooding System Injection	Seq. #	PDS (Plant damage states)	Freq.	Event Sequence
약어	LLOCA	SIT	LPI	HPI	HPR	LPR	HPH	CSI	CSR	RFSI				
											1	OK		LLOCA
											2	43	1.786E-07	LLOCA CDSQ2
											3	27	2.022E-07	LLOCA CDSQ3
											4	28	4.450E-10	LLOCA CDSQ3 CSR
											5	27	1.207E-07	LLOCA CDSQ4
											6	28	3.877E-10	LLOCA CDSQ4 CSR
											7	29	1.703E-10	LLOCA CDSQ4 LPR
											8	30	6.196E-08	LLOCA CDSQ4 LPR CSR
											9	27	4.762E-07	LLOCA CDSQ5
											10	28	8.605E-10	LLOCA CDSQ5 CSR
											11	29	7.871E-10	LLOCA CDSQ5 HPR
											12	30	1.733E-10	LLOCA CDSQ5 HPR CSR
											13	29	9.681E-10	LLOCA CDSQ5 HPI
											14	30	2.187E-13	LLOCA CDSQ5 HPI CSR
											15	31	4.842E-09	LLOCA CDSQ5 HPI CSI
											16	32	7.448E-10	LLOCA CDSQ5 HPI CSI RFSI
											17	27	1.548E-09	LLOCA CDSQ6

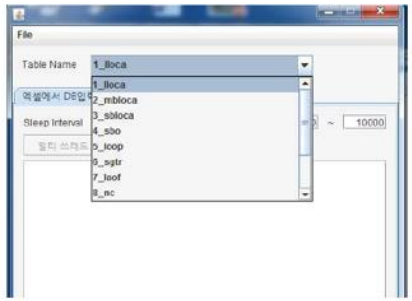
04 Human Performance Evaluation

Experiment Scenario

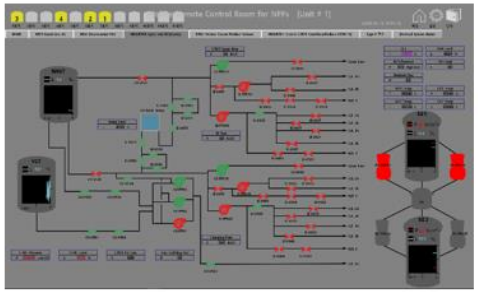
■ Simulation of Multi-Unit Severe Accidents

- For the human performance evaluation responding multi-unit severe accidents, the process variables of each initial event were obtained from the accidents analysis and these process variables were utilized as the multi-unit severe accident simulations.

<Severe Accident Simulation DB>



<DB Update Program>



<Scenario Simulation>

04 Human Performance Evaluation

Performance Measure

Situation Awareness Rating Technique (SART)

- The SART is a quick and easy self-rating situation awareness (SA) measurement technique.
- The SART consists of the three groups of dimensions such as demands on attentional resources (D), supply of attentional resources (S), and understanding of the situation (U).
  - D: a combination of complexity, variability and instability of the situation
  - S: a combination of arousal, focusing of attention, spare mental capacity and concentration of attention
  - U: a combination of information quantity, information quality and familiarity of the situation
- Each question is rated by the subjects as a likert scale of 1 to 7 (1=low, 7=high) and total SA is calculated using the following formula

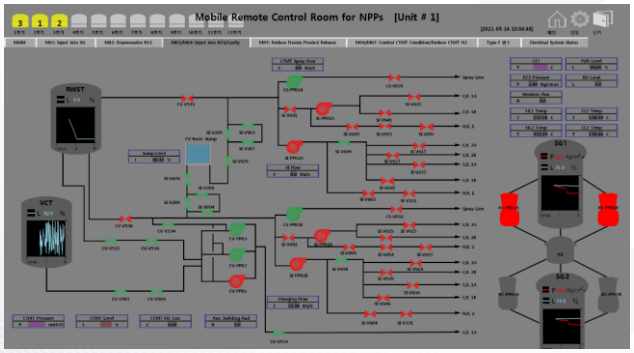
$$SA = U - (D - S)$$

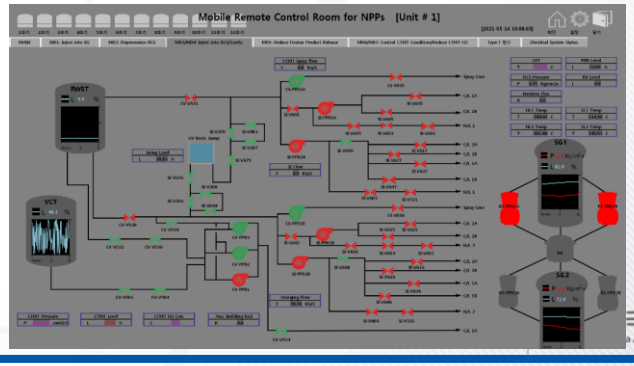
  - The range of SA score can be obtained from -14 (minimum) to 46 (maximum) according to the formula above.

04 Human Performance Evaluation

Experiment Implementation

- The purpose of human performance evaluation in this study is
  - to confirm whether or not the support function such as the priority unit selection logic has a positive effect on the human performance.
- Participants
  - Ten subjects working at the nuclear energy-related organization participated in the human performance evaluation test using the prepared experiment scenarios
- Measurement
  - The subjects' situation awareness are measured by using SART when the support function of priority unit selection logic is provided and not provided.
  - Figures below represent the HSI with and without the support function of priority unit selection logic during the scenario simulations.





04 Human Performance Evaluation

Evaluation Results

■ Results of Situation Awareness Measurement (2-set of SA score)

			S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
SA score without support function (SF)	1	instability of situation	4	5	5	5	6	6	7	6	6	6
	2	complexity of situation	5	6	5	7	6	6	5	6	6	6
	3	variability of situation	5	6	5	6	6	7	6	7	5	6
	4	arousal	6	3	5	7	3	3	5	2	6	5
	5	concentration of attention	5	6	6	6	4	2	7	5	6	5
	6	division of attention	3	1	2	1	1	1	2	1	2	3
	7	spare mental capacity	2	1	2	1	2	1	5	2	2	3
	8	information quantity	3	2	4	7	6	2	1	6	4	4
	9	information quality	4	2	2	4	6	1	5	2	4	4
	10	familiarity with situation	4	4	4	4	2	2	4	4	3	5
		Total SA	**13**	**2**	**10**	**12**	**6**	**-7**	**11**	**3**	**10**	**11**
SA score with support function (SF)	1	instability of situation	1	6	4	3	6	1	7	1	2	2
	2	complexity of situation	1	7	4	3	6	1	5	2	1	3
	3	variability of situation	2	7	5	2	6	1	6	2	5	4
	4	arousal	2	5	6	4	5	7	7	6	2	5
	5	concentration of attention	2	6	6	4	6	7	5	6	4	5
	6	division of attention	6	6	6	4	5	7	6	6	6	6
	7	spare mental capacity	7	6	6	5	6	6	6	7	6	6
	8	information quantity	5	6	7	7	7	6	5	7	6	6
	9	information quality	6	6	6	4	7	7	6	7	7	5
	10	familiarity with situation	4	4	4	4	2	6	4	6	5	5
		Total SA	**28**	**19**	**28**	**24**	**20**	**43**	**21**	**40**	**28**	**29**

Evaluation Results

Paired sample t-test

- In order to validate the mean difference between two sets of SA scores, the paired sample t-test was performed as shown in Table below.

	Paired Differences			t	df	Sig. (2-tailed)
	Mean	SD	Std Error Mean			
Pair 1: w/o SF - w/ SF	**-20.9**	12.59	3.98	**-5.249**	9	**0.001**

- Based on the result of paired sample t-test, the absolute value of ' t ' is larger than 1.96 and p-value is smaller than 0.05, it is possibly said that mean difference between two sets of SA scores is statistically meaningful (the subjects' mean situation awareness can be improved about 20.9 based on the SART standard)
- This result implies that that the support function of priority unit selection logic is helpful to improve the human performance when the subjects are monitoring the multi-unit severe accidents.

05 Summary

- From the previous works, the information displays were developed to mitigate multi-unit severe accidents, but its effectiveness in terms of human performance has not been validated.
- In this study, the effectiveness of information displays applying the priority unit selection logic for responding multi-unit severe accidents were validated by human performance evaluation.
  - The priority unit selection logic automatically selects the units that have to be monitored and controlled as an important order.
  - The human operators are able to confirm the result of priority unit selection on any displays.
- For the human performance evaluation, it was assumed that the severe accidents occurs at seven nuclear power plants (NPPs) independently.
  - The process variables of each severe accident were obtained from the accidents analysis and these process variables were utilized as the multi-unit severe accident simulations.
- In order to evaluate the human performance in the experiments, the situation awareness rating technique (SART) was used.
- Ten subjects participated in the human performance evaluation test and their situation awareness were measured when the support function of priority unit selection logic is provided and not provided.
- From the paired sample t-test using two sets of situation awareness scores, it is observed that the support function of priority unit selection logic is helpful to improve the human performance when the subjects are monitoring the multi-unit severe accidents.

THANK YOU

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