

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

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01 Introduction

» Problem Statements and Objective

- The accident monitoring systems in domestic digital NPPs provide the accident monitoring variables to the operators in the main control room (MCR) continuously during the design basis accidents in order to monitor the status of the reactors.
- However, in case of the severe accidents, the dedicated display to perform the severe accident management guidelines (SAMGs) are not provided in the emergency operation facility (EOF).
- Moreover, R.G 1.97 rev.5 (2019) requires that Type F variables should provide information on fuel damage and the effects of fuel damage under severe accident conditions
- In this light, the research on the development of human-system interface (HSI) for severe accident management are performed.

» Scope

- Identification of HSI inventories for performing SAMGs
- Development of information displays
 - Information Display based on the SAMGs
 - Information Display for Type F variables in R.G 1.97 rev.5
- Multi-unit severe accident management strategies

02 HSI Inventory Analysis of SAMGs

» Scope of HSI Inventory Analysis

- In order to develop the information displays based on the SAMGs, Control and Mitigation guidelines of the SAMGs were selected as the target guidelines.
- All HSI inventories described in the Control-01 and Mitigation-01 to 07 were analyzed to provide the input data for developing the information displays.

	Doc. No.	Title
SAMGs	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

02 HSI Inventory Analysis of SAMGs

» Results of HSI Inventory Analysis

- HSI inventories of each guidelines were analyzed based on the format below.
- Table below shows a part of HSI inventories for 'Inject into SG'.

완화기능	사용목적	직접수단	기기수 (기기명)	관련 정보	상세 정보
증기발생기 급수주입	고압 급수주입	터빈구동 보조급수 펌프	2 (AF-PP01A, AF-P P01B)	손상상태	손상안됨
				증기발생기 압력	5.3 kg/cm2g 초과
				보조급수저장탱크	77.6% 이상
				복수저장탱크	78.8% 이상
				탈염수저장탱크	5% 이상
				원수저장탱크	10% 이상
				보조급수배관	
		전동기구동 보조급 수펌프	2 (AF-PP02A, AF-P P02B)	손상상태	손상안됨
				교류전원	4.16 kV 823-SW01A-G2/SW01B-G2
				제어전원	841-MC01A/01B
				보조급수저장탱크	77.6% 이상
				복수저장탱크	78.8% 이상
				탈염수저장탱크	5% 이상
				원수저장탱크	10% 이상
		터빈구동 주급수 펌프	3 (FW-PP01, FW-P P02, FW-PP03)	손상상태	손상안됨
증기발생기 압력	7.9 kg/cm2g 초과				

02 HSI Inventory Analysis of SAMGs

» Results of HSI Inventory Analysis

- As a result of HSI inventory analysis for Control-01 and Mitigation-01 to 07, monitoring variables and control equipment were derived.
- Table below shows the monitoring variables for implementing SAMGs.

	변수	감시 목적		변수	감시 목적
1	RCS Pressure	1차측 감압확인 및 냉각수 주입 평가	21	CTMT Spray flow	완화 상태정보
2	CTMT Level	노심용융물냉각성 평가	22	CTMT Rad	방사능 방출 가능성 평가
3	HL Temp	노심냉각여부 평가	23	Aux. Building Rad	방사능 방출 가능성 평가
4	CET	노심손상 및 냉각여부평가	24	S/G Rad	방사능 방출 가능성 평가
5	Neutron Flux	노심손상 및 냉각여부평가	25	SFP Level	SFP 냉각유지 평가
6	CL Temp	노심냉각여부 평가	26	SFP Temp	SFP 냉각유지 평가
7	S/G Level	증기발생기 튜브 파손 가능성 및 열침원 사용가능성 평가	27	SFP Rad	SFP 방사능 평가
8	S/G Pressure	증기발생기 튜브 파손 가능성 및 열침원 사용가능성 평가	28	SFP H2 Con.	SFP 수소 가연성 평가
9	AFW Flow	완화 상태정보	29	RV level	노심냉각여부 평가
10	AFST Level	완화 상태 및 소스 정보	30	Site Radiation Inform	방사능 방출 가능성 평가
11	CST Level	완화 상태 및 소스 정보	31	Condenser Pressure	완화 상태정보
12	DWST Level	완화 상태 및 소스 정보	32	PZR Level	완화 상태정보
13	DST Level	완화 상태 및 소스 정보	33	CTMT Temp	완화 상태정보
14	VCT Level	완화 상태 및 소스 정보	34	RWT Level	완화 상태 및 소스 정보
15	Charging Flow	완화 상태정보	35	4.16kV Energized	전원 가용성 평가
16	SI flow	완화 상태정보	36	480kV Energized	전원 가용성 평가
17	RWST Level	1차측 냉각수 수집 가능성 평가	37	TGBCCW Status	2차측 기기냉각 가용성 평가
18	CTMT Pressure	원자로건물 파손위험 평가	38	Instrument Air Status	기기 구동가능성 평가
19	CTMT H2 Concentration	수소 가연성 평가	39	Charcoal Filter Temp	방사능 물질 여과 가능성 평가
20	Sump Level	재순환 운전상태 평가			

03 Development of Information Displays

» Hierarchy of Information Displays

■ Level 1

- Overall status display for multi-unit NPPs
 - Highest level of display for monitoring multi-units
 - Provides a function to move to the desired displays among 12 units
 - Displays important variables such as RCS pressure, CET, and containment pressure according to the relative severity

■ Level 2

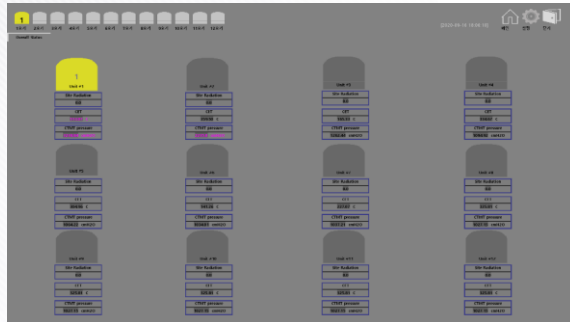
- Main displays for each unit
 - Displays main components in containment, emergency core cooling system, feedwater system, spent fuel pool at a general level

■ Level 3

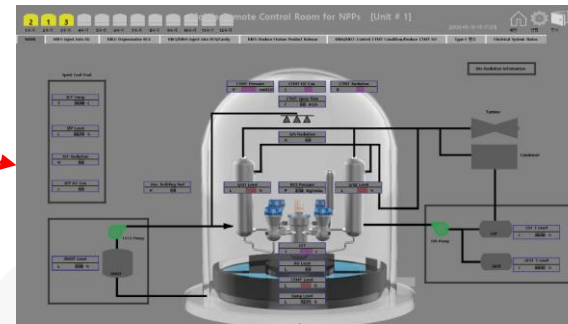
- System based displays for performing SAMGs
 - Displays the monitoring variables and control devices based on the HSI inventory analysis of SAMGs
- Display for Type F variables
- Display for electrical system status

03 Development of Information Displays

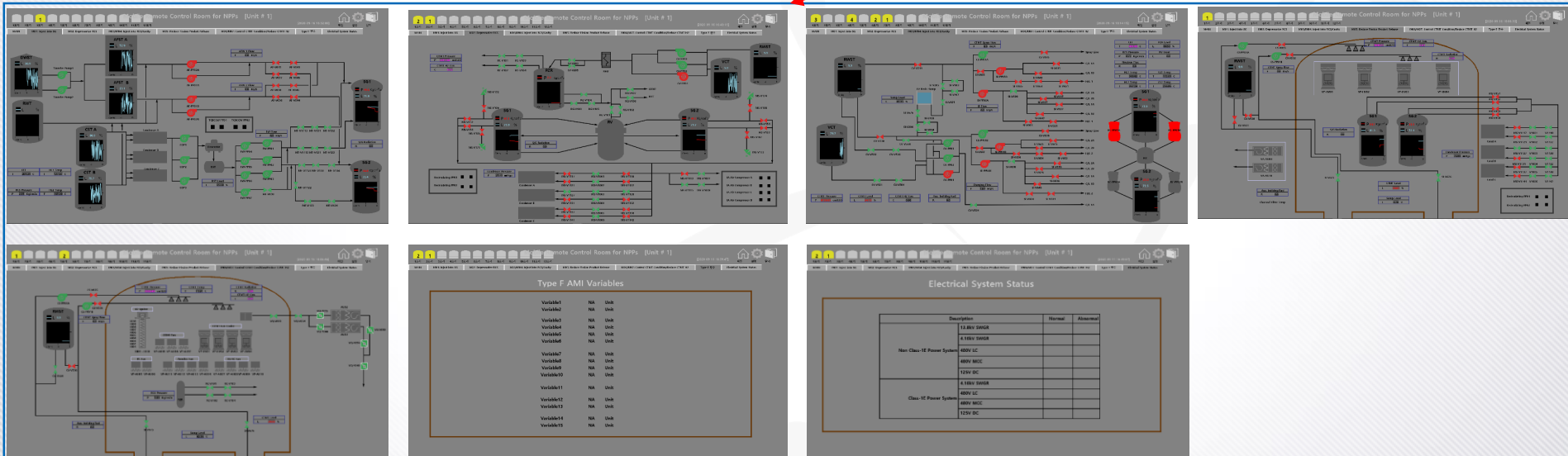
» Hierarchy of Information Displays



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



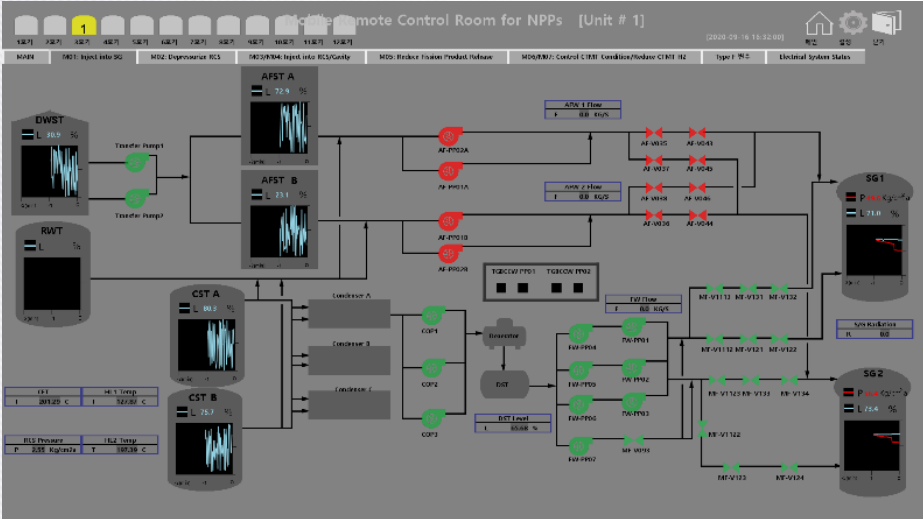
<Level 2: Main displays for each unit>



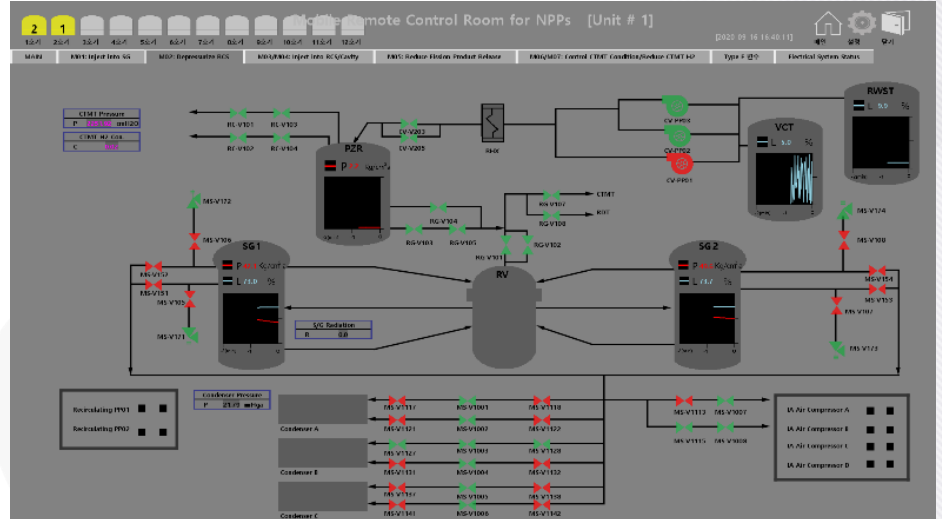
<Level 3: System based displays, Display for Type F variables and electrical system status >

03 Development of Information Displays

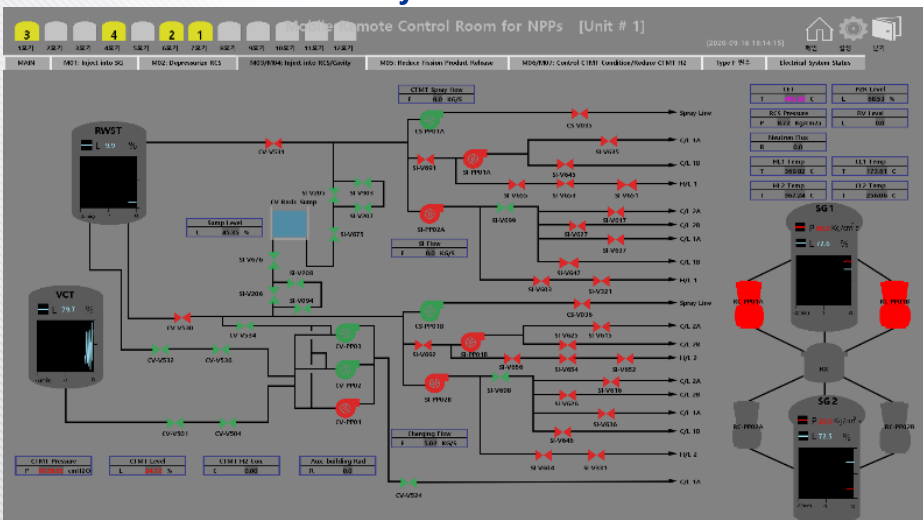
System based displays for performing SAMGs



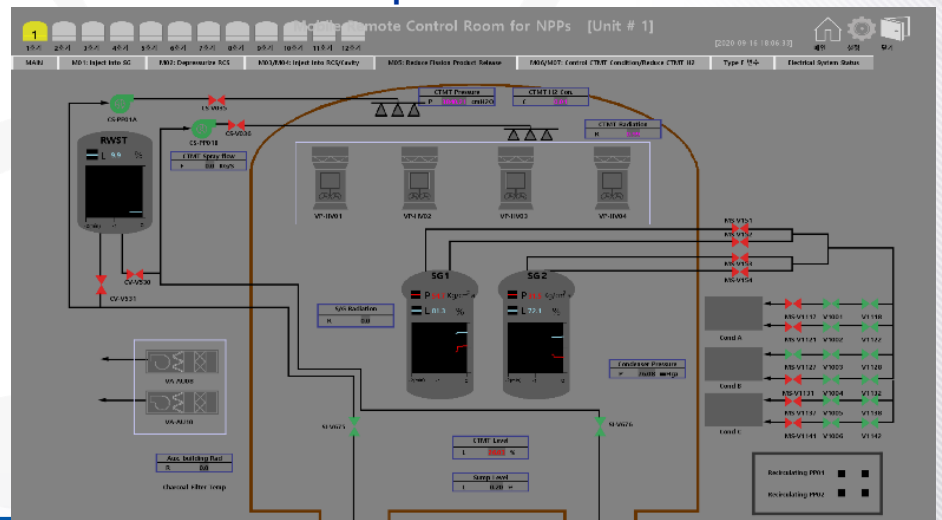
<Inject into SG>



<Depressurize RCS>



<Inject into RCS/Cavity>



<Reduce Fission Product Release>

03 Development of Information Displays

» Display for Type F variables

■ R.G 1.97 Rev.5

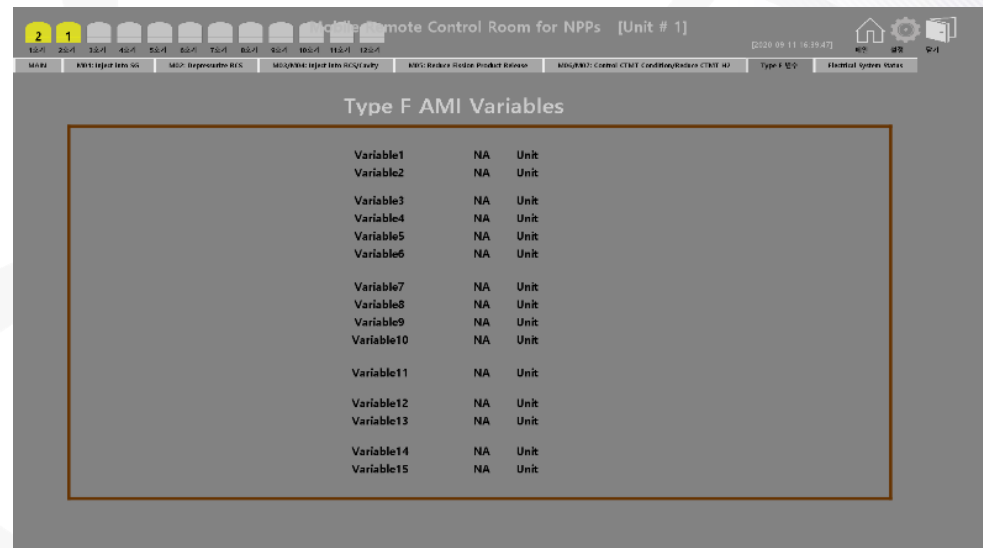
- “Licensees and applicants that have committed to an earlier revision of RG 1.97 may voluntarily add Type F variables, that is, those variables to be monitored while managing a severe accident.”

■ IEEE 497-2016

- “Type F variables shall be those variables that provide primary information to accident management personnel to indicate fuel damage and the effects of fuel damage.”
- “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”

■ Expected Type F variables

- Core Exit Temperature
- RCS Temperature
- Containment Pressure
- Containment Hydrogen Concentration
- Containment Radiation
- Reactor Vessel Level



<Display for Type F variables>

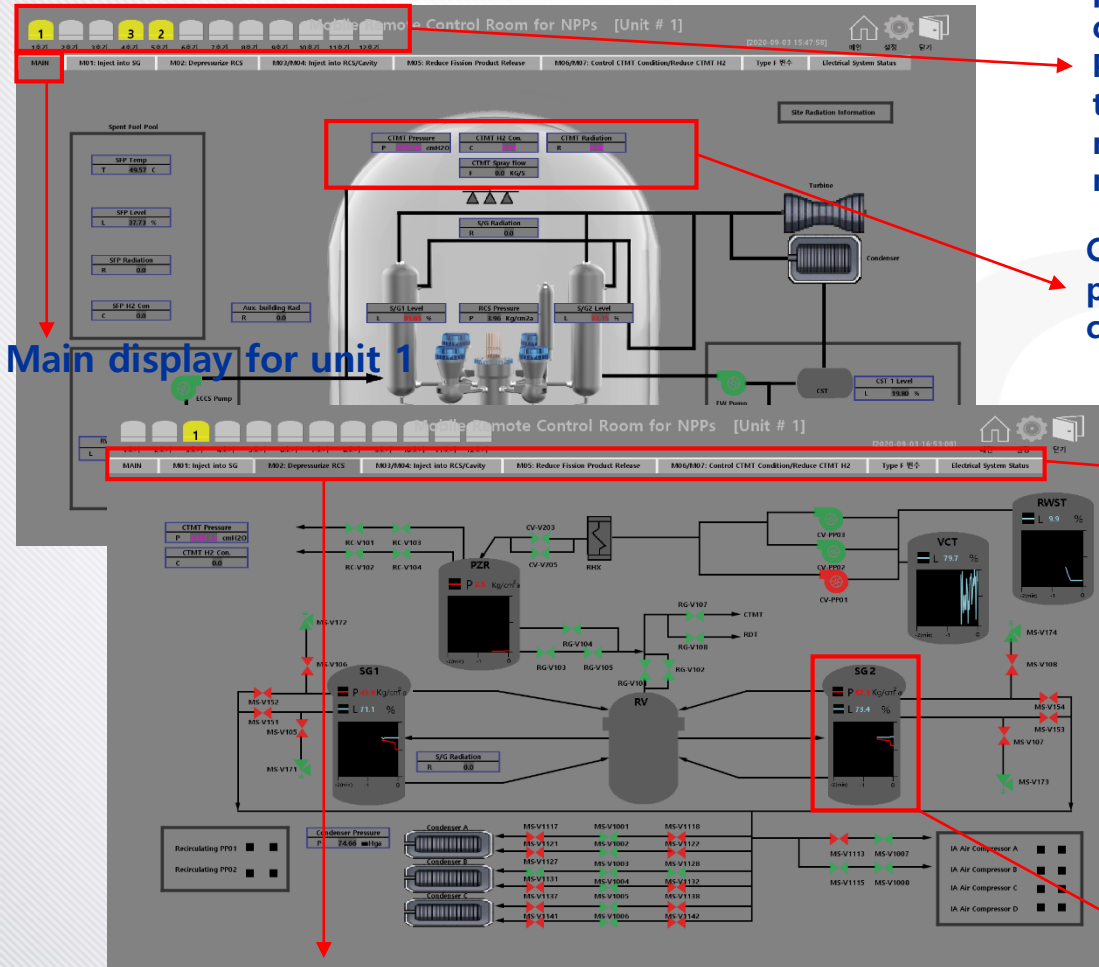
03 Development of Information Displays

Function of Information Displays

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

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

Color coding is provided when setpoint of each predetermined important variable is exceeded in consideration of its severity.



Main display for unit 1

System based display for performing 'Depressurize RCS' of unit 1

Categorization of information displays considering the SAMGs and requirements in R.G 1.97 Rev.5

- Main display
- Display for 'Inject into S/G'
- Display for 'Depressurize RCS'
- Display for 'Inject into RCS/Cavity'
- Display for 'Reduce Fission Product Release'
- Display for Control CTMT Condition/Reduce CTMT H2
- Display for Type F variables
- Display for electrical system status

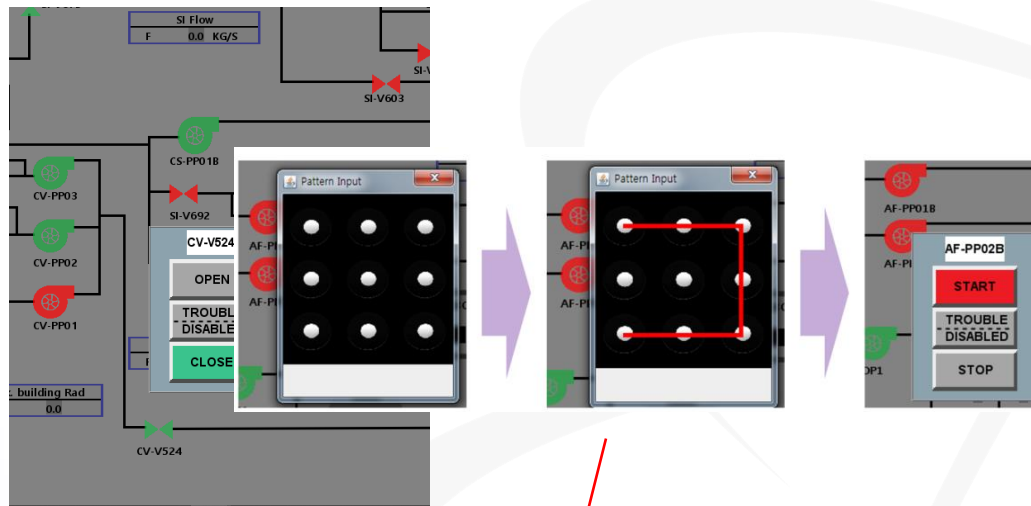
Application of Trend Display requirement in R.G 1.97

03 Development of Information Displays

» Function of Information Displays

■ Control Access Permission

- Since the information displays under development would be used only when the severe accident occurs, it should not have a control function in normal, abnormal, and emergency operation of NPPs



Provision of a LOCK function of control devices to prevent unauthorized component controls in any NPP condition except the severe accident condition.

04 Multi-unit Monitoring Strategies

» Spatially Dedicated and Continuously Visible (SDCV)

- The predefined continuous monitoring variables of multi-unit are provided on an independent display, applying their severities based on the variable setpoints in SAMGs.
- Color coding is applied to the each monitoring variable according to its severity.
- The screen navigation in this display is not allowable to satisfy with SDCV requirement.

	Monitoring Purpose	Variable	Setpoint
1	Core damage prevention	SG Level	1. NR 68%
2		RCS pressure	1. 29.12 kg/cm2a
3	Core damage confirmation	Core Exit Temperature	1. 371.1°C
4			2. 648.9°C
5	Corium cooling evaluation	Containment Level	1. 12.5%
6	Site Radiation	Containment Radiation	1.0.5mSv/hr(30min) or
7		S/G Radiation	5mSv/hr(min)
8		Aux. Building Radiation	2.10mSv/hr
9	Containment Integrity	Containment Pressure	1.1336 cmH2Og
10		Containment Hydrogen Concentration	2.8577.5 cmH2Og
			1. 5%

Mobile Remote Control Room for NPPs					
Plant Accident Monitoring					
		Unit #1	Unit #2	Unit #3	Unit #4
Core damage prevention	SG Level	83.84	79.01	72.83	
	RCS Pressure	4.76	4.55	1.20	2.95
Core damage confirmation	Core Exit Temperature	627.11	399.20	136.98	399.1
	Reactor Vessel Level	0.0	0.0	0.0	0.0
Corium cooling evaluation	Containment Level	25.84	26.19	25.53	1.70
Site Radiation	Containment Radiation	0.99	0.99	0.84	0.98
	S/G Radiation	0.0	0.0	0.0	0.0
	Aux. Building Radiation	0.0	0.0	0.0	0.0
Containment Integrity	Containment Pressure	4770.48	4690.05	1202.86	2939.68
	Containment Hydrogen Concentration	0.01	0.01	0.05	0.05
		Unit #5	Unit #6	Unit #7	Unit #8
Core damage prevention	SG Level		75.68	4.04	85.83
	RCS Pressure	1.34	1.72	161.92	157.55
Core damage confirmation	Core Exit Temperature	496.33	116.48	346.14	325.81
	Reactor Vessel Level	0.0	0.0	0.0	0.0
Corium cooling evaluation	Containment Level	25.46	36.11	0.36	0.0
Site Radiation	Containment Radiation	0.97	0.0	0.0	0.0
	S/G Radiation	0.0	0.0	0.0	0.0
	Aux. Building Radiation	0.0	0.0	0.0	0.0
Containment Integrity	Containment Pressure	1470.85	1032.13	1119.37	1027.15
	Containment Hydrogen Concentration	0.06	0.0	0.0	0.0
		Unit #9	Unit #10	Unit #11	Unit #12
Core damage prevention	SG Level	85.83	85.83	85.83	85.83
	RCS Pressure	157.55	157.55	157.55	157.55
Core damage confirmation	Core Exit Temperature	325.81	325.81	325.81	325.81
	Reactor Vessel Level	0.0	0.0	0.0	0.0
Corium cooling evaluation	Containment Level	0.0	0.0	0.0	0.0
Site Radiation	Containment Radiation	0.0	0.0	0.0	0.0
	S/G Radiation	0.0	0.0	0.0	0.0
	Aux. Building Radiation	0.0	0.0	0.0	0.0

04 Multi-unit Monitoring Strategies

» Prioritization

- In order to efficiently monitor and control the multi-unit NPPs under severe accident condition, it is necessary for the operators to prioritize multi-unit as the important monitoring order. (See table below: the setpoint is referred by ‘Control-01’ of SAMGs)

Priority	Variable	Criteria	Priority Decision
1	CET	$CET1 > 371.1^{\circ}\text{C}$	Priority is given to the unit exceeding the setpoint of CET1
2	CET	$CET2 > 648.9^{\circ}\text{C}$	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)	$CP1 > 1336\text{cmH}_2\text{O}$	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)	$CP2 > 8577.5\text{cmH}_2\text{O}$	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

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

05 Summary

- In order to develop the information displays to perform SAMGs and satisfy with the requirement displaying Type F variables, the research on the development of human-system interface (HSI) for severe accident management was performed.
- Based on the results of HSI inventory analysis of SAMGs and the requirements in R.G 1.97 Rev.5, the information displays such as overall status display, main display, system based displays, and type F variables display were developed.
- The information displays has the various operator support functions such as alarm function, prioritization function applying color and numeric coding, and control access permission function.
- For the multi-unit monitoring,
 - The predefined continuous monitoring variables of multi-unit are provided on an independent display, applying their severities based on the variable setpoints in SAMGs.
 - Prioritization logic for which of the multi-unit needs to be monitored first is also applied to all information displays.

THANK YOU

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