Requirements for development of a prototype of mobile remote monitoring and control facility

Inseok Jang [a*], Chang Hwoi Kim [a]
[a] *Nuclear ICT Research Division, Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea*
[*] *Corresponding author: isjang@kaeri.re.kr*

1. Introduction

Public concerns and worries about the 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 operators are not able to obtain the appropriate information due to the loss of vital power which results in the instrumentation and control (I&C) systems inoperable.

By investigating the lessons learned from Fukushima nuclear accident, the vulnerabilities of I&C systems in Korean NPPs under severe accident (SA) environments can be summarized as follows.

- The I&C cabinets located in the electrical equipment room (EER) cannot acquire the plant status and control plant equipment since they are vulnerable to harsh environment.
- The technical support center (TSC), operational support center (OSC), and emergency operations facility (EOF) are constructed for the emergency response. In particular, the EOF is a kind of head office in offsite for the emergency preparedness and response. However, the utilization of EOF during the SA is limited due to the lack of plant monitoring information. (The safety parameter display system designed as non-safety system is not guaranteed its functions during SA)
- In addition, the EOF cannot be used when the function of I&C cabinets is lost, and evacuation due to radioactive material release is done over 20km.

To overcome these vulnerabilities of I&C systems, a prototype of remote monitoring and control system for coping with SA are being developed by dividing following three sub-topics.

- Developing nuclear black box prototype that survives extreme environment (high temperature, high radiation, high seismic, flooding)
- Developing prototype of mobile remote monitoring and control facility (simultaneously monitoring and control capability for multi-unit)
- Developing high reliable wireless communication within 30km

In this paper, the second topic (Developing prototype of mobile remote monitoring and control facility) are introduced, interfacing with the other topics

2. Prototype of mobile remote monitoring and control facility

The mobile remote monitoring and control facility outside of the plant monitors the internal plant status and controls the plant for accident mitigation during SA. It should have mobility in case of the evacuation over 20km due to radioactive material release. In addition, the mobile remote monitoring and control facility should be designed to monitor and control multi-unit and interface with the organization for emergency preparedness and response. In order to satisfy high level design requirements and develop/prove a prototype (including a prototype features and logics), following activities are performed.

2.1 Database Design

The signals and information that should be displayed in the mobile remote monitoring and control facility are received from the nuclear black box via high reliable wireless communication. First of all, these signals/information should be defined by literatures [1-4], experiences, and expert judgments. Table I shows the selected parameters that should be displayed in the mobile remote monitoring and control facility. (Note that the selected parameter can be different according the type of NPP and adjustable.)

Table I: Monitoring and Control Parameters

	Parameter
1	RCS Pressure
2	RV Level
3	Hot Leg Temperature
4	Core Exit Temperature
5	Neutron Flux Logarithmic Power
6	Cold-Leg Temperature
7	SG Level
8	Pressurizer Level
9	Aux Feedwater Flow
10	AFST Level
11	SI Flow
12	SC Flow
13	RWST Level
14	ESF CCW Flow
15	Containment Pressure

16	Containment Hydrogen Concentration
17	Sump Level
18	Containment Spray Flow
19	Containment Radiation Level
20	Aux Building Radiation Level
21	S/G Radiation Level
22	SFP Water Level
23	SFP Temperature
24	SFP Area Monitoring
25	SFP Hydrogen Concentration
26	Reactor Cavity Level
27	Site Area Monitoring

Since the mobile remote monitoring and control facility has function to display multi-unit parameters and also control multi-unit, the database should be designed with appropriate tag numbers such as unit#_SG #level.

2.2 Simulation for Normal and SA condition

During development of the mobile remote monitoring and control facility, it is not possible to obtain real NPP parameters from multi-unit, in particular, the parameters in SA condition. Therefore, the simulation data/parameters are used for normal and SA condition. There are two objectives to use simulation data (normal and SA condition);

- To provide multi-unit parameter information to the mobile remote monitoring and control facility
- To implement and prove parameter severity display and priority unit selection logic explained in the section 2.3 and 2.4

The simulation for normal and SA condition are performed using compact nuclear simulator (CNS) and MAAP code. Table II shows the MAAP and CNS parameter codes corresponding to the selected parameters shown in Table I.

Table II: MAAP and CNS parameter codes

	Parameter	MAPP	CNS
1	RCS Pressure	PPS	PPRZ / PPRZN / PPRZW
2	Reactor Cavity Level	ZWRB(2)	ZREAC
3	Hot Leg Temperature	TGUH/TGBH	UHOLEG(1)
4	Core Exit Temperature	TGUP	UUPPPL
5	Neutron Flux Logarithmic Power		XPIRM
6	Cold-Leg Temperature	TGUC/TGBH	UCOLEG(1)
7	SG Level	ZWBS/ZWUS	ZSGW(1)
8	Pressurizer Level	ZWPZ	ZPRZ
9	Aux Feedwater Flow	WWFWBS/WWFWUS/WESFDC	WAFWS(1)
10	AFST Level		ZAFWTK
11	SI Flow	WESFCL	KCHRGP(1)
12	SC Flow		WRHRRE
13	RWST Level	ZWRWST	ZRWST
14	ESF CCW Flow		KCCWSP
15	Containment Pressure	PRB(3)	PCTMT
16	Containment Hydrogen Concentration	NFH2RB(3)	H2CONC
17	Sump Level		ZSUMP
18	Containment Spray Flow	WSPTA	KCTMTSP
19	Containment Radiation Level	FCOT(1)/MFPCOT(1)	DCTMT
20	Aux Building Radiation Level		
21	S/G Radiation Level	FBST(1)/MFPBST(1)	
22	SFP Water Level		
23	SFP Temperature		
24	SFP Area Monitoring		
25	SFP Hydrogen Concentration		
26	RV Level		
27	Site Area Monitoring		

Based on Table II and expert decision, the parameters for developing mobile remote monitoring and control facility and its logic are extracted.

2.3 Parameter severity display

There are several parameters more important than the other parameters in Table I. These important parameters are also used for the SA diagnosis and monitoring in severe accident management guidelines (SAMGs). Therefore, these important parameters called real time monitoring parameters should be provided to the operators in spatially dedicated position with their importance/severity. The severity of real time monitoring parameters is defined using parameter setpoints in SAMGs if possible. Table III shows real time monitoring parameters and their severity criteria referred by SAMGs.

Table III: Real time monitoring parameters and their severity criteria

Monitoring purpose	RT monitoring parameter	Severity Setpoint
Site Radiation	Containment Radiation Level	1. 0.5mSv/hr(30min) or 5mSv/hr(2min), 2. 10mSv/hr
	S/G Radiation Level	
	Aux Building Radiation Level	
Core Damage Prevention	SG Level	1. 68%
	RCS Pressure	1. 29.12kg/cm2a

Core Damage	Core Exit Temperature	1. 371.1, 648.9
	RV Level	TBD
Containment Integrity	Containment Pressure	1. 1336 cmH2Og 2. 8577.5 cmH2Og
	Containment Hydrogen Concentration	1. 5%
In-Vessel Retention	Reactor Cavity Level	1. 12.5%

The severity criteria of each parameter shown in Table III can be modified due to following reasons;

- Since the CNS and MAAP cannot generate site radiation information (site area monitoring), alternative and indirect measure such has containment, SG, and aux building radiation level are used during the mobile remote monitoring and control facility development phase.
- Since MAAP code only uses specific parameter unit such as K, PA, Kg, and Meter, the simulation data by MAAP code should be transferred. However, there are several data (radiation related data) from MAPP difficult to transfer the unit we want. In this case, the expert decision might be needed.

2.4 Priority unit selection logic

Since the mobile remote monitoring and control facility monitors and control multi-unit, it is necessary for the operators to prioritize multi-unit as important order. Only plant information under SA condition is provided to the operator. In this light, the priority unit selection logic is provided using specific RT monitoring parameter and SAMG setpoints. Basic rules for the priority unit selection logic are based on the general accident phenomena order (CET increase – RV failure – Containment failure – Radioactive material release). Table IV shows the suggested priority unit selection logic.

Table IV: Priority unit selection logic

	Parameter	Criteria	Decision
1	CET	CET1>371.1	
2	CET	CET2>648.9	
3	Containment Pressure (CP) Containment Hydrogen Concentration (CH)	CP1>1336cmH2O & CH2>5%	In case, more than 2 units are over CET2 criteria, Apply this criteria
4	Containment Pressure (CP) Containment Hydrogen Concentration (CH)	CP2>8577.5cmH2O & CH2>5%	In case, more than 2 units are over CET2 criteria, Apply this criteria
5	Site Radiation	Site Rad. = Y/N Site Rad.= 0 or 1	In case, more than 2 units are over CET2, CP and CH 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

(Note that the suggested priority unit selection logic can be modified in the logic validation phase.)

3. Discussion and Conclusion

The prototype of mobile remote monitoring and control facility is now on initial development phase. There are many things that should be resolved to finalize the prototype developments.

- Hardware selection (How many displays are needed: Many displays or Display many things efficiently)
- Prototype validation (Parameter severity and Priority unit selection logic)
- HF validation (Human performance using the prototype)
- Interface with the other systems (Nuclear black box, High reliable wireless communication)
- Etc.

With consideration of the above issues during the project, it is expected that the mobile remote monitoring and control facility is developed to mitigate SA effectively.

REFERENCES

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