Development of Post-Accident Monitoring System for Severe Accidents

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Abstract: To cope with a severe accident such as Fukushima Nuclear power plants, fully independent monitoring and control system separated (isolated) from the conventional instrumentation and control system is needed. Also, a remote control room which is movable and usable at a distant location is needed for safe plant control and monitoring in emergency. In this paper, we will suggest a new concept for remote mobile control room and hardened I&C equipment to cope with a severe accident in nuclear power plants.

Keywords: Severe Accident, Hardened I&C equipment, Mobile Control Room, Fukushima Accident, Emergency Facility.

1. INTRODUCTION

The Fukushima Dai-ichi and Dai-ni NPP were hit by the Off the Pacific Coast of Tohoku Earthquake ("the Earthquake") and accompanying tsunami waves ("the Tsunami"). The Earthquake was of Magnitude 9.0 and the Tsunami waves height at the Fukushima Dai-ichi NPP exceeded 15 meters. Six nuclear power units stood at the Fukushima Dai-ichi NPP: Units 1 to 3 were in operation, and Units 4 to 6 were in maintenance modes at the time of the Earthquake.

Units 1 to 3 appeared to have automatically scrammed at the Earthquake, but external power supplies and almost all in-house AC power supplies were lost due to the Earthquake and the Tsunami. Reactors and spent fuel pools at the Fukushima Dai-ichi NPP lost their cooling capabilities. Explosions occurred on Units 1, 3 and 4, which were caused presumably by the hydrogen released from the possible core damage and filled in the reactor buildings. The reactor core of Unit 2 also seems to have been damaged, although the investigation is still incomplete. A large amount of radioactive materials were released and spread from the Fukushima Dai-ichi NPP.

The zone up to 20km from the site was designated as the Access Restricted Areas and no entry is allowed unless authorized. Some areas outside 20km from the site were also designated as the Deliberate Evacuation Areas. As many as more than 110,000 people have evacuated. Many people are still forced to live in evacuation, and radiation contaminations have caused serious impacts in extended areas.

The fundamental problem at the Fukushima Dai-ichi plant after the accident is lack of information about the true situation of the units. Especially, the power supply was failed and an accident-proof back-up battery system was not prepared. And the monitoring system for the emergency case was not designed for these types of accidents.

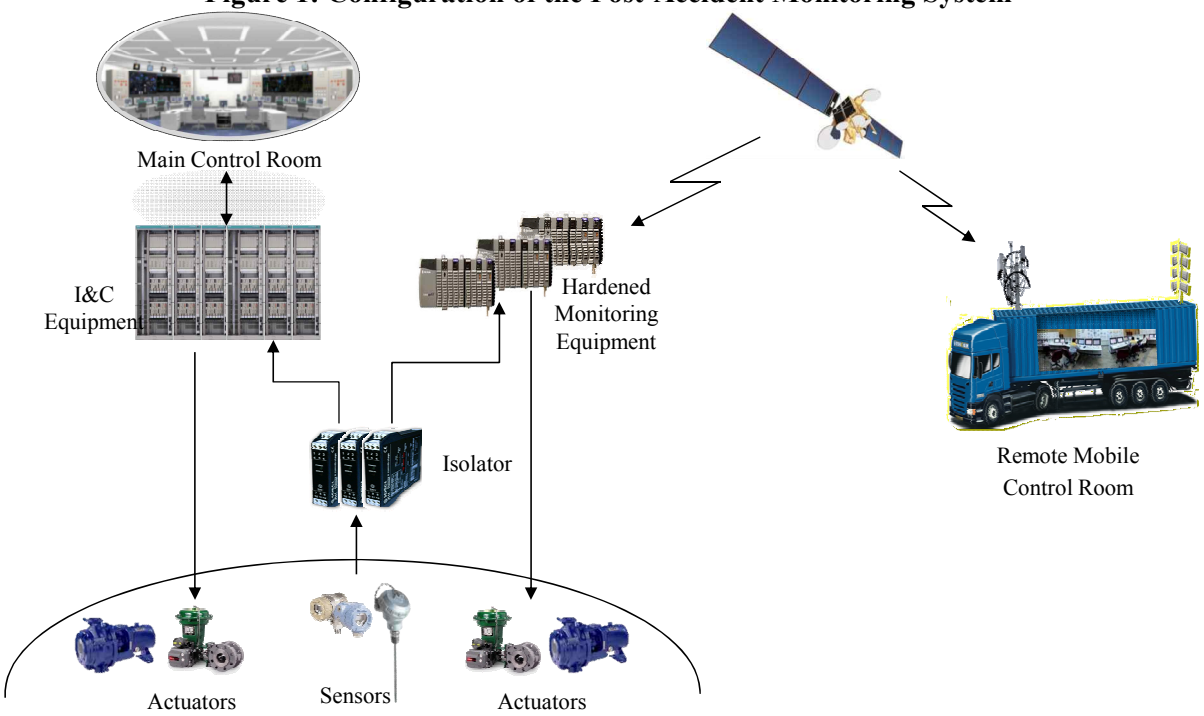
To cope with a severe accident including Fukushima cases, fully independent monitoring system separated (isolated) from the conventional instrumentation and control system is needed. Also, a remote control room which is movable and usable at a distant location is needed for safe plant control and monitoring in emergency.

Korea Atomic Energy Research Institute (KAERI) has started a new project to cope with these problems. Hardened monitoring equipment that consumes low power and survives extreme environment such as high temperature, high radiation, and strong earthquake is developing. And, a remote mobile control room to observe plant situation in off-site area is developing. The hardened monitoring equipment and remote mobile control room is conceptually connected through wireless communication and satellite communications.

2. SYSTEM DESCRIPTION

The configuration of the post-accident monitoring system and conventional I&C system is as figure 1. The post-accident monitoring system is consisted of hardened monitoring equipment, Remote mobile control room, and satellite (wireless) communication. The severe accident related sensor signals such as reactor temperature, reactor pressure, coolant flow, and radioactivity are distributed to hardened monitoring equipment via signal isolators.

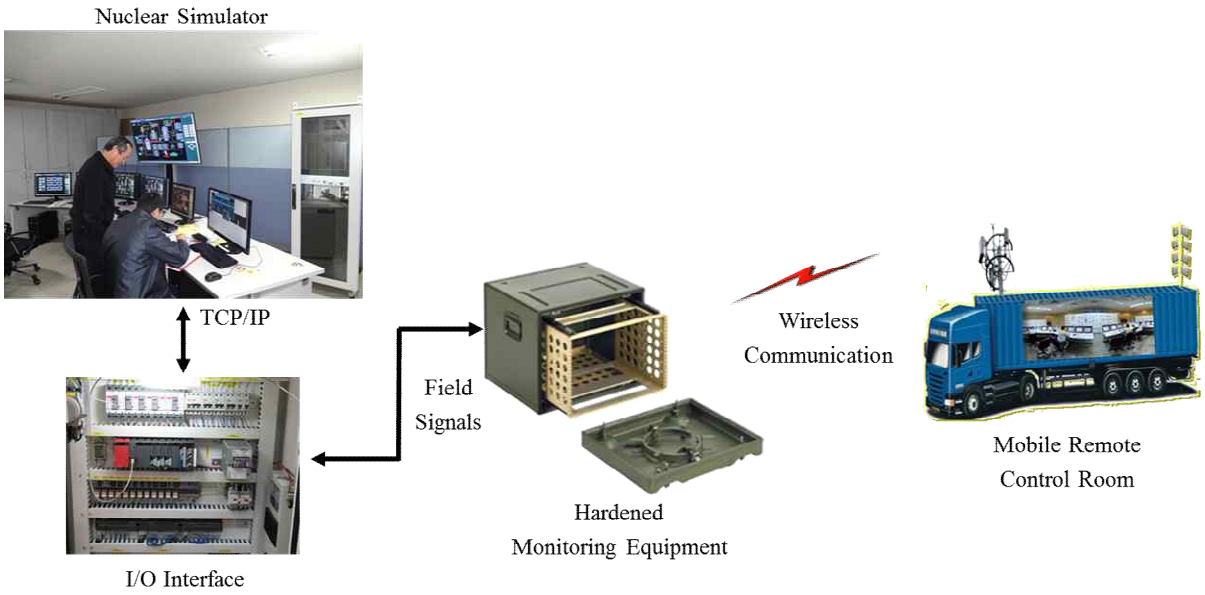
Figure 1: Configuration of the Post-Accident Monitoring System



If the MCR(Main Control Room) and/or conventional I&C equipment is failed caused by severe accident such as natural disasters, radiation leak, or station blackout, etc., the relevant parameters inside containment and spent fuel pool reactors during and after a severe accident can't be monitored like as the Fukushima Dai-ichi NPP. In this case, the hardened monitoring equipment acquires and processes severe accident related signals and then sends the signals to remote mobile control room using wireless (satellite) communication. The capabilities of the remote mobile control room can monitor multi-units' severe accident and control actuators necessary for severe accident mitigation operation.

To evaluate of the functional performance for the post-accident monitoring system, we installed a test-bed. The test-bed is consisted of nuclear power plant simulator and I/O interface equipment.
The figure 2 shows test environment.

Figure 2: Test Environment for the Post-Accident Monitoring System



3. REQUIREMENTS

The top tier requirements for the post-accident monitoring system are as follows:

- The hardened monitoring equipment is fully independent monitoring system separated (isolated) from the conventional instrumentation and control system
- The hardened monitoring equipment uses independent power supply from own rechargeable battery for 100+ operation hours
- The hardened monitoring equipment is not protection system. But the environment condition test (temperature, seismic/vibration, EMI/EMC/EMP, water proof, etc.) will be performed.
- The hardened monitoring equipment is able to measure severe accident related parameters such as temperature (RTD/TC), pressure, water level, radiation, hydrogen concentration, and flow, etc.
- The hardened monitoring equipment transmits measured parameters to remote mobile control room using wireless communication.
- The remote mobile control room will be located in off-site area about 30km.
- The remote mobile control room has monitoring capability all nuclear power units in the site respond to the multi-units accidents (maximum 10 nuclear power units).
- Effective display for selected-accident parameters and control to properly the plant subsequently to severe accident.
- The remote mobile control room has ability of organic connection with Emergency Operating Facility (EOF).
- The remote mobile control room has data storage and recovery capability for accident analysis
- Secure and reliable data communication between hardened monitoring equipment and remote mobile control room is provided.
- The post-accident monitoring system shall be non-safety system. But seismic classification is seismic category 1.

The table 1 shows severe accident related parameters for KSNP (Korea Standard Nuclear Power Plant).

Table 1: Severe accident related parameters for KSNP

	Variables	Purpose

1	Core Exit Temperature	Evaluation of Core Cooling Function and Damage
2	Rx Vessel Water Level	Determine the Core Exposure. Monitoring of Coolant Injection.
3	SG Water Level	Evaluation of loss of 2ndary heat sink source. Information for determination to use alternate heat sink source.
4	RCS Pressure	Monitoring of Coolant Boiling.
5	CV Pressure	Verification of LOCA and CV Integrity.
6	CV Temperature	Verification of LOCA and CV Integrity.
7	CV Hydrogen Concentration	Determination of Core melt and CV Ventilation.
8	ICIS Thimble Tube Room Water Level	Verification(Monitoring) of Cooling Source for Melted Core
9	CV Refueling water level in CV Circulation Sump Water Level	Verification of Emergency Core Cooling Source
10	Monitoring Post	Assessment of Regional Radioactivity
11	High Range Area Radiation Monitor	Assessment of Radioactivity in CV
12	Exhaust High Range Gas Monitor	Evaluation of Radioactivity of Ventilation Gas
13	Main Steam Line Monitor	Monitoring of SG Tube Rupture
15	NIS	Determine Sub-criticality (of reactor core)
16	CCW flow	Assessment of Functionality of Heat Sink Source

The table 2 shows requirement and specification of the hardened monitoring equipment and conventional safety/non-safety I&C system.

Table 2: Requirement and specification for the hardened monitoring equipment

	Conventional I&C System Environment Specification		**Harden monitoring equipment environment Specification**
	Non-safety System	**Safety System**	
Radiation	10 Gy/40years	10 Gy/40years	2 kGy/100hr
Temperature	10-50°C	10 ~ 60°C	10 ~ 80°C
Humidity	10-90%	10 ~95 %	100 %
Seismic	Not consider	10 G	15 G
EMI/EMC	MIL-STD-461E (EMI/EMC)	MIL-STD-461E (EMI/EMC/ESD/Surge)	MIL-STD-461E (EMI/EMC/ESD/Surge)
Power consumption	250 W/Rack	150 W/Rack	> 40 W/Rack
Explosion-	Not consider	Not consider	EXeIICT5 /100%

proof			

4. CONCLUSION

To develop hardened monitoring equipment, we are performing gamma irradiation test for electric device. A power regulators, OP AMPs, logic devices, communication devices, AD and DA converters, micro-processors and etc., were tested and successfully selected according to the irradiation specification. Using the selected device, we are developing pre-prototype for hardened monitoring equipment. The pre-prototype for remote mobile control room is developed using multi touch screen and table PC for monitoring multi-units accidents.