Integrated Monitoring and Action Support System (I-MAS) for Mitigating Accidents in the Nuclear Facility

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1. Introduction

After the Great East Japan Earthquake and the Fukushima accident, various supplementary measures were taken for domestic nuclear power plants. Establishing a mobile response facility and establishing an emergency response headquarters inside the nuclear power plant site are parts of the supplementary measures under way. In the event of damage to the safety systems built into the nuclear power plant or difficulty in their functional actuations, the need for mobile response facilities is recognized because they are the only means of mitigating accidents. The site's emergency response headquarters can guarantee the immediateness and accessibility of emergency response, which has been demonstrated in the Fukushima nuclear accident. However, the case of the Fukushima nuclear power plant shows that an effective emergency response system requires systematic requirement analyses. In particular, it is essential for the emergency response headquarters to provide functional support to enable emergency response personnel to effectively monitor and make decisions on accident situations. This paper describes a system that can effectively support emergency response personnel in connection with the establishment of mobile response facilities and emergency response headquarters. The system includes new support features as well as improvements to existing response facilities.

2. System Development

As an essential process for developing an effective support system, an explicit concept of operation and design requirements should be defined at first. The investigating chronological reports on events and response activities of Fukushima accident, response systems of domestic and other countries, and literature survey were carried out, then temporal and spatial situations were specified and design requirements for the support system were defined [1].

A functional structure of the system which the design requirement applied to is depicted in Fig.1. As shown in Fig. 1, the system is named as I-MAS (Integrated Monitoring and Action Support System) and composed of many functions. To implementing the concept, a project aiming to develop prototype of the system is going on [4]. Several selected support functions are developed in the project [2][3].

The selected support functions are:

- Sharing information
- Managing mobile facilities
- Assisting SAMG operation
- Helping knowledge-based decision-making

Sub-systems correspondent to the support functions are being developing in the project. Next sections describe each sub-system.

Fig. 1 Functional Structure of the I-MAS

2.1 Information Sharing Display (ISD)

As existing EOFs (Emergency Operation Facilities) are equipped with large displays just showing output from CCTVs installed in the nuclear power plant site, it is determined that efficient information transfer system or communication means are necessary for the emergency response headquarter. ISD is a sub-system for information sharing among emergency response personnel in and out of the emergency response headquarter.

ISD provides with:

- Information derived from regulatory requirements
- Radioactivity level and distribution of site area
- Reports from working groups
- High-level status of each unit

Fig. 2 shows a snapshot of the ISD.

2.2 MACST Operation Assistance System (MOAS)

MACST (Multiple-barrier Accident Coping Strategy) is the domestic comprehensive countermeasures against large disasters in nuclear power plant site. It consists of three- phase copying strategies: built-in emergency facilities, mobile emergency facilities and external facilities. Mobile facilities such as mobile pumps, mobile tanks, mobile generators, mobile heat-exchangers, and so on, are newly deployed in domestic every nuclear site. A supply chain for securing external emergency facilities is also structured. MOAS is developed to support efficient management of MACST.

MOAS provides with:

- Overall information on units' status (refer to Fig. 3)
- Internal radioactivity information (refer to Fig. 3)
- Critical Information of individual unit (refer to Fig. 3)
- Information on every cooling water resources (refer to Fig. 4)
- Deployment of mobile facility (refer to Fig. 5,6)
- Modes of every mobile facilities (refer to Fig. 5)
- Operational state of individual mobile emergency facility (refer to Fig. 6)
- Information on related systems: SCS (Shutdown Cooling System), FWS (Feedwater System), CCS (Component Cooling System), ES (Electricity System) (refer to Fig. 4)

Fig. 2 Snapshot of the ISD

Fig. 3 Snapshot of plant status of the MOAS. Every cooling assets are depicted with important plant parameters and mobile emergency facilities.

Fig. 4 Snapshot of feedwater system of the MOAS. Mobile emergency facilities are shown with system situation.

Fig. 5 Snapshot of individual unit of the MOAS. Mobile emergency facilities deployed at each unit are depicted with their state (deploying, operating, power, quantity of resources, etc)

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Fig. 6 Snapshot of mobile emergency facility of the MOAS. Individual status of all mobile emergency facilities in the site are shown in a screen.

2.3 SPDS Improvement for Managing SAMG (SIMS)

After the TMI (Three Mile Island) accident, SPDS (Safety Parameter Display System) for accident monitoring is a required system which should be installed at main control rooms and the emergency operation facility of nuclear power plant site. However, SPDS is designed to copy with design basis accidents ranged from abnormal to emergency operation. In the event of severe accidents or large disaster, SPDS might be an insufficient means for copying with them. To expand its coverage to severe accidents, SPDS should be improved. SIMS was proposed to improve SPDS so that it covers from abnormal operation to severe accident mitigation.

SIMS provides with supportive information such as:

- Decision on SAMG entry condition and strategy selection (refer to Fig. 7)
- Availability of equipment (refer to Fig. 8)
- Effect evaluation of the actuation of a strategy
- Execution of individual SAMG item
- Decision on status, based on maps/tables (refer to Fig. 8)

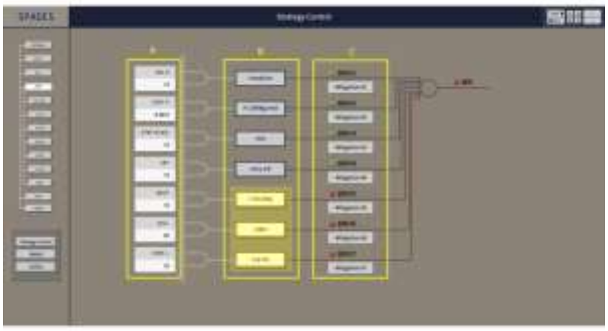

Fig. 7 Snapshot of SANG strategy selection of the SIMS. Individual status of all mobile emergency facilities in the site are shown in a screen.

Fig. 8 Snapshot of mobile emergency facility of the MOAS. Individual status of all mobile emergency facilities in the site are shown in a screen.

2.4 Ecological Interface Design (EID)

Keeping preparedness to unknown accidents requiring knowledge-based decision-making activities of operators is more difficult than to known accidents and events. Countermeasures to an unexperienced event is fully dependent of operators' knowledge and experience.

Sometimes, the hierarchically-structured abstracted information of a system is crucial cue to solve a problem. Ecological interface design (EID) is developed on the basis of the abstraction hierarchy of complex systems, it is told EID is an effective means to deal with unknown state. An EID was proposed for the I-MAS to support emergency personnel in the beyond design basis accident situation including severe accidents.

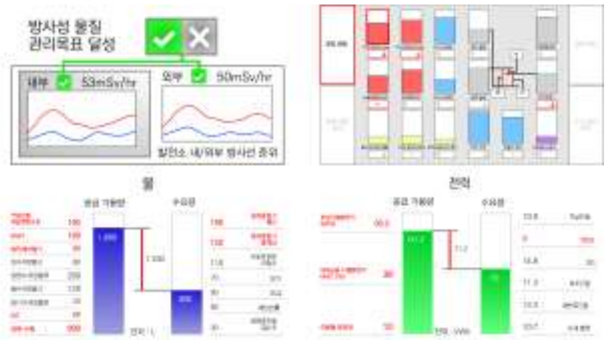

Fig. 9 Snapshot of high-level abstraction of EID. Radioactivity information, states of major parameters, and balance of water resources and electrical power are shown in a screen.

Fig. 10 Snapshot of lower-level abstraction of the EID. Possible cooling paths, state of important parameters and supportive information are shown along with selected metric (temperature, level, radioactivity, pressure)

2.5 Prototype of the I-MAS

A prototype integrating above-mentioned sub-systems is developed to verify their effectiveness on the various accident situation. A nuclear simulator provides simulated plant process information to the prototype. To supply information about mobile facilities and newly defined variables, an emulator was developed. Fig. 11 show the overall structure of signal communication for the prototype of I-MAS.

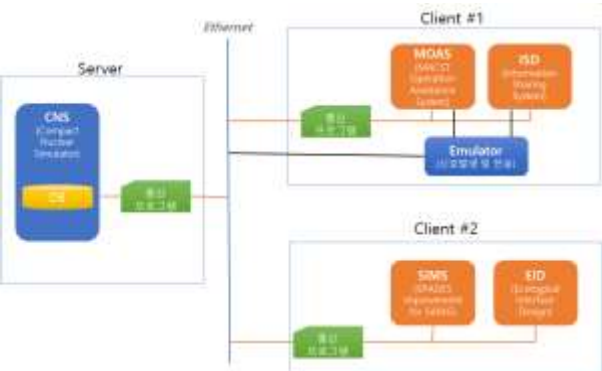

Fig. 11 Structure of I-MAS Prototyping. CNS and emulator supply simulated signals to each sub-system of the I-MAS.

3. Conclusions

As a support means, I-MAS (Integrated Monitoring and Action Support System) is introduced in this paper. I-MAS consists of sub-systems taking charge of their individual functions such as information sharing, mobile facilities management, SAMG operation and knowledge-based activity support, and so on. The prototype is being developed and it will be verified its effectiveness under accident situation.

I-MAS is a unique support system that

- can be used in the emergency response headquarter newly constructed in domestic nuclear power plant sites.
- can manage various mobile emergency facilities and newly deployed countermeasures efficiently.

It is expected to contribute to accurate situation assessment and mitigation by supporting emergency response personnel under beyond design basis accident and further disaster in nuclear power plant sites.

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