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Preliminary Study on Information Display System for Operator Support in Severe Accident

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1. Introduction

This paper discusses the issues related to the severe accident of Fukushima Daiichi Nuclear Power Electric Power, which occurred on March 11, 2011, due to the Pacific Ocean Earthquake and the ensuing tsunami generated by the Earthquake. As a result of this severe accident, a large amount of radioactive material was released. From an I&C(instrumentation and control) point of view, I&C equipment did not function sufficiently or was shut off due to the loss of power supplies. The operator could not react effectively under these conditions because it was difficult to obtain the appropriate information needed to take countermeasures. Most commercial nuclear power plants use an operator support system such as an SPDS (safety parameter display system) under normal and emergency conditions to support the prompt decision of the operator [1]. However, SPDS is suitable for emergency conditions, not for severe accident conditions. Therefore, this paper proposes an information display system dedicated to a severe accident and presents the conceptual requirements to support a prompt decision of operators under severe accident conditions.

2. Fukushima accident and its countermeasure in I&C system

On March 11, 2011, the Pacific Ocean Earthquake and the ensuing tsunami generated by the earthquake occurred at the Fukushima Daiichi nuclear power station. The entire reactor was automatically scrammed by the earthquake, but the fuel was exposed due to the total loss of AC power, and the core started melting afterward. As a result of this severe accident, a large amount of radioactive material was released.

From an I&C point of view, most I&C equipment did not function sufficiently, or was shut off due to the loss of the power supplies after the SBO (Station Black Out). Some of I&C equipment had a wrong signal. The safety parameter display system (SPDS) developed to provide information on plant conditions to support operators during an emergency was survived, but the computers of units 1 and 2, which were expected to send data to the SPDS, did not function due to the tsunami. Also, there was a data communication problem between them in unit 3[2]. Therefore, the operator could not make the appropriate decisions and reaction effectively because it was difficult to obtain appropriate information required to take countermeasures.

At present, many countermeasures or recommendations have been reported and reflected in I&C fields.

NISA (nuclear and industrial safety agency, Japan) reported that six items of 30 items were necessary in the I&C field to prevent the occurrence and progression of a severe accident [2].

- Prepare emergency command center
- Secure the communication tools for accident
- Improve the reliability of the measurement equipment for an accident
- Enhance the monitoring functions for the plant conditions
- Enhance the emergency monitoring functions

The USNRC reported the near-term task force review of insights from the Fukushima Daiichi accident and recommended 12 items for enhancing nuclear safety [3].

- Enhance the spent fuel pool makeup capability and instrumentation for the spent fuel pool.
- Pursue emergency preparedness topics related to decision-making, radiation monitoring, and public education

Korea performed special safety inspections in April 2011 and reported fifty recommendations to be implemented by 2015 [4]. There are three items related to the I&C field among those recommendations.

- Improving the seismic capacity of the main control room (for example, the seismic event alarm window in the control room)
- Installing an automatic seismic trip system
- Devising a means of securing the necessary information in case of a prolonged loss of electrical power

3. SIDS overview and conceptual requirements

Reflecting on the countermeasures described in the previous section selectively, and considering SPDS, this paper proposes an SIDS (Severe accident Information Display System) dedicated for a severe accident in terms of enhancing the monitoring function.

The SPDS is used to provide the necessary information to operators covering normal operation to emergency operation, and mainly focused on core cooling and core damage prevention. On the other hand, under severe accident conditions where the nuclear core begins to melt, many factors are important, for example the behavior of the core meltdown material, behavior of the reactor containment and prevention of radioactive material release. Therefore, there are differences in the key parameters between normal/emergency operation and severe accident operation. That is why the SPDS is not used under severe accident conditions directly [5]. Table 1 shows the differences between an emergency accident operation and a severe accident operation.

Table 1. Emergency accident and severe accident.

	Emergency Accident	Severe Accident
Safety Goal	Prevention of reactor core damage	Prevention of reactor containment damage and radioactive materials release
Effects	Plant itself and production of electric power	Social, economic and environment impacts
Guidance	Emergency Operating Guideline (EOG)	Severe Accident Management Guidance (SAMG)

Also various countermeasures and recommendations reported from various organizations after the Fukushima Daiichi accidents should be applied to a severe accident operation. The SIDS should apply countermeasures and recommendations of the Fukushima Daiichi accident selectively, and apply HFE (human factor engineering) requirements applied to the SPDS. The assumptions considered in the SIDS design are as follows:

1) The fifty recommendations reported in Korea in 2011 are implemented and they work properly.

2) The instruments and I&C equipment perform their own functions after proper actions of the operator or maintenance personnel during a severe accident.

3) The instruments and I&C equipment perform their own functions after supplying an alternative power source.

4) The SIDS uses the severe accident management strategy, which will be developed later for its information design and developing strategic operations.

The above considerations for SIDS are for using existing systems and equipment, not for adding additional systems and equipment.

The classification of SIDS is shown in Table 2. SIDS is designed to have seismic class “I” to maintain its function and provide the required information to operators during a seismic accident.

Table 2. Classification of SIDS.

Safety class	NNS
Quality class	T
Seismic class	I
Electrical class	Non-1E
Software class	Important to Safety(ITS)

Also SIDS is designed to have following functions.

1) Critical function monitoring function
2) Post-accident monitoring function
3) Alarm functions
4) Information display functions for operator support
5) Data validation functions
6) Information Display functions in MCR, RSR, TSC, and EOF

SIDS is designed to be independent and isolated from the safety systems. SIDS does not apply the single failure criteria that is necessary for safety related systems or safety systems.

4. Conclusions

In this paper, SIDS, which mainly supports the decision-making of operator under severe accident conditions, was proposed and its conceptual requirements were presented to support a prompt decision of operators under severe accident conditions. Also the conceptual requirements regarding the functions, performance, and information display were established. Further study on designing additional systems and equipment for severe accidents will be accomplished in the future after analyzing the SAMG, severe scenarios, and equipment survivability from instrument sensor to I&C facilities.

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