An Optimal Core Cooling Path Searching Methodology for Early Human Action During Severe Accidents

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1. Introduction

Since the Fukushima accidents in Japan, worldwide nuclear societies have been particularly concerned about the proper accident response during severe accidents (SA) including site-extensive damage. [1]

This study suggests a methodology of severe accident mitigation support with speediness and credibility. This methodology contains the accident symptom identification, the proper mitigation function selection, available mitigation paths, and an optimal mitigation path(s).

2. Action Required Time Evaluation

The expected human action time and human tasks to achieve a proper mitigation action were evaluated based on the SAMGs [2],[3]. Table 1 shows the evaluation results in the case of supply of cooling water to the primary system to achieve core damage prevention. Human tasks can be divided into status confirmation, plant/process evaluation, and control tasks in the case of severe accidents. As seen in table 1, the minimum required time is one hour for TSC to notice the core damage possibility and provide cooling water to the reactor coolant system, and the maximum necessary time is about 2 hours. The amount of human workload for confirmation is 59. The minimum necessary time stated above applies when the ECCS pump that the guideline recommends is usable. If it is not usable as the result of the check, plant personnel try to take control in the order of charging pump and RCP. When this occurs, it takes up to 113 minutes when only the last possible means have been used.

Table 1 Tasks and action required time for RCS water injection during SA

Task	Task amount		Required time (min.)		Remark
	Max.	Min	Max.	Min.	
Monitoring	118	40	59	20	30 sec./task
Evaluation	32	24	48	36	90 sec./task
Control	5	5	5	5	60 sec./task
Total	145	69	113	61	

3. Methodology

Figure 1 shows the overall function composition of an automated severe accident mitigation support system.

First, it inspects the credibility of severe accident parameters. Based on this, it provides a real-time analysis of the symptoms and proper mitigation function. Next, it automatically analyzes and offers real-time information of all plant means and paths that can carry out the chosen mitigation function. Although the final control of the mitigation means is done by the human staff, the system assesses in real-time whether the mitigation means is properly performed by receiving process feedback about the result of the control. Lastly, it provides real-time information about whether the severe accident has ended, and monitoring result about long-term parameters of concern.

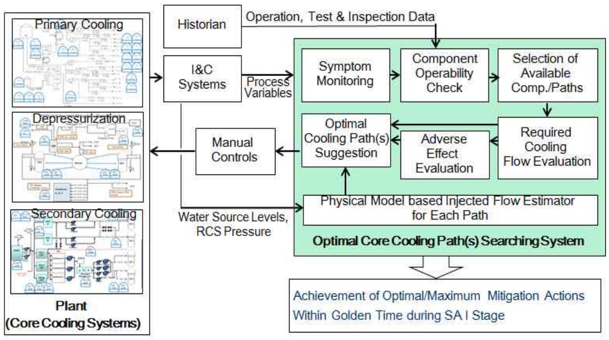

Fig 1. Overall Function of the system

3.1 Accident Identification

It is realistically difficult and at times unnecessary to analyze which type the accident is because multiple design basis accidents happen simultaneously in the case of severe accidents. Therefore, severe accidents are automatically judged whether they fit into seven categories including the core damage, loss of secondary heat sink, radiation leak, and loss of containment integrity, which are the plant's severe accident mitigation priority of such symptoms. When accident symptoms are observed, the system automatically provides the accident mitigation function and means.

3.2 Available Path(s) Evaluation

After assessing the accident and automatic suggestion of mitigation function, the system lays out every means and path that can perform the suggested mitigation function.

Component operability, process status and source availability information are automatically offered with every suggested path. Based on such information, the system also automatically suggests every path capable of mitigation measures in a given situation. Whether mitigation mean is possible or not is determined by a comprehensive validation of information such as the source status, assessment of every condition necessary to operate the component, and process condition of the destination.

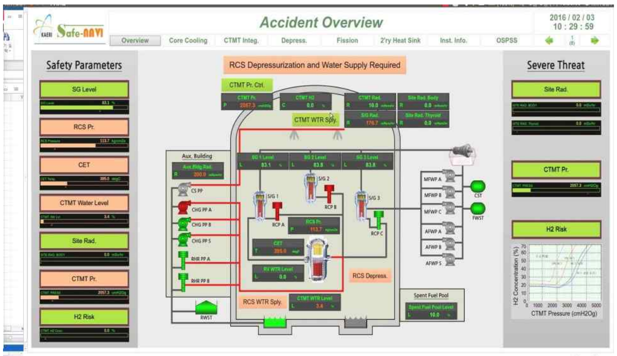

Fig 2. Accident Identification MMI

3.3 Optimal Path(s) Searching

As available paths are evaluated, an assessment of optimal mitigation path is performed based on the estimated (calculated) flow capacity of each path. The simplified physical model of injection systems provides the flow capacity of each path based on the water source status and RCS pressure. Fig. 2 shows an example of the modeling of the simplified injection paths

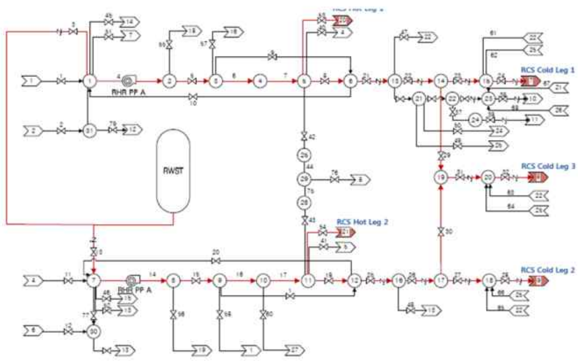

그림 5 RHR 풀리모델 Nodal Diagram

Fig 3. Simplified injection model for evaluation of path flow capacity

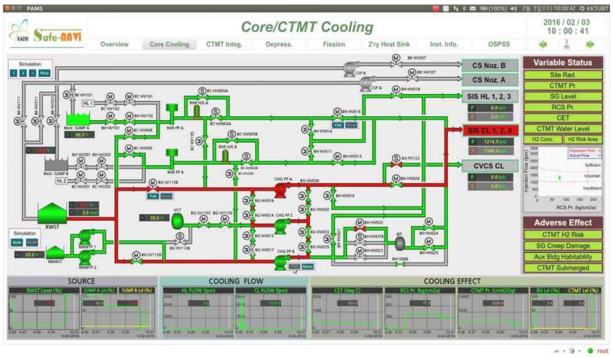

Fig 4. MMI example for available paths (green color) and optimal path(s) (red color) during RCS water injection

The required injection flow for core cooling is calculated based on the RCS pressure which described in SAMGs. And then, combination of optimal path(s) is automatically suggested.

Fig.4 provides various information such as available paths, optimal path(s), estimation/measured flow of each path, measured parameters and their trends, adverse effects and their countermeasures, and equipment status and failure causes.

4. Conclusion

This study suggested a methodology of severe accident mitigation support with speediness and credibility. Using this methodology, a severe accident is automatically identified based on the information credibility check. Then, a proper mitigation function, available mitigation routes, and an optimal mitigation path are automatically suggested. Through this, if symptoms of a severe accident are discovered, the system is able to offer credible accident analysis to the plant personnel, and is also able to precisely recommend a response action for the core damage and radiation release by providing the proper response means, available mitigation path(s), and optimal mitigation path(s).

Acknowledgement

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REFERENCES

[1] "Recommendations for Enhancing Reactor Safety in the 21st Century, The near-term task force review of insights from the Fukushima Dai-ichi Accident", July, 2011

[2] "Development of Severe Accident Management Guidelines for KSNPs" KAERI/RR-1939/98, KAERI, 1998.

[3] NEI05-07, Industry Mitigation Strategy Study Guideline, Sep. 2005.