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Development of Prototype Critical Parameter Display System for Severe Accident Management of KSNP

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Abstract

The Critical Function Monitoring System (CFMS) has been installed in Korean Standard Nuclear Power Plants to support main control room personnel during normal and emergency operation. When the existing CFMS is used under a severe accident situation, some problems may be expected from: different design basis, different parameters for decision-making, and different domain and depth of information to recover the plant. To resolve the problems, KAERI is developing a display system to assist severe accident management. Severe Accident Management DIsplay System (SAMDIS) prototype is developed to display relevant information to plant personnel for the execution of a severe accident management strategy in effect. The developed system consists of two modules: General Plant Status Display (GPSD) which displays overall plant status and Integrated Display for Strategy Execution (IDSE) which systematically displays detailed information. SAMDIS displays all relevant information on one screen even including success paths. This concept is considered quite effective when used together with severe accident guidelines.

I. Introduction

After the TMI-2 accident, the need to introduce improvements in presentation of plant parameters in a nuclear power plant control room was emphasized. In particular, it was found that the TMI-2 operator was not capable of ascertaining the status of the plant and of the critical safety functions, because of the massive increase of information derived from a change in plant conditions such as alarms and indications; in this situation, it is generally difficult to gather the really important data needed for correct operations management.

Modern plant computers provide access to a large number of measured and calculated data. These data can be used by a number of application programs or systems to support the operator’s work in the control room. A major aspect of nuclear power safety is the acquisition of a maximum amount of data on plant behavior using various diagnostic means and the further processing of this numerical information both in the normal and abnormal plant states. Of utmost importance is that the data should be processed so that the plant operator can understand easily without mistakes.

The Safety Parameter Display System (SPDS) shall provide the control room operator with a concise display of critical plant variables, so that the safety status of the plant can be determined in a rapid and reliable manner. It shall be operable both during normal plant conditions and during emergency conditions, but it does not consider severe accident situation. It will continuously display necessary information so that control room personnel shall readily and reliably assess the plant safety status plant safety status.

A lot of operator support systems have been developed in many countries and some of them have been installed and are being utilized to assist plant personnel [1-6]. Especially, a number of SPDS have been developed to represent necessary information to the operator by summarizing and reorganizing various plant parameters [1-2,7]. A typical SPDS in the operation field of Korean nuclear power plant is the Critical Function Monitoring System (CFMS) that is installed in the Technical Support Center (TSC), in the Operation Support Center (OSC), and in the Emergency Operating Facility (EOF) as well as in Main Control Room (MCR) of YGN and UCN Units which are Korean Standard Nuclear Power Plants (KSNPs) [8]. The structure of CFMS is based on critical safety functions (CSFs), and it monitors the parameters that are important to normal and emergency operation and displays them with simplified system drawings.

In some countries, studies for SPDS for severe accident situation are being performed with the development of operator support system in aspects of integrated severe accident management [9-10], and KAERI is developing the advisory system for severe accident management. One of the major functions for integrated severe accident management is the monitoring of plant status and the display of plant parameters.

During severe accident situation, most decision are done by TSC personnel, and SPDS may be utilized to providing necessary parameter reading because there is no direct indicator in the TSC room. And also, the necessary information can be obtained by communicating with MCR personnel.

The Korea Severe Accident Management Guidelines (KAMG) is under development at Korea Atomic Energy Research Institute (KAERI) [11], and the appropriate SPDS for these guidelines are developed in this paper in order to effectively execute the KAMG. If the existing system, CFMS, were used in severe accident condition, some problems may occur: (1) different design basis, (2) different parameters for decision-making, and (3) different domain and depth of information to recover the plant. In order to resolve these problems, Severe Accident Management Display System (SAMDIS) is developed to assist plant personnel during execution of KAMG.

In the next section, and the state of the art for SPDS in Korea in aspects of nuclear power plant operation and the overview for KAMG will be described briefly. The characteristics and structures for SAMDIS developed in this paper will be described in the next section.

II. The Status of the Art for SPDS in Korea

In Korea, CFMS is a typical SPDS that assists operation of nuclear power plants, and is installed onto YGN and UCN Units. CFMS can be used during normal operation, abnormal operation, and emergency operation in case that Emergency Operating Procedures (EOP) is applicable and is not severe accident situation.

The CFMS is designed to provide field sensor information from which the operator may quickly monitor and diagnose the safety status of the plant during normal and abnormal operations. The CFMS shall accomplish this objective by monitoring the status of the critical functions such as core reactivity control, core heat removal, and so on. The CFMS shall provide information that enables the operator to consult emergency procedures and existing qualified instruments for the purpose of making and implementing decisions. The CFMS shall provide this information in a concise, understandable and integrated format to assist the operator to quickly assess the plant safety status.

As mentioned before, KAMG is being developed at KAERI to provide guidelines to plant personnel to restore plant from uncontrollable state due to severe accident. There are seven strategies in KAMG: RCS Injection, RCS Depressurization, Containment Hydrogen Control, and so on. The priority of execution among these strategies is determined by monitoring plant parameters that are critical to decide which strategy should be executed at the current situation.

In order to execute the strategy effectively, relevant parameter display system is essential because severe accident management requires integrated information of plant status. That is, it may require plant parameters and/or equipment status across many systems at a time. The current CFMS, therefore, cannot be directly applied in the case of severe accident situation, beyond EOP. More detailed reasons, that the current CFMS cannot be applied for severe accident situation, are as follows:

- Different design basis: The ultimate purpose for plant safety during severe accident is to protect radiation release to environment whereas that for normal and emergency operation is to prevent core melt. The major parameters to cool reactor down and to prevent core melt thus may differ with those for preventing radiation release. For example, parameters for containment performance may not be directly related to core cooling.

- Different parameters for decision-making: The parameters for decision-making for normal or emergency operation are different with those for severe accident situation. For the normal or emergency operation, plant personnel should consider the protection for component and/or system. However, in the severe accident situation, the plant personnel should unconditionally perform the relevant strategy with all possible means to restore the plant to a controllable state.

- Different domain and depth of information to restore the plant: During operation within EOP, the operator has to check detailed component status to achieve the goal of action including possible negative effect of the action. And also, the domain for each recovery action is usually component-wise or subsystem-wise. For the severe accident, however, the domain for each strategy is system-wise or function-wise because of inadequate severe accident phenomena. To perform a severe accident strategy, a lot of systems should be considered simultaneously. That is, the domain for severe accident strategy is more extensive, the information depth is shallower, and the system drawings should be more simplified in severe accident.

- Each severe accident strategy may require status verification for some major components at a time, so the information and status for relevant components should be summarized at a glance.

III. Development of SAMDIS

In order to develop the information display system for executing KAMG during severe accident situation by resolving the above problems, Severe Accident Management Display System (SAMDIS) is developed in this paper. As stated earlier, SPDS for severe accident have to be developed by considering KAMG, and SAMDIS must provide necessary information during execution of KAMG strategies. For example, available water source, pumps, and injection paths shall be provided to plant personnel at a time, especially to TSC personnel.

1. Characteristics of SAMDIS

The principle function of SAMDIS is to provide all necessary information to plant personnel during execution of KAMG strategy. While performing a strategy in KAMG, TSC personnel should access the current value of major parameters, component status, valve lineup, and so on. There are a lot of display panels for alarms and controls in the control room, but there is no such panel in TSC. The TSC personnel thus must obtain such information by communicating with MCR personnel or by utilizing operator support system such as SPDS.

Most personnel who are using SAMDIS are already familiar with EOP, and thus it is recommended to adopt similar methodology of EOP as soon as possible during development of SPDS for severe accident. One of the major items is the use of color concept in representing the severity of challenge for current plant or component status by plant parameters.

SAMDIS is designed in accordance with KAMG, so all necessary information for executing each strategy will be provided by summarizing and integrating all relevant plant data. The success path concept is adopted to provide all available means to perform the strategy. The first step of KAMG strategy is to check status of all available components to perform the strategy, and the concept of success path is introduced in representing the information for available components.

2. Structure of SAMDIS

The SAMDIS is developed with two modules: one is display for current plant status, General Plant Status Display (GPSD), and the other is display for detailed information, Integrated Display for Strategy Execution (IDSE). Figure 1 shows schematic diagram of SAMDIS.

1) General Plant Status Display (GPSD)

The GPSD module monitors critical plant parameters and displays them with graphical interface so as to understand overall plant status as in Fig.2. According to the diagnosis rule of KAMG, seven parameters were selected as critical parameters to determine current plant status. These parameters always are on screen so that plant personnel can check the current plant status at any time. The severity of challenge of the parameter is represented with different colors as in EOP. The meaning of each color is as follows: green means normal, yellow means warning, and red means danger.

In this module, the historical trend of each parameter can be displayed as in Fig.2 and plant personnel can obtain the historical background of current status of plant. Currently, GPSD displays twelve parameters continuously with their respective current values with relevant color.

In addition these parameter display, current type of emergency of plant is displayed at the right-upper corner as in Fig.2. There are three types of emergencies in KSNP plant: Alert (white), Site Area Emergency (blue), and General Emergency (red). According to the type of emergency, the severity for strategy execution of priority for strategy may differ.

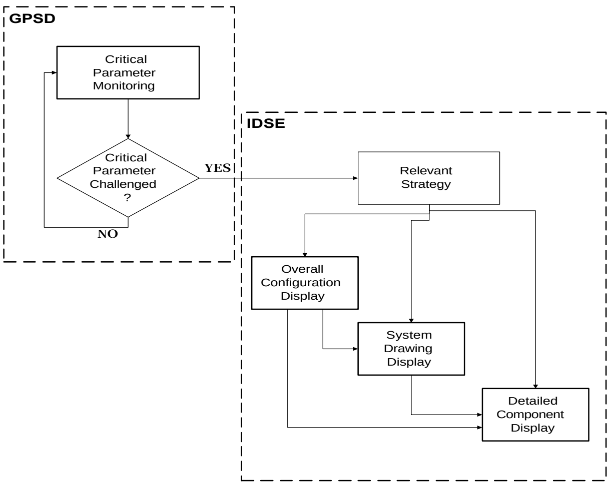

Figure 1. The Schematic Disgram of SAMDIS

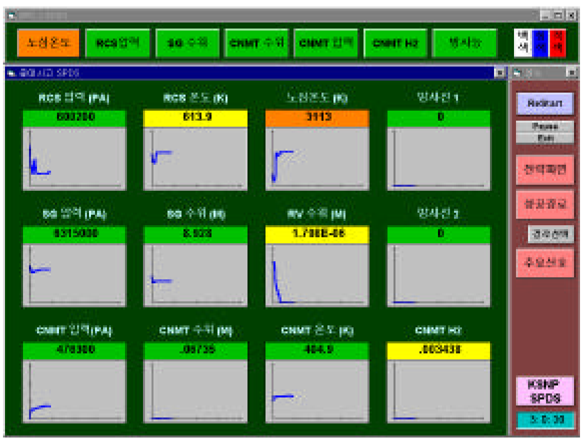

Figure 2. GPSD Module

2) Integrated Display for Strategy Execution (IDSE)

In the GPSD module, if it is detected that any parameter challenges severe accident criteria, the relevant strategy is in effect according to KAMG and this module provides all necessary information in executing the strategy. This module provides more detailed information necessary for executing each severe accident management strategy.

The IDSE module is designed with hierarchical manner and there are three levels in the display according to depth of information. The first level is plant configuration display, the second level is system drawing, and the third level is detailed information display for components. This enables plant personnel may skip the second or third level if it is not necessary to assess such detailed information.

The first level of IDSE module displays overall configuration with their respective status as in Fig.3. The first step for each KAMG strategy is to check available components or paths in order to perform the strategy, and all these checking items are included in the first step display. In this level, each displayed item may be a group of components or function of plant. In order to check a component listed in this step, a lot of conditions should be checked.

For example, in the case of HPSI pump, conditions necessary to operate pumps such as electric power and RCS pressure and conditions that may limit the ability to operate pumps such as seal cooling, motor cooling, and lube oil cooling, have to be checked by plant personnel. In representing each item, the same color concept with EOP is adopted: green for ‘normal/operable’ and red for ‘failure/not operable’. Because of simpler design of screen by success path concept, plant personnel can easily figure out all available means for achieving the strategy as in Fig.3.

The second level of IDSE displays major components simplified system drawings as in Fig.4. Whereas the first level is logical representation, the second level displays more detailed information graphically. Among a number of components of systems necessary for executing the strategy, only important components are displayed with current values of major parameters. In addition, the success paths from logical start to logical end, especially from RWT to RCS in case of RCS injection, are displayed with different color. For representing each item, the color concept is used to represent the component status as in the first level.

The third level displayed more detailed status of a component including the status of support system and environmental conditions of the component, and all these checking items are derived from attachment of strategy in the KAMG. As in the first and second level, the color concept is used to represent the status of support components, too.

The IDSE displays are designed for all severe accident management strategies of KAMG. As the strategy to be performed is determined in GPSD, the relevant screen design of the first level is displayed and the relevant second and third level screens may be selected in IDSE.

IV. Conclusion

In this paper, as the current CFMS covers from normal operation to emergency operation, SAMDIS is developed to assist plant personnel for effective execution of the severe accident management guidelines. In the case of applying the current CFMS into severe accident situation directly, there are problems: different design basis due to different system purpose, core melt vs. and radiation release, different parameters for decision-making, and different domain and depth of information.

SAMDIS is developed in this paper to assist plant personnel, especially TSC personnel, in performing the severe accident management strategy in Korea. SAMDIS provides information on major plant parameters mainly to TSC personnel by displaying current value with the status of related components. There is no direct indicator in the TSC room, and thus all information necessary executing accident management guidelines should be accessed by utilizing SPDS or by communicating with MCR personnel.

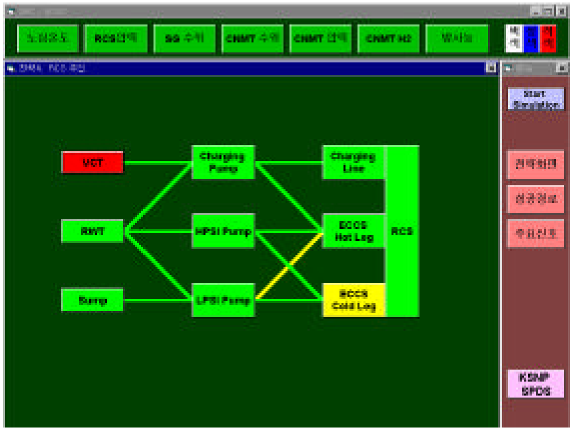

Figure 3. IDSE Module – Level 1

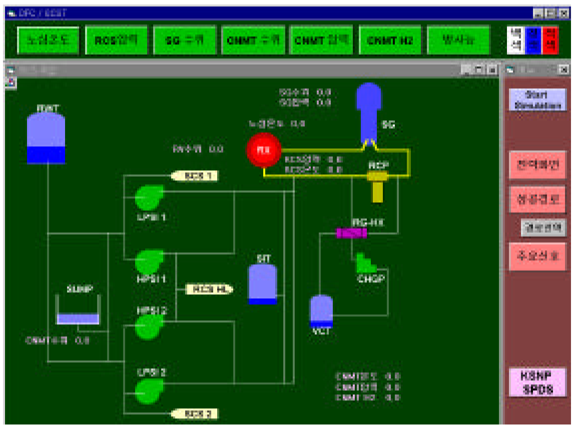

Figure 4. IDSE Module – Level 2

All necessary information for executing the strategy are included in SAMDIS and can be displayed with graphical manner that enables to easily understand the current status of plant condition and the current value of parameter. SAMDIS consists of two modules: GPSD and ISDE. The GPSD provides overall plant conditions and IDSE provides detailed information for executing severe accident management strategy.

As introducing SAMDIS, TSC/EOF personnel are only to check the screen instead of communicating with main control room personnel to get information for plant status. In aspects of collecting the important parameters of severe accident management strategy, e.g. from the primary system to containment, SAMDIS has advantages as displaying them in a screen. Therefore amount of task of TSC/EOF personnel in executing severe accident management strategy shall be reduced considerably. The developed SPDS, SAMDIS, shall be a portion of integrated operator support system for integrated severe accident management and SAMDIS shall make a central role of severe accident operator support system in Korea.

For the further development, the correlation between the current CFMS should be established in detail, e.g. the integration of the CFMS function and SAMDIS concept for severe accident condition.

V. Acknowledgements

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