SPDS Design Improvement as Operator Support System

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1. Introduction

Safety Parameter Display System(SPDS) is required to operate for Nuclear Power Plant according to post-TMI action requirements such as NUREG-0696 [1] and NUREG-0737 [2]. Supplement 1 to NUREG-0737 [3] describes requirements for SPDS which displays the minimum set of parameters for the operator to monitor the safety status of plant. SPDS should provide plant safety status information during normal and emergency operation, and contain minimum set of information for reactivity control, reactor core cooling and heat removal from the primary system, reactor coolant system integrity, radioactivity control, and containment condition. SPDS should be designed to meet the requirements which include concise display, rapid and reliable determination of safety status, aid to control room personnel, convenient location, continuous display, and sufficient information based on NUREG-0696 and Supplement 1 to NUREG-0737.

2. Types of SPDS in Korea

There are four types of SPDS which are operating now in nuclear power plants in Korea.

2.1 SPDS

The first type is the Safety Parameter Display System being operated in Kori Nuclear Power Plant Units 2,3,4, Hanbit Nuclear Power Plant Units 1,2 (HBN 1,2) and Hanul Nuclear Power Plant Units 1,2 (HUN1,2). They have been operating since 1992. The function of the SPDS is to provide safety function alarm to indicate abnormal plant status and integrated information to assess plant condition after accident. The SPDS has three level of hierarchy for display; Level 1 shows status of 7 safety related parameters, Level 2 provides traceability of safety parameter changing, and Level 3 contains system mimic for detail information.

2.2 CFMS

The second type is the Critical Function Monitoring System (CFMS) being operated in Korean Standard Nuclear Power Plants including HBN 3,4,5,6, and HUN 3,4,5,6. The CFMS was originally developed by Combustion Engineering in early 1980's. The CFMS is a kind of SPDS to assist control room personnel in evaluating the safety status of the plant. It provides on-line monitoring and displays for the critical safety function status and two major functions such as processing Critical Function alarm algorithm and supporting information displays. However, the CFMS displays inconsistent information with Emergency Operating Procedure (EOP) because of its structure during emergency operation, and it was indicated through KINS Request for Additional Information.

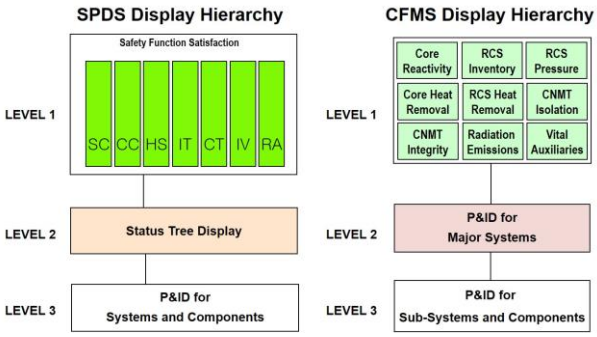
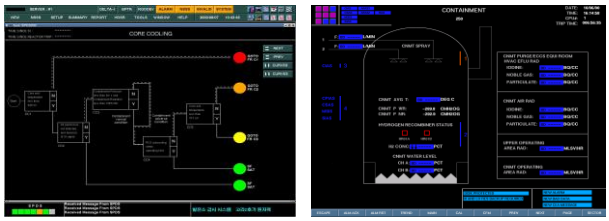


Fig. 1. SPDS/CFMS Configuration

SPDS Displays CFMS Displays

Level 1

Level 2



Level 3

Fig. 2. SPDS/CFMS Displays

2.3 SPADES

The third type of SPDS is the Safety Parameter Display and Evaluation System (SPADES), which is operating for Shin Kori Nuclear Power Plant Units 1,2 (SKN 1,2) and Shin Wolsong Nuclear Power Plant Units 1,2 (SWN 1,2). One of its advantage is that the SPADES has consistent information structure with EOP. It provides information of critical safety function status during normal and emergency operation in a concise, understandable and integrated format. The SPADES was designed based on the human factors engineering design process described in NUREG-0711 [4] in order to improve interaction between system and operator, reduce human errors according to the enhancement of operator's working condition, and increase reliability and availability of the system.

2.4 SPADES+

The fourth type is the SPADES+ which is designed and being operated for SKN 3,4 and Shin Hanul Nuclear Power Plant Units 1,2 (SHN 1,2). The Success Path Monitoring (SPM) function which provides success path availability and performance information was added to the SPADES. The SPM function provides useful information about function recovery to operator when plant is operated with functional recovery procedure during emergency operation.

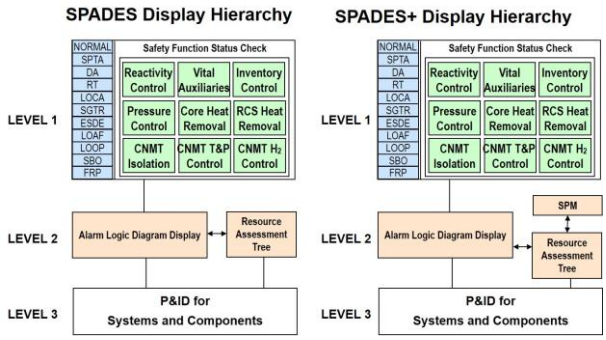


Fig. 3. SPADES/SPADES+ Configuration

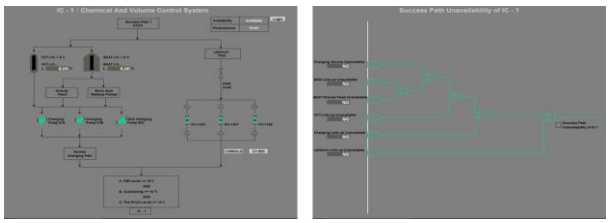


Fig. 4. SPADES/SPADES+ Displays

2.5 Comparing the SPADES with the CFMS

There are some differences between CFMS and SPADES in the point of display hierarchy and structure (refer to Table I).

Table I. Differences between CFMS and SPADES

	CFMS	SPADES
Level 1	Inconsistent Critical Safety Function (CSF) with EOP - Same CSFs regardless of the event characteristics - Inconsistent priority and acceptance criteria with EOP	Consistent CSFs with EOP - Event dependent CSFs - Emphasis on priority level of CSFs - Same acceptance criteria with EOP
Level 2	System based display - Major system such as Primary, Secondary, Containment	Function based display - Alarm logic diagram display corresponding to each CSF - Resource Assessment Tree display
Level 3	- Sub-system and components	- System and components - Direct link from Level 2

3. HFE Design Process for SPADES

NUREG-0711, Rev. 00, HFE Program Review Model (HFEPRM) was applied to design process for the SPADES. HFEPRM was developed by NRC specifically to address the programmatic review of Human System Interfaces (HSIs) for advanced reactor design. It categorizes 4 phases for design process such as Human Factors Engineering (HFE) planning, Analysis, Design, and Verification and Validation (V&V). For the SPADES design process, specific HFE program elements were selected. For planning phase, HFE program management was performed. For analysis phase, operating experience review, functional requirements analysis and task analysis were performed.

For design phase, interface design was performed. For V&V phase, HFE verification and validation was performed. Figure 5 shows overall design process based on HFE program.

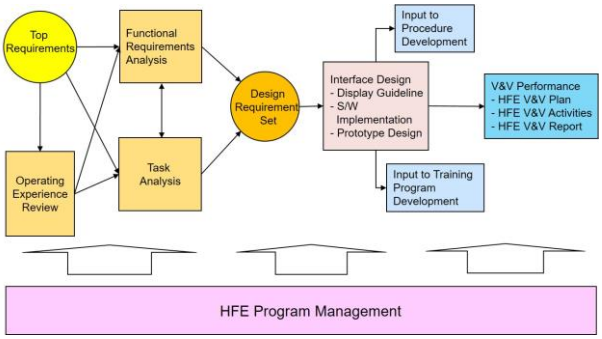


Fig. 5. SPADES Design Process

3.1 Planning Phase

In planning phase, HFE Program Plan(HFEPP) was generated. HFEPP defines general HFE program goals and scope, HFE team organization, management process and procedure, HFE issue tracking and technical program during design process.

3.2 Analysis Phase

Operating Experience Review, Functional Requirements Analysis and Task Analysis were performed in analysis phase. The operating experience review form was prepared to fill previous operating experience from plant operators and design resolution by designers. For functional requirements analysis, the review of previous CFMS functions, appropriate Critical Safety Function selection, proper input parameter selection and generation of alarm algorithm for each CSF based on the EOP were performed. Also, task analysis was performed based on operator's action and SPADES functions related with EOP. Following paragraphs provide the functional and display requirements for the SPADES derived in Analysis Phase.

1) Functional Requirements:

- The SPADES shall provide present field sensor information from which the operator may quickly monitor and diagnose the CSF status of the plant during emergency operation.
- All CSF alarms of the emergency operation shall be generated when the values of plant parameters, parameter trends or component status do not satisfy the acceptance criteria of each Safety Function Status Check (SFSC).
- The SPADES shall provide the information on the reason for alarm generation by providing the plant instrument parameters, component status, or calculated variables.

2) Display Requirements:

- The level 1 display shall provide the SFSC selection menus for each emergency operation procedure based on the hierarchy.
- The level 1 display shall provide the CSF alarm legs which belong to each CSF. The boxes containing CSF alarm leg shall be highlighted when the corresponding alarm leg is set to abnormal. The SPADES shall display the alarm generation logic and the processed input parameters used to generate the CSF alarm. The alarms shall be generated when the acceptance criteria of each CSF are not satisfied.

3.3 Design Phase

The system design for the SPADES included preparation of display guideline, prototype design to resolve critical HFE problems in early stage of design, software design including testing according to system and functional requirements defined in analysis phase, and documentation.

3.4 V&V Phase

In V&V Phase, availability verification, suitability verification, and validation were performed. For availability verification, comparing implemented information with required information contents for supporting operator's task was performed. For suitability verification, information format and navigation features in terms of HFE design guideline were checked. Validation was performed to confirm that necessary tasks could be performed in reliable and convenient fashion when it is expected to be used. Human Engineering Discrepancy generated during V&V was evaluated to determine the need for correction and identify design solution.

4. Conclusion

Four types of SPDS have been operating in Korea. There are problems on displaying inconsistent information against plant state under emergency condition, which caused for operator not to refer the information of the CFMS. The SPADES was designed by applying the HFE program from the planning to V&V phase to resolve those problems of previous systems. Enhancement in system reliability and availability can be achieved by reducing human errors as well as system errors according to the application of well-defined HFE program. HFE design concept developed for the SPADES can be applied to the design for other computerized operator support systems, so that a more reliable and effective system may be constructed. Furthermore, enhancement in the interface design between the SPADES and the Computerized Procedure System can be considered for operator to assess plant safety status more effectively. And it is strongly

recommended that replacement of CFMS to SPADES be performed for consistent information display with EOP.

REFERENCES

[1] NUREG-0696, Functional Criteria for Emergency Response Facilities, February 1981.
[2] NUREG-0737, Clarification of TMI Action Plan Requirements, November 1980.
[3] NUREG-0737 Supplement No. 1, Requirements for Emergency Response Capability, January 1983.
[4] NUREG-0711, Rev.0, Human Factors Engineering Program Review Model, July 1994.