Proceedings of the Korean Nuclear Society Autumn Meeting
Yongpyong, Korea, 2003

Development of Safety Function Assessment Trees for Pressurized Heavy Water Reactor LP/SD Operations

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Abstract

The objective of Configuration Risk Management Program(CRMP) is to maintain the safety level by assuring the defense-in-depth of nuclear power plant while the configurations are changed during plant operations, especially for the LP/SD. Such a safety purpose can be achieved by establishing the risk monitoring programs with both quantitative and qualitative features. Generally, the quantitative risk evaluation models, i.e., PRA models are used for the risk evaluation during full power operation, and the qualitative risk evaluation models such as safety function assessment trees are used. Through this study, safety function assessment trees were developed.

1. Introduction

The objective of Configuration Risk Management Program(CRMP) is to maintain the safety level by assuring the defense-in-depth of nuclear power plant while the configurations

are changed during plant operations, especially for the LP/SD. Such a safety purpose can be achieved by establishing the risk monitoring programs with both quantitative and qualitative features. Generally, the quantitative risk evaluation models, i.e., PRA models are used for the risk evaluation during full power operation, and the qualitative risk evaluation models such as safety function assessment trees are used.

2. Safety Functions for PHWR

Safety functions can be defined in terms of the plant operational status, or which safety function is required for a specific POS. Among the assessment functions of ORAM-Sentinel, safety function assessment using SFAT is the largest portion of plant overall safety status assessment especially for LP/SD operation. Therefore the development of SFAT for PHWR was focused through this study and the preliminary safety functions for Wolsung 2 were classified and presented in table 1. Main safety systems perform the multiple safety functions depending on the situation to which plant entered. Therefore the safety system classification can be altered by the POS and such alteration can be reflected by developing different filters and SFAT related to the appropriate filter

3. PHWR CRMP Development Strategy

The typical plant elements that should be considered in a CRM program are as below:

- Removal of equipment from service and the restoration of the equipment to service.
- Changes in plant operating mode, including mode changes, important changes in operating temperature changes, water levels and pressures.
- Changes in the operating alignment of risk-affecting systems.
- The presence of environmental factors.
- The performance of routine plant maintenance and testing activities that could affect the likelihood of a plant transient such as plant trip or loss of power.

The strategy and procedures for the PHWR CRMP development was established through this study and those are as below.

(1) LP/SD Operation Analysis
   1) Operational modes
   2) Outage type
   3) Determination of Plant Operational Status(POS) classification factors
   4) Operation procedure analysis
   5) POS classification
   6) Identification of safety function required for each POS
   7) Identification of systems and components which perform the safety functions need for each POS

TABLE 1. PHWR Safety Functions

Safety Function	Systems
1. Reactivity Control	Shutdown System No. 1 Shutdown System No. 2 Poison Adding System
2. Core Cooling	Primary Heat Transport System Emergency Core Cooling System Shutdown Cooling System Steam Generators Moderator System
3. Secondary Heat Removal	Main Feedwater System Auxiliary Feedwater System Degasser Condenser Condensate Storage Tank
4. Primary Heat Transport Inventory	Pressurizer Emergency Core Cooling Tank Dousing Tank Moderator System
5. Essential Electric Power	Class IV Electric Power Supply Class III Electric Power Supply Standby Diesel Generator Emergency Diesel Generator
7. Cooling Water and Other Vital Support System	Recirculated Cooling Water System Raw Service Water System Emergency Water System
8. Containment Integrity and Cooling	Containment System Dousing System Local Air Cooler System Containment Isolation System

(2) PCDB Development
    1) Component/Train Variables
    2) Configuration Variables
    3) High risk evolution variables
(3) SFAT development
    1) Safety Function Definition
    2) Filter development
    3) SFAT logic development
(4) PTAT development
    1) Initiating event definition
    2) Filter development
    3) PTAT logic development
(5) Plant Safety Evaluation
(6) CRMP Development

The POS of PHWR LP/SP operation can be categorized into 3 phases depending on the reactor inlet header temperature and other indicators, and several PHWR SFATs were developed for each POS depending on the safety system configurations.

4. Safety Function Assessment Trees for PHWR

The SFATs were developed for the POS of PHWR SD/LP operation and the POS was illustrated in figure 1.Through this study, safety function assessment trees were developed

and Figure 2,3, and 4 are presented as example.

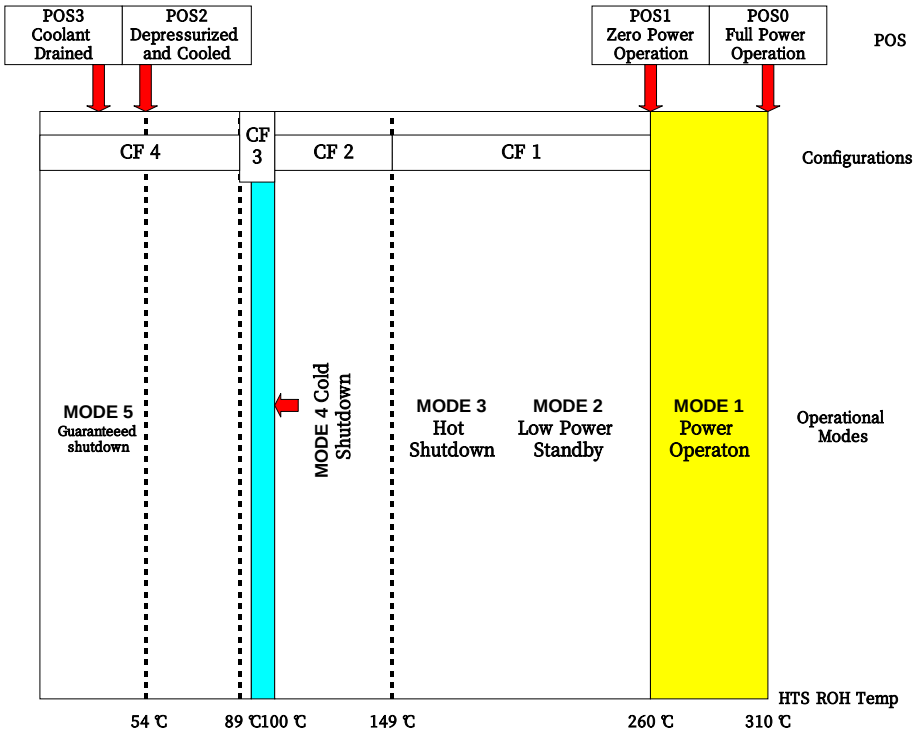

Figure 1. Plant Operational Status and Configurations of PHWR

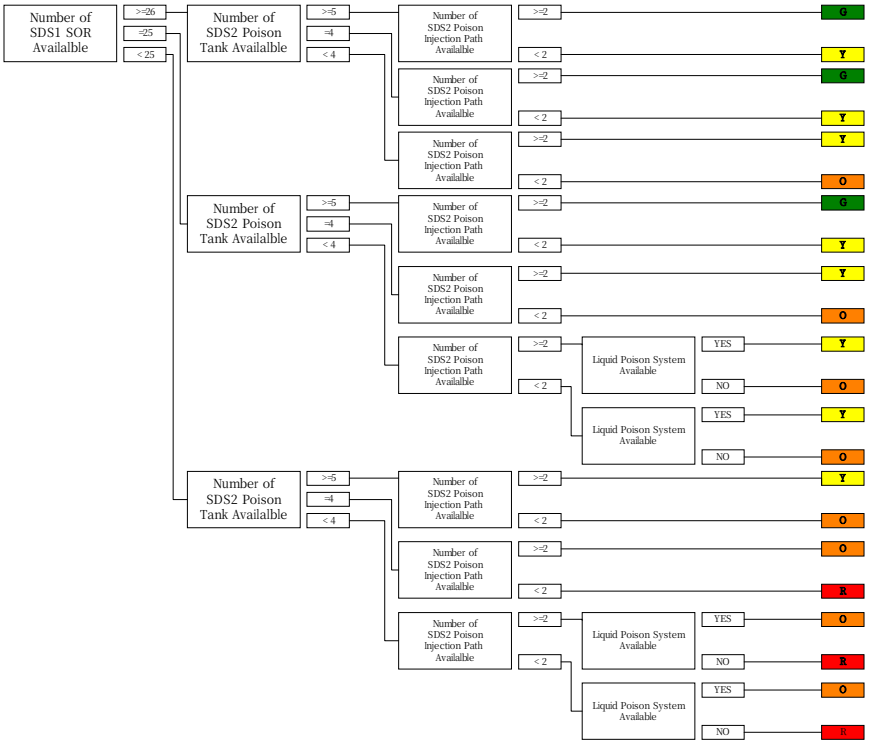

Figure 2. Subcriticality Safety Function Assessment Tree for Configuration 1

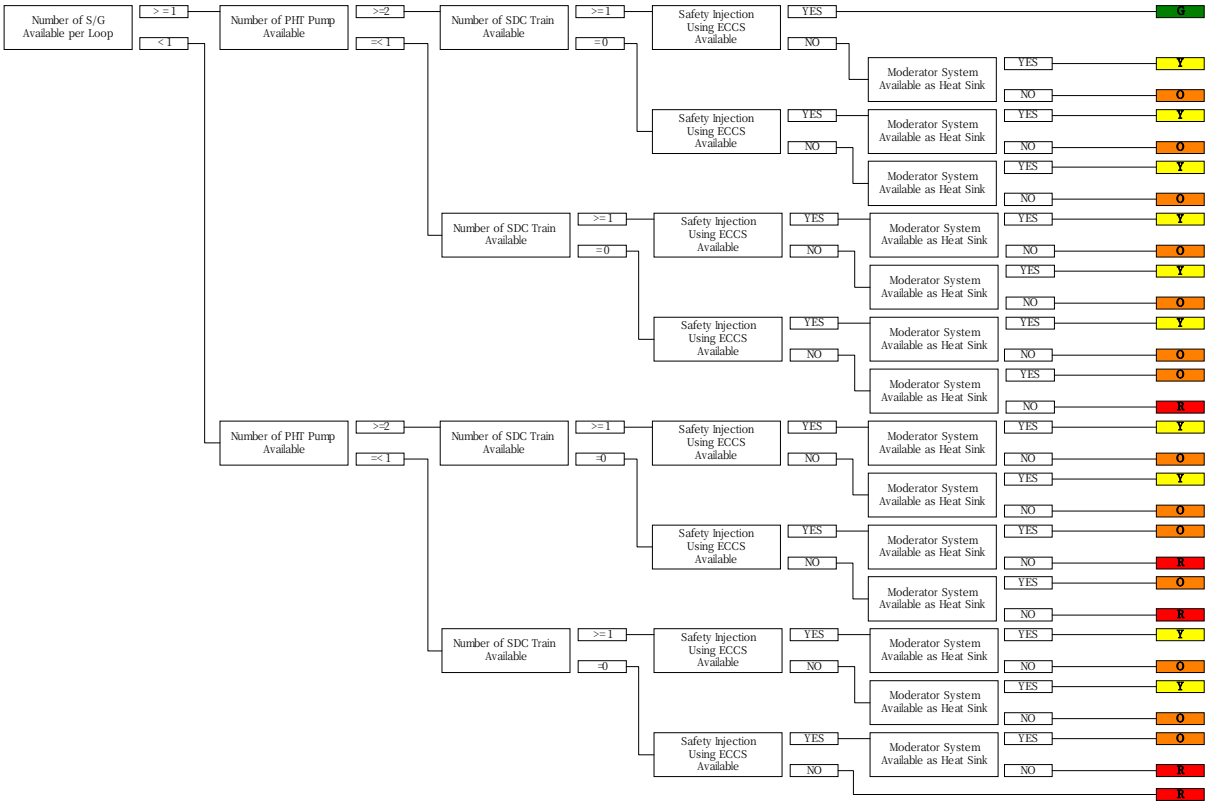

Figure 3. Core Cooling Safety Function Assessment Tree for Configuration 1

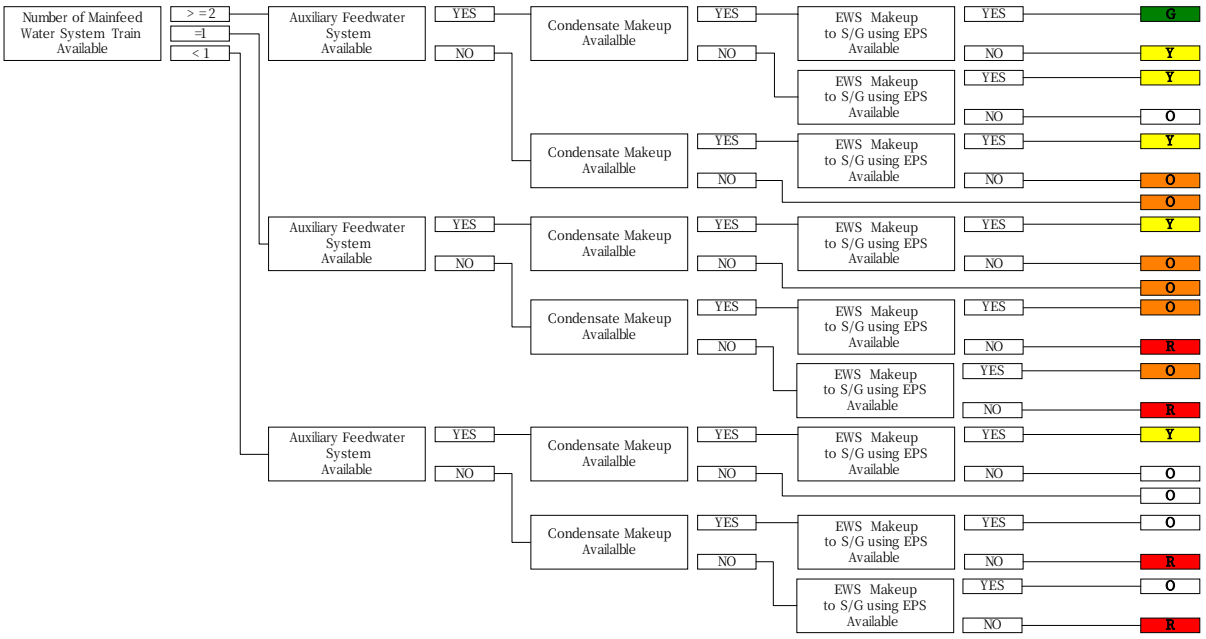

Figure 4. Secondary Heat Removal Safety Function Assessment Tree for Configuration 1

5. Conclusion

The strategy and procedures for the PHWR CRMP development was established through this study, and the risk evaluation model for PHWR LP/SD operation in terms of defense-in-depth, i.e., SFATs were developed. Considering the resources available for the risk assessment, the qualitative evaluation features of this strategy can contribute to the effective risk management and to the development of risk management program. The plant safety status assessment trees developed through this research can be utilized in the development of ISTS or RISTS for Korean NPPs also.

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