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Development of Critical Safety Function Status Trees for Pressurized Heavy Water Reactors

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Abstract

Critical Safety Function Status Trees are to provide information on the safety status of nuclear power plant based on the safety variables which represent the critical safety functions. The combination of safety parameters can designate the status of critical safety functions which are necessary to maintain the defense-in-depth safety and the capability to mitigate the accident sequences. In this study, the safety functions were identified and the safety parameters for each safety functions were selected and the critical safety function status trees for PHWR were developed.

1. Introduction

Critical Safety Function Status Trees are to provide information on the safety status of nuclear power plant based on the safety variables which represent the critical safety functions. The combination of safety parameters can designate the status of critical safety functions which are necessary to maintain the defense-in-depth safety and the capability to mitigate the accident sequences. For Westinghouse nuclear power plants, the critical safety function status assessment trees were developed as a part of Emergency Operation Procedures and the similar decision trees were developed for CE plants. In Computerized Technical Advisory System for the Radiological Emergency(CARE) developed by KINS and MOST, such critical safety function status trees were implanted except for the pressurized heavy water reactors(PHWR) in Korea. To develop the critical safety function status trees for CANDU reactors, the defense-in-depth safety and related safety functions should be identified first. After the identification of the safety functions of PHWR, safety parameters should be selected among the parameters for PHWR in Safety Information Display System (SIDS) of CARE. Then the main logic for each safety function should be developed. In this study, the safety functions were identified and the safety parameters for each safety functions were selected and the critical safety function status trees for PHWR were developed.

2. Safety Functions of PHWR

To identify the safety functions of PHWR, the safety related information was analyzed. The primary information source is Emergency Operation Procedures and Abnormal Operating Manual for Wolsung. Through this analysis, safety functions of PHWR, and the relationship between defense-in-depth concept and safety functions were identified and presented in figure 1.

3. Safety Parameter Selection for Safety Functions

After identification of safety functions, the symptoms those mean the failure of safety function were identified through the analysis for the technical rationales of EOP, especially for the EOP-002, Critical Safety Parameters Monitoring and Restoration.

For each safety function, safety parameters were selected such that the parameters could represents the status of relevant safety function. The primary sources for safety parameters are the digital and analogue parameters processed by the digital control computer of Wolsung plant, and the safety parameters processed by SIDS of CARE.

Subcriticality is the most important safety parameter to prevent the neutron reaction from reaching criticality again after reactor shutdown. Subcriticality function is to be performed by shutdown system(SDS) No. 1 and No. 2 and the failure of this safety functions is the neutron flux high indication after reactor trip by SDS1 and 2. The reactor power level permitted in EOP is 2% FP and the rationale for the value, 2% FP is that the occurrence of fuel dryout at such power level of decay heat, is not expected for PHWR.

Core Cooling Safety functions should be performed after the reactivity concern is resolved. Best indicators for core cooling capability is the subcooling margin at the reactor inlet header (RIH). By EOP-002, the acceptable subcooling margin at RIH is 5º C. Another indicator for core cooling capability is the reactor outlet header(ROH) temperature. Normal operating temperature is about 310º C and the maximum temperature range for the post accident ROH temperature measure is 320º C.

Heat Sink can be maintained by steam generators, shutdown cooling system, and emergency core cooling system and finally moderator system. The criteria for selection of safety parameters for each system were defined through the analysis for EOP, FSAR, Heat Sink Assurance Plan, and Safe Design Marix.

Coolant Inventory should be assured during core cooling and the pressurizer level and heavy water storage tank level can be good indicators for coolant inventory.

Besides inventory of coolant, the integrity of coolant should be secured for the assurance of the coolability. High pressure of coolant can threaten the integrity of primary heat transport system and emergency core cooling capability.

Reactor Building Integrity is important in terms of final barrier to the radioactive material release to the environment. Reactor building integrity is affected by the pressure rise inside reactor building. The water level inside reactor building also can affect the reactor building integrity because the transmitter lacks could be flooded when the reactor water level rises over 2.4m. Once transmitter lacks were flooded, the steam generator level control and moderator temperature control capability could be lost.

Radioactivity Release to environment should be prevented. For this purpose, the radioactivity inside and outside of reactor building should be monitored and the acceptable range of radioactivity at each monitoring detectors were specified by EOP.

The critical safety function status trees for subcriticality is presented in figure 2 and 3 as example. Critical safety function status trees for each safety function are developed in two types, i.e., Westinghouse and Combustion Engineering types.

4. Conclusion

The safety functions for PHWR were defined and the safety parmeters for each safety function were selected. In addition, the detailed logic for critical safety function status trees were developed through this study. The remained issue about the development of critical safety function status trees is the definition of the criteria of safety parameters. Because of the lack of digital and analogue safety parameters processed DCC in Wolsung plants, it is necessary to develop the alternative safety parameters. Another issue is the definition of acceptable values for each safety parameters. Critical safety Function Status Trees are the key feature of CARE and these safety status indication will help to assess the radiological consequences of possible accident and to provide the necessary counter measures.

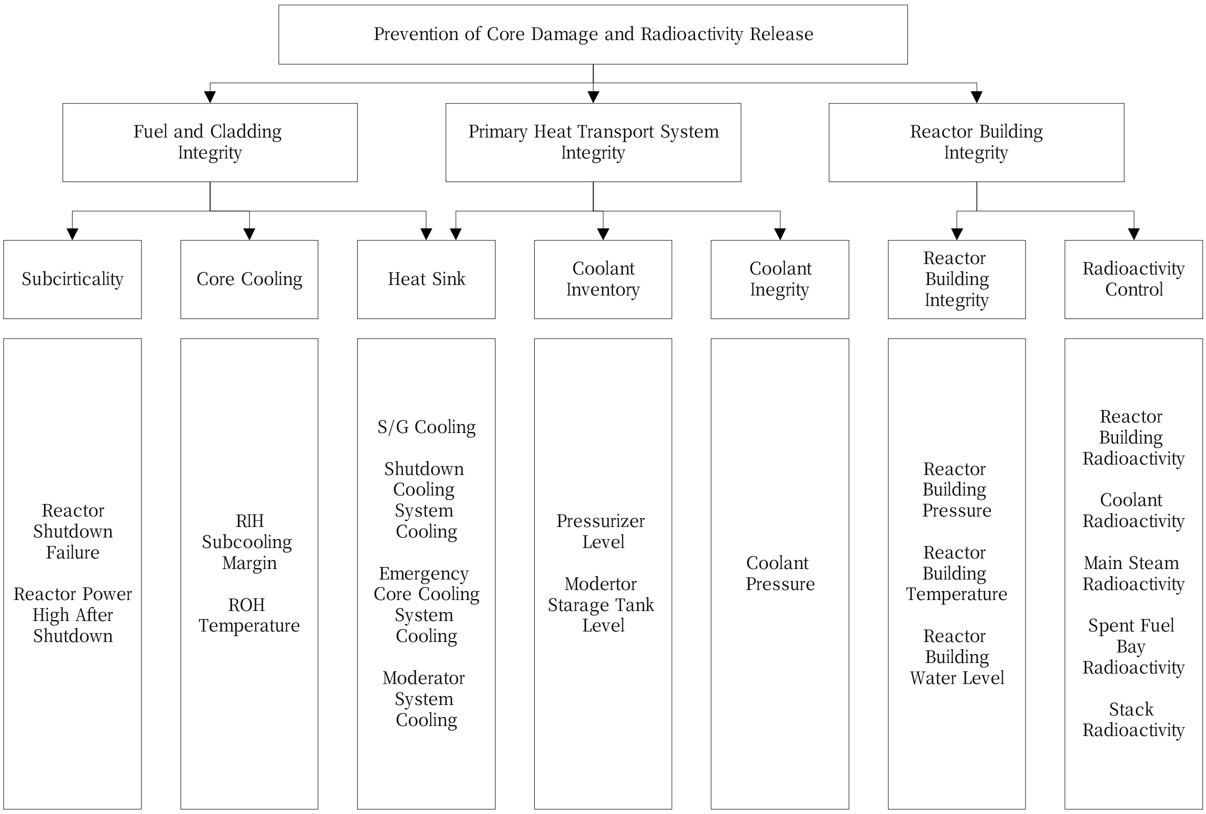

Figure 1. Defense-in-depth and Safety Functions of PHWR

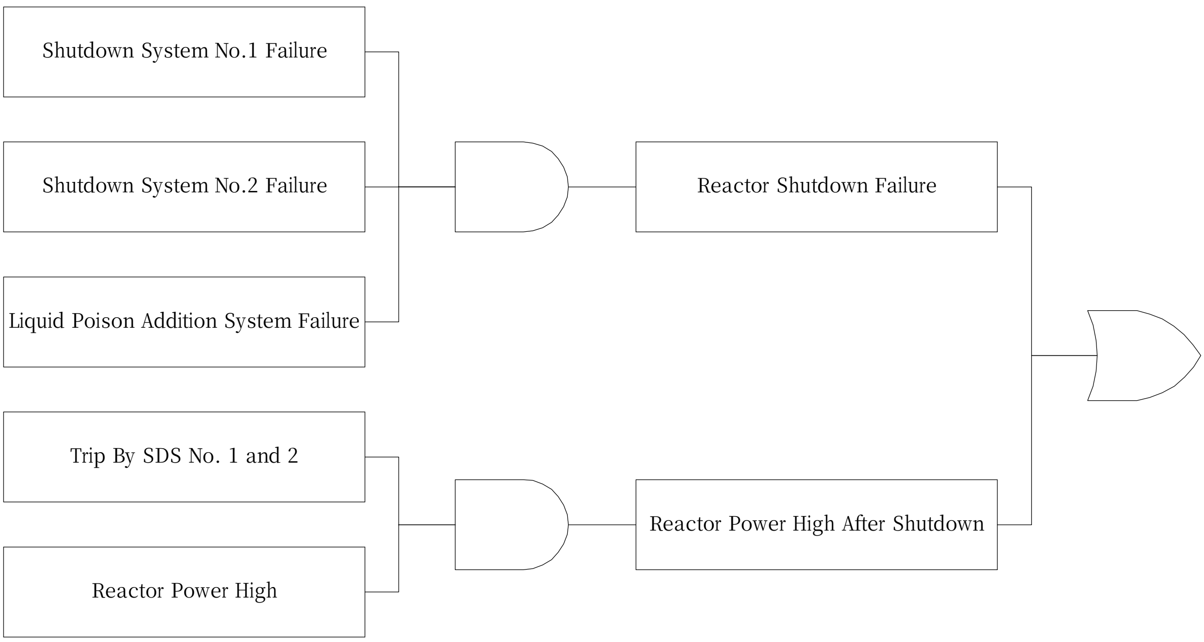

Figure 2. Subcriticality Safety Function – CE Type

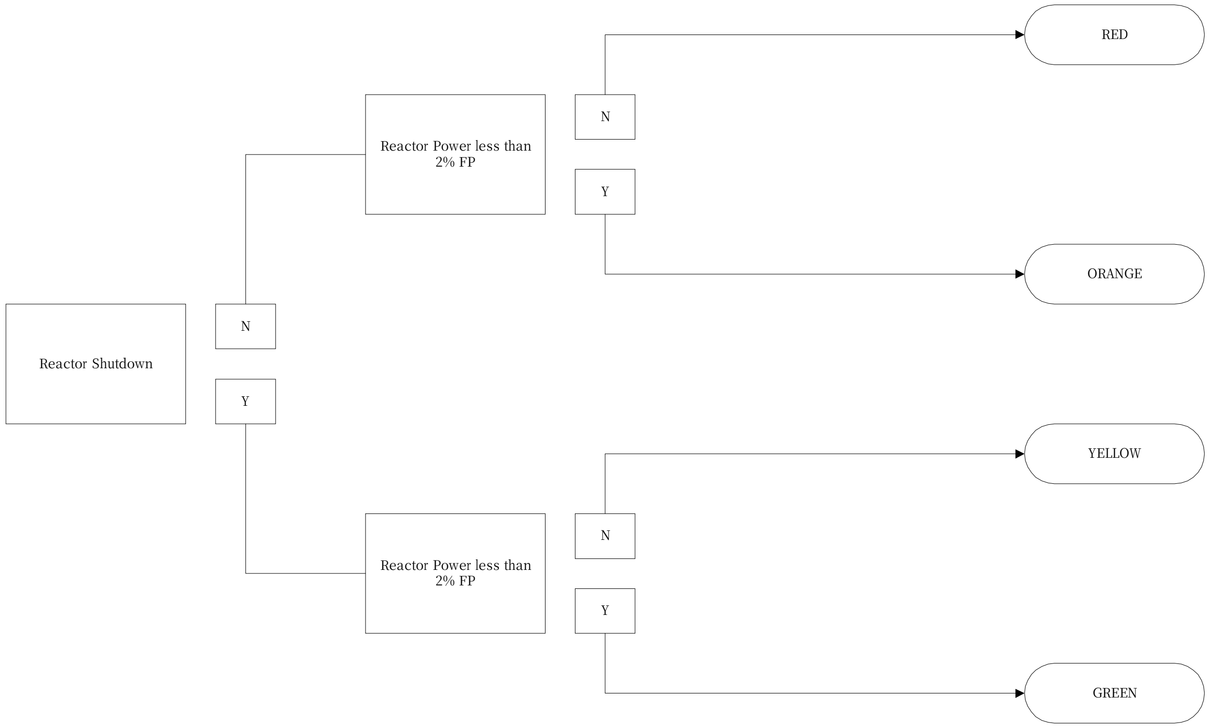

Figure 3. Subcriticality Safety Function – WH Type

References

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3. Westing House, Emergency Response Guidelines-Background, July 1087