CANDU Reactor Severe Accident Management Strategies for Plant Specific Features

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1. Introduction

The objective of this paper is to establish basic logical scheme for severe accident management strategies. For development of severe accident management strategies, plant specific features and behaviors must be studied by detailed analysis works. This analysis scope will serve to cover overall methods and initiating event selections to understand the most likely severe accident sequences that could occur at CANDU plant for identification of any plant specific vulnerabilities to severe accidents. Also collected useful information from the development of severe accident management strategies could help prevent or mitigate severe accidents.

2. Methods and Results

In this section, analysis techniques used to model the CANDU plants and are described.

2.1 Severe Accident phenomena Model for Plant Specific Failure

One of the major credits of CANDU plants is a large inventory of moderator which surrounds the fuel channels. Unlike PWRs, CANDU plants consist of the separate two loops and an automatic loop isolation occurs to reduce the rate of reactor coolant loss in the event of a LOCA. When the decay heat can be removed from the intact loop to the steam generator secondary side, half the core keeps its integrity and neither the calandria tank nor the containment fails in the mission time. This characteristic seems to the unique to CANDU plants.

Basically the same methodology used for PWRs is applied to CANDU plants for specific strategies from e results of Level 1 PSA analyses are grouped into plant damage states (PDSs). Containment failure mode and timing, and source term characteristics are considered in defining PDSs.[1]

Once the RCS or PHTS has voided (via break or boil-off), further gradual pressurization of the containment building will occur from the generation of steam in the calandria tank and in the calandria vault for CANDU plants and in the reactor cavity for PWRs. Non-condensable gases generated from the interaction of molten corium with the concrete of the calandria vault for CANDU plants and with the concrete of reactor cavity floor for PWRs, contribute to the pressure build up in the containment. This pressurization process could last from hours to several days, depending upon the effectiveness of engineered safety features.

Based on the previously typical analyses [1], severe accident induced containment event tree (CET) is constructed using nine top events for PWRs. These are: 1) Mode of induced primary system failure, 2) Possibility of core-melt arrest, 3) Possibility of alpha mode containment failure, 4) Amount of corium ejected out of cavity, 5) Mode of early containment failure, 6) Status of late recirculation spray, 7) Debris coolability at the reactor cavity, 8) Mode of late containment failure, and 9) Basemat melt-through. Meanwhile, CET for CANDU plants has been developed using seven top events: 1) Core integrity maintainability, 2) Status of end shield cooling, 3)Status of secondary heat removal, 4)Status of containment local cir coolers, 5) Status of containment dousing sprays, 6) Mode of late containment failure, and 7) Mode of very late containment failure. [2]

2.2 Severe Accident management strategies based on initiating events selected for Plant Specific Features

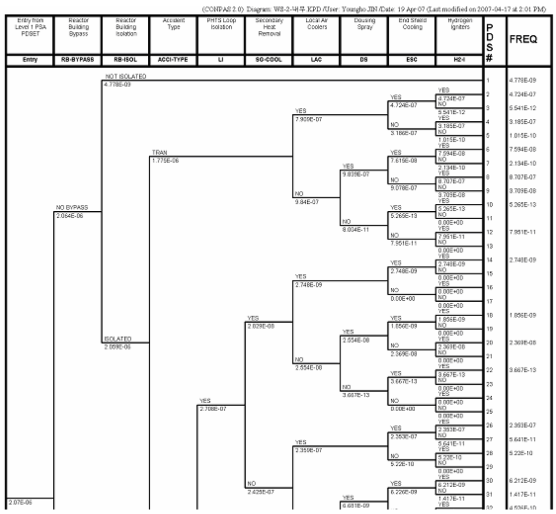

Figure1. Typical Plant Damage State Event Tree for Plant Specific Features

For development of accident management strategies, various initiating scenarios are selected by logical category schemes for Wolsong units 2, 3, 4 as typical CANDU plant.

1) After grouping of every initiated possible event into similar plant behavior categories, most severe scenarios are selected according to theses analysis

results. For Wolsong CANDU Plant, 35 initiating events are considered. But 5 initiating event groups are summarized and selected by severe accident analysis experiences with expert insight. 5 initiating groups are as follows ①large LOCA, ②small LOCA, ③SGTR, ④pressure tube rupture in calandria vault, ⑤transient (including station blackout)

2) Initiated events are selected according to PSA results ordering by number of core damage frequencies (CDF). Therefore, most conservative sequence cases are selected for selected initiating events. For internal event of Wolsong CANDU Plant case is shown as table 1.

Table 1. Typical Initiating Events by Plant Damage Frequencies for Plant Specific Features

Initiating Event	CDF	Contribution Percent	Cumulative Percent
IE-CL4	7.362E-07	35.57	35.57
IE-IA	4.192E-07	20.25	55.82
IE-ESC	2.696E-07	13.02	68.85
IE-SW	2.407E-07	11.63	80.47
IE-FBS	2.370E-07	11.45	91.92

3) 5 PDSs are selected according to PSA results from ordering number of core damage state frequencies. Next, most conservative sequence cases are selected for selected initiating events. For internal event of Wolsong CANDU Plant case is shown as table 2.

Table 2. Typical Initiating Events by PDS Frequencies for Plant Specific Features

Initiating Event	PDS	PDS frequencies	Contribution Percent	Cumulative Percent each PDS
IE-CL4	PDS8	6.300E-07	72.364	72.364
IE-IA	PDS2	4.174E-07	88.373	88.373
IE-ESC	PDS4	2.685E-07	84.307	84.307
IE-FBS	PDS26	2.312E-07	98.264	98.264
IE-CL4	PDS6	6.102E-08	80.355	80.355

4) 5 PDS event tree sequences are studied according to PSA results from ordering number of core damage state frequencies. Next, most conservative sequence cases are selected for selected initiating events. For internal event of Wolsong CANDU Plant case is shown as table 3.

Table 3. Typical Initiating Events by PDS Event Tree Frequencies for Plant Specific Features

Initiating Event	PDS	PDS frequencies	Contribution Percent	Cumulative Percent each PDS
IE-IA_S32	PDS8	3.665E-07	77.590	77.590
IE-ESC_S47	PDS4	2.685E-07	84.307	84.307
IE-CL4_S71	PDS8	4.388E-07	50.397	50.397
IE-SW_S7	PDS8	2.312E-07	26.713	77.110
IE-FBS_S15	PDS6	6.102E-08	80.355	80.355

3. Conclusions

In order to select the useful severe accident management strategies, plant specific features must be identified by logical schemes using detailed studies for the characteristics of CANDU plants. For simply covering overall events, representative initiating events for unique CANDU features are identified by experience expertise. 5 initiating groups are ①large LOCA, ②small LOCA, ③ SGTR, ④pressure tube rupture in calandria vault, ⑤transient (including station blackout). On the other hand, a reasonable alternative way for selecting initiating events is served as PDS event tree based initiating event approach. These selected initiating sequences are suggested such as ① IE-IA_S32, ② IE-ESC_S47, ③ IE-CL4_S71, ④ IE-SW_S7, ⑤IE-FBS_S15 with containment event tree headings which are different from previous grouping method by experience expertise. After selecting initiating event, the tedious works must be accompanied for mitigating strategies on severe accident containment failure mechanism.

REFERENCES

[1].USNRC, "Individual Plant Examination: Submittal Guidance", NUREG-1335, August 1989
[2]. KEPCO, "Risk Monitoring System Development for Wolsong units 2,3,4", 2007.5