Comparison of Unavailability between Different Types of Reactors

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1. Introduction

Canadian Nuclear Safety Commission (CNSC) determines a limit of safety system unavailability for CANDU reactor as 1.0E-3 per year. Unavailability of Emergency Core Cooling System (ECCS) in Wolsong Unit 1, which is Korean CANDU reactor, is found that do not satisfy this limit through probabilistic safety assessment (PSA).

As a part of safety improvement assignment, Wolsong Unit 1 is planned to perform design change of ECCS. It is considered essential to compare unavailability of Wolsong Unit 1 with other Pressurized Water reactors to estimate whether ECCS of Wolsong Unit 1 is safe or not. But the design difference between Wolsong Unit 1 and other PWRs makes it difficult to compare unavailability of ECCS.

In this paper, comparison for unavailability of ECCS between Wolsong Unit 1 and other PWR is performed.

2. Methods and Results

2.1 Development of Fault Tree for quantification

ECCS operates in both various modes and conditions. Demanded operation modes are decided by accident scenarios. Accident scenarios are represented in the event trees. Fig. 1, 2 show Kori Unit 3,4 Small Loss of Coolant Accident (SLOCA) and Steam Generator Tube Rupture (SGTR) event tree respectively.

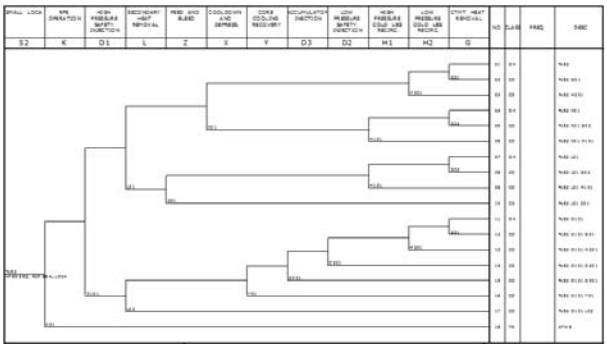

Fig. 1. Kori Unit 3,4 SLOCA Event Tree

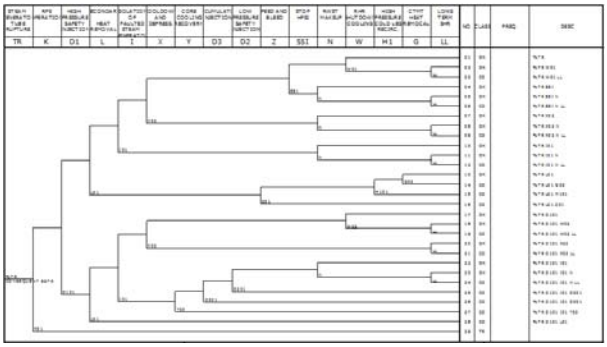

Fig. 2. Kori Unit 3,4 SGTR Event Tree

As shown at Fig. 1 and 2, operation modes of ECCS are different for each sequence. Operation modes also depend on the state of other safety systems. In the progress of quantification in PSA, Core Damage Frequency is calculated by combining probabilities of each sequence. Unavailabilities of each operation modes of ECCS are quantified in this progress, but additional efforts are required to calculate unavailability of whole ECCS.

On the purpose of calculating unavailability total ECCS, we developed new fault trees. Fig. 3, 4 shows a developed fault tree of one sequence of SLOCA and SGTR respectively.

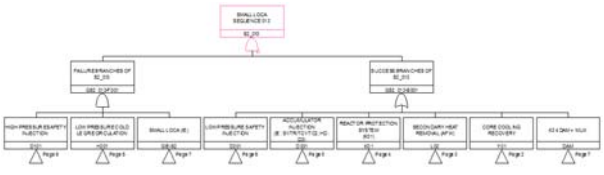

Fig. 3. Kori Unit 3, 4 Fault Tree of SLOCA Sequence #13

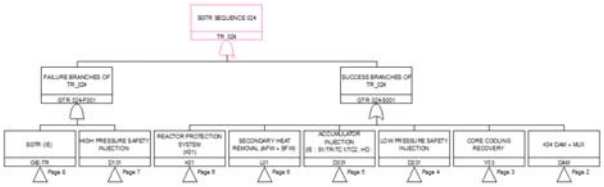

Fig. 4. Kori Unit 3, 4 Fault Tree of SGTR Sequence #24

These fault trees consist of failure branches and success branches. Failure branches include ECCS failure logic. Success branches include success logic of successfully operated systems. Inadequate logics, which should not be considered during quantification, are included in success branches. If these inadequate logics are included in failure branches, they are deleted in the process of quantification.

System unavailability for specific initiating event can be calculated by combining above fault trees. For example of Kori Unit 3, 4, there are three accident sequences which include failure of ECCS when Medium LOCA occurs. Following Fig. 5 shows Medium Loss of Coolant Accident (MLOCA) event tree and sequences which include failure of ECCS. Fig. 6 shows developed fault tree for quantification of ECCS unavailability in MLOCA. Unavailability of ECCS when MLOCA occurs can be calculated by quantifying top gate of this fault tree.

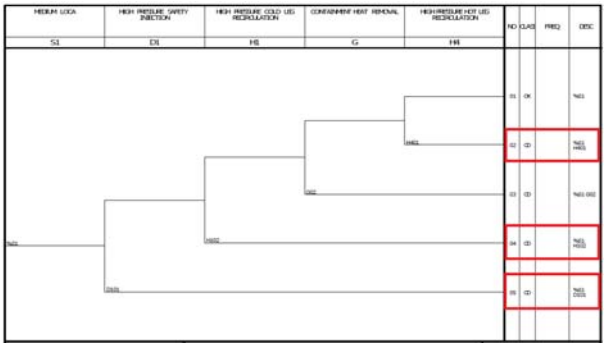

Fig. 5. Kori Unit 3, 4 MLOCA Event Tree. ECCS related sequences are marked in red.

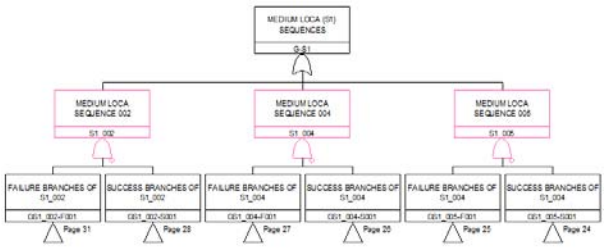

Fig. 6. Developed fault tree for calculating ECCS unavailability in MLOCA.

2.2 Quantification of Kori Unit 3, 4

For comparison analysis with Wolsong Unit 1, Kori Unit 3, 4 are selected as representatives of PWR.

From the result of PSA research in Kori Unit 3 and 4, it is confirmed that ECCS operates when 11 case of initiating events are happened. Quantification is conducted by using developed fault trees which shown at section 2.1.

As a result of quantification, it is found that ECCS unavailability has the highest value when Main Steam Line Break (upstream) occurs. Table 1 shows unavailability of ECCS for each initiating events.

Initiating Event	Unavailability of ECCS (per year)
Small Loss of Coolant Accident	5.56E-3
Medium Loss of Coolant Accident	7.755E-3
Large Loss of Coolant Accident	6.12E-3
Steam Generator Tube Rupture	4.78E-3
General Transient	5.08E-2
Loss of Opposite Power	3.50E-3
Station Black Out 1	7.81E-8
Station Black Out 2	6.86E-8
Main Steam Line Break (upstream)	1.81E-1
Main Steam Line Break (downstream)	4.69E-3
Loss of Component Cooling Water	1.11E-4

Table 1. Unavailability of Kori Unit 3,4 ECCS at each initiating events.

2.3 Quantification of Wolsong Unit 1

From the result of Wolsong Unit 1 PSA, it is confirmed that 7 initiating events need ot operate ECCS to reduce risk of nuclear power plant. Quantification is conducted by using developed fault trees.

As a result of quantification, it is found that ECCS unavailability is highest when Feeder Stagnation Break occurs. Table 2 shows unavailability of ECCS for varied initiating events.

Initiating Event	Unavailability of ECCS (per year)
Small Loss of Coolant Accident	3.77E-2
Large Loss of Coolant Accident	3.77E-2
Feeder Stagnation Break	1.35E-1
Main Steam Line Break Inside Turbine Building	3.77E-2
Total Loss of Service Water	3.84E-2
Dual Control Computer Failure	4.03E-2
Multiple Steam Generator Tube Rupture	3.25E-2

Table 2. Unavailability of Wolsong Unit 1 ECCS at each initiating events.

3. Conclusions

Canadian Nuclear Safety Commission determined limits of system unavailability for CANDU reactor as 1.0E-3 per year. And Wolsong Unit 1 do not satisfy this limits. From the result of this study, it is demonstrated

that ECCS of Wolsong Unit 1 is less safety than Kori Unit 3 and 4.

From the result of importance analysis in this study, it is found that main cause of excessive unavailability is Component Cooling Water inlet and outlet valves of Heat Exchanger. And it is planned to construct additional Component Cooling Water flow line for redundancy of system. So, we can expect safety of ECCS will be improved by design change.

4. Acknowledgement

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