System Response Analysis of Rod Ejection Accident for APR1400 Using KNAP Hot Spot Model

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1. Introduction

Korea Electric Power Research Institute (KEPRI) has been developed the non-loss-of-coolant accident (non-LOCA) analysis methodology, called as the Korea Non-LOCA Analysis Package (KNAP), for the typical Optimized Power Reactor 1000 (OPR1000) plants. Considering current licensing methodology conducted by ABB-CE, however, the KNAP could be applied to Advanced Power Reactor 1400 (APR1400) also. In spite of some difference in design concepts of two plant types, there is a close resemblance between their nuclear steam supply systems (NSSS). So, in this study, the rod ejection accident (REA) event was analyzed using KNAP hot spot model (HSM) for APR1400 to estimate the feasibility of the application and the results were compared with those given in APR1400 Standard Safety Analysis Report (SSAR), which were calculated using the CESEC-III and STRIKIN-II code of ABB-CE. Through the study, it was concluded that the KNAP could be applicable to APR1400 on the view point of REA.

2. Plant Modeling

2.1 Reactor Coolant System Modeling

Prior to analysis, the reactor coolant system (RCS) of object plants, APR1400, was modeled with several volumes and junctions to simulate the accident. The core was partitioned into 6 vertical volumes and 2 separated hydraulic channels, respectively. In the case of steam generators, tubes and secondary sides were modeled with 12 and 14 volumes, respectively, to represent the U-tube bundles and two feedwater-paths or economizer. In fact, the standard RCS model for OPR1000 used in the KNAP had been applied to the object plants with minor changes considering the characteristics of them.

2.2 Hot Spot Modeling

Based on the review over the STRIKIN-II model of APR1400, the average and hot spot channel model presenting the fuel assemblies were developed. To reflect the characteristic of the STRIKIN-II model, the hot spot channel was divided up to 25 meshes of 0.5 ft height in axial direction and 17 segments in radial direction.

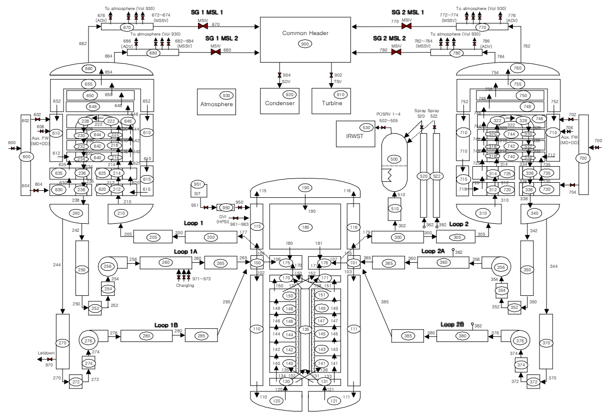

Fig. 1 RETRAN nodal diagram for APR1400

3. Rod Ejection Accident Analysis

The REA is classified as an ANS plant condition IV incident due to the extremely rare probability and catastrophic consequence. The safety criteria of the accident, on the viewpoints of system responses, are the average fuel enthalpy, the maximum fuel temperature, the peak RCS pressures, and the cladding temperature. Any other limitations are covered with these criteria.

The conditions led to REA would be classified into 4 cases, such as hot zero power (HZP) at the beginning of cycle (BOC), hot full power (HFP) at BOC, HZP at the end of cycle (EOC), and HFP at EOC. In this study, however, two cases, *i.e.*, HFP and HZP, were selected to confirm the applicability of KNAP to APR1400.

Table 1. Initial Conditions for REA Analysis

Parameter	Value
Core power Level, MWt	4062.66
Core Inlet Coolant Temp. ^{o}F	563.0
Core Mass Flowrate, 10^{6}lbm/hr	153.52
Pressurizer Pressure, psia	2,175
Delayed Neutron fraction, β	0.00412
Moderator Temperature Coefficient, $\Delta\rho/^{o}F$	0.0
Ejected CEA Worth, $10^{-2}\ \Delta\rho$	0.11
Total SCRAM Worth, $10^{-2}\ \Delta\rho$	-6.0
Postulated CEA Ejection Time, sec	0.05
Maximum Peaking factor	2.63

To compare the results of this study with those mentioned in SSAR, which are calculated with CESEC-III and STRIKIN-II codes, the same initial conditions and assumptions were used. Most of them were quoted from the SSAR. As given at table 2, the trends of the transients are similar figures each other.

Table 2. Sequence Comparison

Event	SSAR		RETRAN	
	Time	Value	Time	Value
CEA Ejection	0.0		0.0	
Reactor Trip	0.045		0.045	
Max. Power, %	0.1	135.2	0.09	133.9
Turbine Trip	0.595		0.596	
Max. Fuel Temp., ^{o}F	3.5	4,769.8	3.53	4,692.4

As mentioned in the figure 2 the calculated power from HSM show the similar trends to those mentioned in SSAR. And it would be found that the power fractions of the hot spot were jumped to about 355% of the initial power, although the overall powers were risen up to about 135% in the case of the average channel.

In the case of the fuel temperature, the temperature was calculated through the heat conductors used to represent the fuel assemblies and the maximum was the temperature of the most inner node. Despite of little difference, the results show the similar trends to those in SSAR as depicted in figure 3.

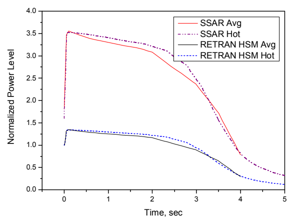

Figure 2. Power Trends

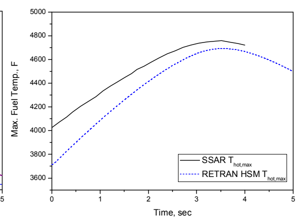

Figure 3. Max. Fuel Temp.

Figure 4 and 5 show the pressurizer and steam generator shell side pressure, respectively. The results of RETRAN show somewhat different trends due to the comprehensive non-equilibrium pressurizer and multi-node steam generator secondary side models. On a standpoint of variation, however, they show the similar trends each other.

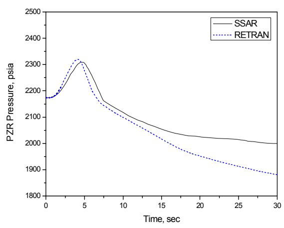

Figure 4. PZR Press.

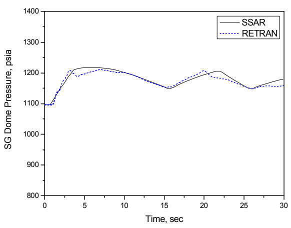

Figure 5. SG Shell Press.

4. Conclusion

The REA was analyzed to estimated the feasibility of the KNAP application to APR1400. The results of the analysis were compared with those mentioned in SSAR, which are calculated by CESEC-III or STRIKIN-II code of ABB-CE. Through the feasibility study, it was concluded that the KNAP application showed the acceptable results and could be used further works.

Acknowledgements

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