Preliminary System Response Analysis of Rod Ejection Accident for APR1000

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1. Introduction

Korea Electric Power Co. (KEPCO) has designed the Advanced Power Reactor 1000 (APR1000) plants implementing the advanced safety features to Optimized Power Reactor 1000 (OPR1000) plants. Prior to developing the detail design, the preliminary design project has been launched since the end of 2009 as a feasibility study. In spite of some difference in safety-related design concepts of two plant types, they could be treated as the same plants considering the main features or systems. In this study, the rod ejection accident (REA) event was analyzed using Korea Non-LOCA Analysis Package (KNAP) hot spot model (HSM) for APR1000 to examine the feasibility of the design concepts and the results were compared with those values calculated by the Safety Analysis Report (SAR) conditions of typical OPR1000 plants. Through the study, it was concluded that the design concepts and the analysis package could be applicable on the view point of REA.

2. Plant Modeling

2.1 Reactor Coolant System Modeling

The reactor coolant system (RCS) of APR1000 plants was modeled with 123 volumes and 173 junctions to simulate the accident. The core was partitioned into 6 vertical volumes and a hydraulic channel, respectively. In fact, in the standard KNAP model, the core was modeled in two separate hydraulic channels. In the case of REA, however, the single channel model could be applicable considering the characteristics of the accidents. The tubes and secondary sides of steam generators were modeled with 12 and 14 volumes, respectively, to represent the U-tube bundles and two feedwater-paths or economizer.

2.2 Hot Spot Modeling

Based on the standard KNAP HSM, the average and hot spot channel model presenting the fuel assemblies were developed. The average channel model employed the same channel model as the KNAP basedeck. On the other side, the hot spot channel was divided up to 25 meshes in axial direction and 17 segments in radial direction. The detail fuel data, such as gap gas composition, plenum pressure, *etc*., was developed based on the outputs of fuel design code FATE.

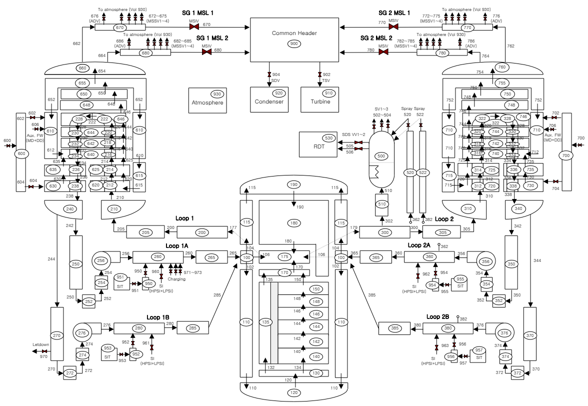

Fig. 1 RETRAN nodal diagram for APR1000

3. Rod Ejection Accident Analysis

The REA is defined as the mechanical failure of control rod mechanism pressure housing resulting in the ejection of control rod assembly and drive shaft and classified as an ANS plant condition IV incident due to the extremely rare probability and catastrophic consequence. The reactivity increases following the ejection, the thermal power also boosted over 1.6 times to rated power, and fuel rods possibly led to localized damage. 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.

Table 1. Initial Conditions for REA Analysis

Parameter	Value
Core power Level, MWt	2815
Core Inlet Coolant Temp. ^oF	572
Core Mass Flowrate, 10^6lbm/hr	112.0
Pressurizer Pressure, psia	2,350
Moderator Temperature Coefficient, $\Delta\rho/ ^oF$	0.0
Ejected CEA Worth, $10^{-2}\ \Delta\rho$	0.1584
Total SCRAM Worth, $10^{-2}\ \Delta\rho$	-6.0
Postulated CEA Ejection Time, sec	0.05
Maximum Radial Peaking factor	2.855

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, the HFP at BOC case was selected to examine the applicability of design concept and analysis package.

The results of this study were compared with those values calculated with typical OPR1000 SAR conditions to examine the applicability. As given at table 2, the trends of the transients are similar figures each other.

Table 2. Sequence Comparison

Event	OPR1000		APR1000	
	Time	Value	Time	Value
CEA Ejection	0.0		0.0	
Reactor Trip	0.03		0.03	
Max. Power, %	0.08	164.2	0.08	157.3
Max. PZR Press, psia	2.44	2500.0	2.23	2500.0
Max. Fuel Temp., ^{o}F	3.44	4,875.0	3.53	4,692.4

The power trends of APR1000 show the similar trends to those mentioned in SAR of OPR1000 (Fig. 2). The less mild trends would be caused by the smaller values of ejected CEA worth and radial peaking factor.

The mild trends of APR1000 were reflected on those of maximum fuel temperatures and averaged enthalpy rise (Figs. 3 & 4). In the cladding, the values of APR1000 were slightly higher than those of OPR1000 (Fig. 5).

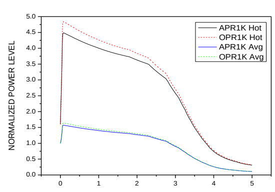

Figure 2. Normalized Power

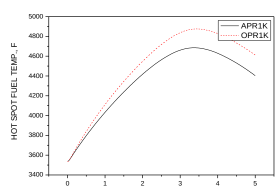

Figure 3. Max. Fuel Temp.

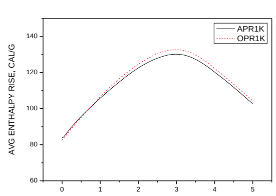

Figure 4. Avg. Enthalpy Rise

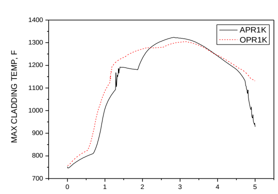

Figure 5. Max. Clad Temp.

The pressure trends of pressurizer and steam generator shell side were as mentioned in Fig. 6 and 7, respectively. In the case of pressurizer, the trends of two plants were so similar in spite of the characteristic difference of safety valves. In the case of steam generators, however, the trends showed some remarkable difference. It would be caused by the difference of characteristic curves of main steam safety valves. So, to mitigate the pressures in the system, the set-points capacities should be adjusted later.

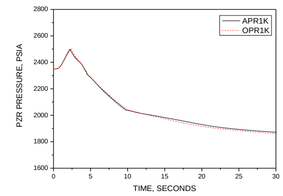

Figure 6. PZR Press.

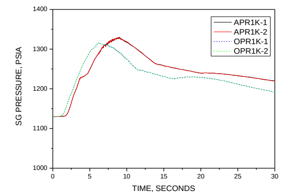

Figure 7. SG Shell Press.

4. Conclusion

To examine the feasibility of the design concepts and analysis package, the REA event of APR1000 was analyzed and the results were compared with those values calculated by the SAR conditions of typical OPR1000 plants. Through the feasibility study, it was concluded that the design concepts and the analysis package could be applicable on the view point of REA.

Acknowledgements

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