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Simulation of RCCA Withdrawal from Sub-critical in WH 3-Loop

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1. Introduction

The RCCA(Rod Cluster Control Assembly) withdrawal event is defined as a transient condition in which an uncontrolled reactivity is added to the reactor core by RCCA withdrawal, which can result in a burst of power. This condition may be caused by failure of the reactor control system or failure of the control rod system. RCCA withdrawals are classified as RWFS(RCCA Withdrawal from Sub-critical) and RWAP(RCCA Withdrawal at Power). This study was analyzed using point kinetics and 3D kinetics for RWFS of WH 3-Loop nuclear power plant.

2. Methods and Results

In order to simulate this case, a PC version of RETRAN-3D developed by the US EPRI was used as the system code for system analysis[1,2].

2.1 Analysis Conditions

RWFS refers to the withdrawal of the RCCA from the non-critical or low power, usually for analysis when the Operation Mode 2 at the start or stop of the operation. Therefore, the initial conditions required for analysis are the same as those in Operation Mode 2. RWFS is classified as ANS Condition-II, and the safety assessment criteria in the analysis of event are minimum DNBR for ensuring integrity of the cladding, and RCS pressure for ensuring system integrity. In addition, normal operation shall be possible after the accident and shall not lead to ANS Condition-III accident. However, RWFS is usually classified as an accident with a main concern of DNBR.

2.2 RETRAN Modeling

The input used in this calculation was made during the development of a safety analysis methodology for Westinghouse type nuclear power plants[3].

In order to simulate WH 3-Loop, the main system in the Nuclear Steam Supply System of the power plant was modeled with about 60 control volumes and about 100 junctions used to connect them or express boundary conditions. A trip card and a control card were used to control the setpoint and response time. WH 3-Loop nodalization for RETRAN code and 3D modeling are shown in Fig. 1, 2, 3.

The RCP was modeled for each loop by reflecting the pump characteristic curve, and each start/stop was performed by a trip card. The Steam Generators were also modeled for each loop, and U-tube serving as primary and secondary heat transfer were divided into 4 vertical heat conductors. And the secondary system was divided into 5 volumes for accurate simulation of behavior under steady and transient conditions. The decay heat considered the error of 2σ in ANS-79.

In this simulation, since the power of the analysis is low power of 20% or less, an error occurs in setting the steady-state when the steam generator is modeled with multiple nodes. Therefore, the steam generator secondary side was modeled as a single volume.

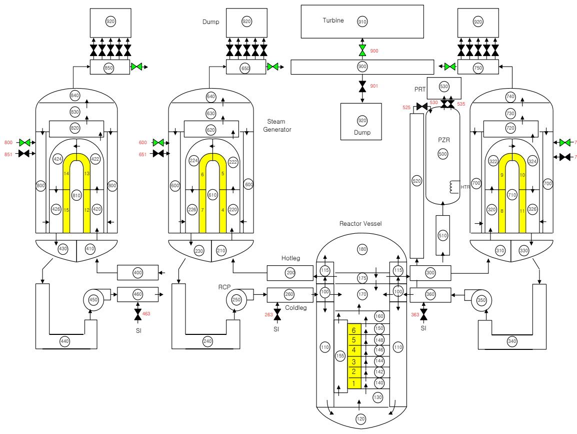
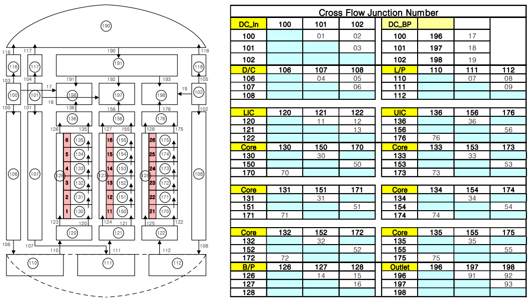


Fig. 1. WH 3-Loop nodalization for RETRAN code



Cross Flow Junction Number							
DC_In	100	101	102	DC_BP			
100		01	02	100	196	17	
101			03	101	197	18	
102				102	198	19	
D/C	106	107	108	L/P	110	111	112
106		04	05	110		07	08
107			06	111			09
108				112			
LIC	120	121	122	UIC	136	156	176
120		11	12	136		36	
121			13	156			56
122				176	76		
Core	130	150	170	Core	133	153	173
130		30		133		33	
150			50	153			53
170	70			173	73		
Core	131	151	171	Core	134	154	174
131		31		134		34	
151			51	154			54
171	71			174	74		
Core	132	152	172	Core	135	155	175
132		32		135		35	
152			52	155			55
172	72			175	75		
B/P	126	127	128	Outlet	196	197	198
126		14	15	196		91	92
127			16	197			93
128				198			

Fig. 2. RETRAN model for integrated code

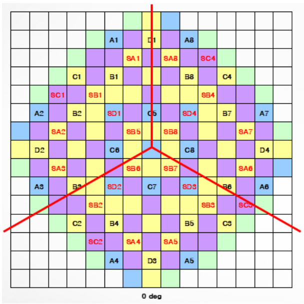


Fig. 3. Core mapping model

2.3 Analysis Results

Fig. 4 shows the power. The reactivity is added upon withdrawal of the control rod assembly, so the power rises rapidly to reach 35% power at 6.1 seconds, resulting in a trip signal of the reactor. After the reactor trip, the power and pressure continue to rise, increasing to 127.8% rated power, and then decreasing.

Fig. 5 shows the DNBR. For DNBR, the calculation model of the RETRAN-3D DNBR[4] was used, but the analysis was made by considering the core hot channel minimum flow rate of 0.63 lbm/sec, the radial peak factor of 2.14, and the axial peak factor of 3.1. Using the W-3 DNBR correlation, this analysis has calculated that the minimum DNBR is 1.354.

Fig 6, 7 show the power and DNBR using the 3D kinetics. The power rises at about 40 seconds and rises to 35.63% rated power at about 55 seconds. The Minimum DNBR is 3.2.

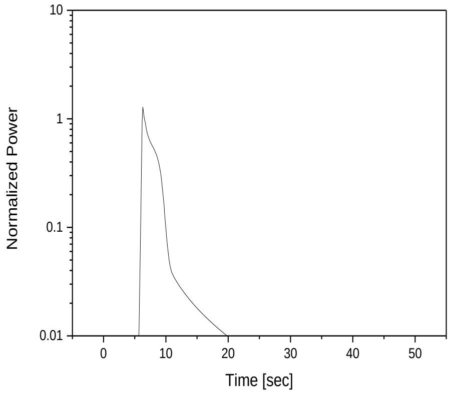


Fig. 4. Power trend (Point Kinetics)

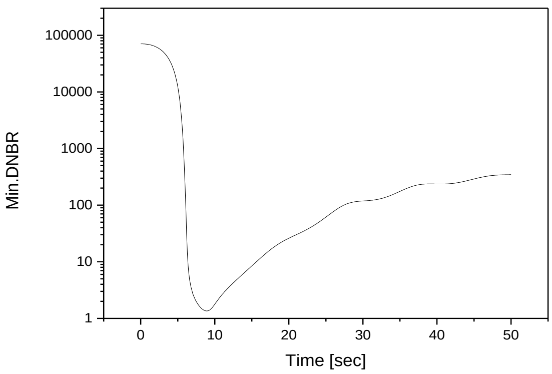


Fig. 5. DNBR trend (Point Kinetics)

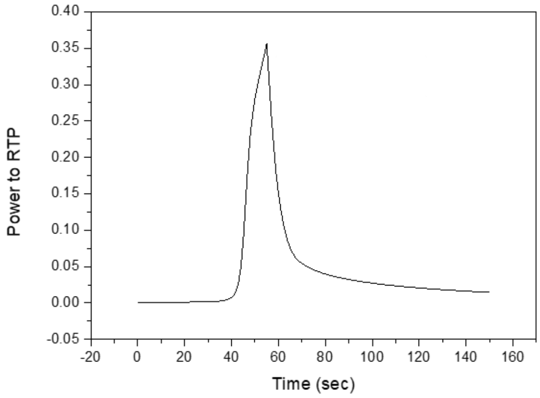


Fig. 6. Power trend (3D Kinetics)

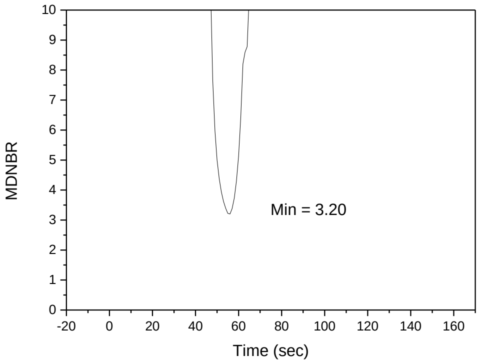


Fig. 7. DNBR trend (3D Kinetics)

3. Conclusions

The RCCA Withdrawal from Sub-critical in WH 3-Loop was analyzed using the point kinetics and 3D kinetics. As a result of the analysis, when 3D kinetics was used, it was possible to verify that the power was reduced to a level of 1/4 and the DNBR margin was increased. For more accurate analysis, a 3D kinetics analysis code using the SPACE+RAST-K is currently being developed.

REFERENCES

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