The APR1400 Core Design by Using APA Code System

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1. Introduction

The nuclear design for APR1400 has been performed to prepare the core model for Automatic Load Follow Operation Simulation. APA (ALPHA/ PHOENIX-P/ANC) code system is a tool for the multi-cycle depletion calculations for APR1400. Its detail versions for ALPHA, PHOENIX-P and ANC are 8.9.3, 8.6.1 and 8.10.5, respectively.

The first and equilibrium core depletion calculations for APR1400 have been performed to assure the target cycle length and confirm the safety parameters. The parameters are satisfied within limitation about nuclear design criteria. This APR1400 core models will be based on the design parameters for APR1400 Simulator.

2. Design Specification

2.1 Core [1]

The reactor core is designed to generate 3,983MWth at hot full power condition. And it is composed of 241 fuel assemblies and 93 CEAs(Control Element Assembly). The core performance specifications of APR1400 are 2,250 psia system pressure and 555˚F inlet temperature. For more details spec. refer to PSAR.

2.2 Fuel Assembly[1,2]

Standard fuel assembly specifications are utilized to model the fuel assemblies for APR1400 core, instead of PLUS7 in PASR to perform the evaluation from the first to equilibrium cycle.

Active core length is 381cm and fuel assembly configuration is consist of 16x16 fuel rods and 5 guide tubes for CEA and 1 instrumentation tube .

The 8 w/o Gd_2O_3-UO_2 ceramic rod are used for the burnable poison rod to control the excess reactivity at BOC as shown in Table I.

Table I: Fuel Assembly Data

Cycle	ID	No.	Enrich.	No. Rod	Gd	Enrich.
First	A0	81	1.6	236		
	B0	28	3.28	236		
	B1	48	3.28/2.78	172/52	12	8
	B2	4	3.28/2.78	124/100	12	8
	C0	20	3.78/3.28	172/52		
	C1	60	3.78/3.28	120/100	16	8
Eq.	J0	16	4.70/4.20	184/52		
	J2	8	4.70/4.20	172/52	12	8
	J3	68	4.70/4.20	168/52	16	8

2.3 CEA[3]

There are 12 & 4 element full strength and 4 element part strength in APR1400. Each CEA configurations and locations are seen in Table II and Fig. 1.

Table II: CEA Configurations for APR1400

CEA	5	4	3	2	1	SA	SB	P1	P2
No.	4	8	12	8	8	9	8	16	20
Abs.	B_4C							Inconel	

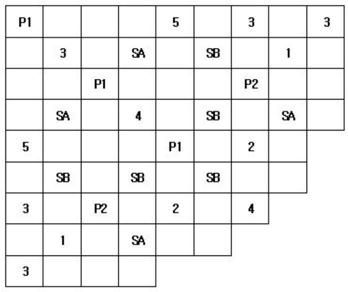

Figure I: CEA Locations for APR1400

3. Calculation Results

3.1 Depletion Results

The first and equilibrium cycle of APR1400 has been depleted at HFP condition by ANC using a 3-D model of the quarter core.

Table III: Depletion Characteristics

First Cycle			Equilibrium Cycle		
BU[1]	CBC[2]	Fxy	BU	CBC	Fxy
0	1077	1.603	0	1280	1.520
50	815	1.509	50	1209	1.500
500	744	1.470	500	1139	1.500
1000	742	1.470	1000	1096	1.494
2000	736	1.490	2000	1033	1.495
3000	717	1.500	3000	968	1.490
4000	691	1.500	4000	899	1.484
5000	668	1.500	5000	834	1.480
6000	652	1.490	6000	774	1.477
7000	644	1.490	7000	719	1.480
8000	637	1.490	8000	670	1.483
9000	614	1.490	9000	626	1.490
10000	568	1.490	10000	586	1.501
11000	507	1.480	11000	546	1.506
12000	438	1.470	12000	497	1.500
13000	364	1.450	13000	435	1.484
14000	285	1.440	14000	360	1.466
15000	203	1.420	15000	278	1.451

16000	119	1.410	16000	193	1.441
17320	10	1.390	17000	107	1.430
			18130	10	1.416

1: MWD/MTU, 2: ppm

The power peaks are fulfilled within safety limits as shown in Table III. The cycle length for equilibrium core is evaluated much longer than the respected burnup of 17,500 MWD/MTU.

3.2 CEA Bank Worth

CEA Worth is calculated at BOC, MOC and EOC of HFP condition as shown in Table IV.

Table IV: CEA Bank Worth ($\%\Delta\rho$)

	First Cycle			Equilibrium Cycle		
Bank	BOC	MOC	EOC	BOC	MOC	EOC
5	0.25	0.32	0.31	0.21	0.25	0.28
4	0.38	0.43	0.46	0.29	0.31	0.35
3	0.98	1.02	1.09	0.94	0.99	1.09
2	0.83	0.81	0.92	0.67	0.70	0.77
1	1.49	1.22	1.48	1.40	1.47	1.63
P1	0.17	0.21	0.24	0.15	0.19	0.22
P2	0.15	0.16	0.20	0.13	0.16	0.19
SA	3.42	3.55	4.08	3.03	3.36	4.02
SB	7.70	8.73	9.31	7.00	7.62	8.36
Total	15.37	16.46	18.09	13.82	15.05	16.91

3.3 Boron Worth

Table V shows Boron Worth.

Table V: Boron Worth (pcm/ppm)

First Cycle			Equilibrium Cycle		
BOC	MOC	EOC	BOC	MOC	EOC
-10.34	-9.98	-10.98	-6.98	-7.48	-8.58

3.3 MTC & FTC

Table VI shows moderator temperature coefficient and fuel temperature coefficient at BOC, MOC and EOC.

Table VI: MTC & FTC (pcm/°F)

	First Cycle		
	BOC	MOC	EOC
MTC	-4.798	-11.311	-27.095
FTC	-1.167	-1.957	-3.612
	Equilibrium Cycle		
	BOC	MOC	EOC
MTC	-9.636	-18.983	-32.870
FTC	-1.976	-2.778	-4.4

4. Conclusions and Future Works

The nuclear design of APR1400 has been performed by APA systems, which oriented to Westinghouse type reactor core. The calculation results shows that the power peak(Fxy) limit of initial and equilibrium core design for APR1400 was satisfied within PASR limit. Also cycle length of 17,500MWD/MTU can be confirmed by APA system. Therefore, the core model for APR1400 in this works will be useful for generating the APR1400 simulation parameters. PDIL(Power Dependent Insertion Limit) and Rod Bank Overlap will be evaluated to determine the optimal condition for Load Follow Operation..

REFERENCES

[1] Korea Hydro & Nuclear Power Co. Ltd., ARP1400 Preliminary Safety Analysis Report.
[2] Korea Nuclear Fuel, N-411FN-D301-0011, 1998.
[3] Korea Nuclear Fuel, N-411-FN-D301-002, 1998.
[4] Westinghouse Electric Company, METCOM.
[5] Westinghouse Electric Company, ALPHA User Manual.
[6] Westinghouse Electric Company, PHOENIX-P User Manual.
[7] Westinghouse Electric Company, ANC User Manual.