A Feasibility Study of Improving ASI Control Performance by Modifying Part-strength Control Element Assemblies in APR1400

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1. Introduction

Domestic nuclear power plants are known to have limited potential for daily load follow operations through preliminary operation tests and prior research in the early stages of the first cycle core. The main limitations are the lack of control worth of the part-strength control element assemblies used to suppress xenon oscillation and the operation limitation requirements for the accumulated time of the control rod insertion limit.

In this work, in order to alleviate the above restrictions, an alternative neutron absorber was selected and the axial shape index(ASI) control performance was verified through the core depletion calculation.

2. Methods and Results

Simulation is carried out in the equilibrium core of the APR1400 using STREAM/RAST-K codes[1] to verify the performance of controlling axial power distribution through part-strength control element assemblies′ absorption material change.

2.1 Alternative Absorber

The control rod is inserted into the core to control the axial power distribution, and when the control rod is inserted above a certain control rod position, the control rod insertion accumulation time is limited in consideration of imbalance in core depletion, swelling of the absorbent of the control rod, and worth reduction of control rod by neutron irradiation. Table 1 compares the characteristics of the control rods used in domestic and foreign nuclear power plants. The absorber AgInCd was selected as an alternative absorbent because it has no irradiation swelling problem and relatively little reduction in control rod worth[2].

Table 1. Control Rod Characteristics by Reactor Type

	WEC	OPR/APR
Absorber	AgInCd	B_4C/Inconel
Swelling	No	Weak/No
Worth Reduction	Medium	Large/Small
Insertion Time Limit	No	Yes

2.2 AIC PS Control Worth

It was assumed that the cross-sectional area as the absorbent material is the same as that of WH type nuclear reactors. Table 2 compares the control worth of part-strength control element assemblies. The control worth of the part-strength control element assemblies increased by more than three times compared to the inconel absorbent material.

Table 2. Part-Strength Control Worth(Unit: pcm)

	INC	AIC
BOC(0GWD/MTU)	211	772
MOC(11GWD/MTU)	265	874
EOC(18GWD/MTU)	290	909

2.3 Core Depletion Mode

RAST-K Code is used to calculate the depletion of the reload equilibrium core in the APR1400 nuclear power plant, and when simulating the daily load follow operation in the N-cycle core, it is assumed that fullpower operation is performed until 18,000MWD/MTU, followed by 500MWD/MTU operation at 50% power, and finally, full power operation until the end of cycle(EOC) in N-1 and N-2 cycle. Table 3 compares the cycle burnups of the full power equilibrium core and those of the depletion model adopted in this study.

Table 3 Cycle Burnup (Unit: MWD/MTU)

Cycle	Eq. Core	Depletion Model
N	19,670	19,335
N-1	19,605	18,690
N-2	19,384	18,730

During the long-term low-power operations and the 7-daily load follow operation, the axial shape index with the AgInCd PS CXEA is controlled within the equilibrium axial shape index(ESI) limit of 0.05[3], while that with inconel PS CEA exceeds the limit. Power rates of 3%/hr, 10%/hr and 3%/min are assumed for the long-term low-power operations and Power rates of 10%/hr and 3%/min are assumed for 7-daily load follow operation

Table 4. ASI control possibility

Power		INC PS		AIC PS	
		LTLPO*	7DLF**	LTLPO*	7DLF**
90%		Possible	Possible	Possible	Possible
80%		Possible	Impossible	Possible	Possible
70%		Impossible	Impossible	Possible	Possible

60%		-	-	Possible	Possible
50%		-	-	Possible	Possible

*LTLPO:Long Term Low Power Operation
**7DLF:7-daily Load Follow

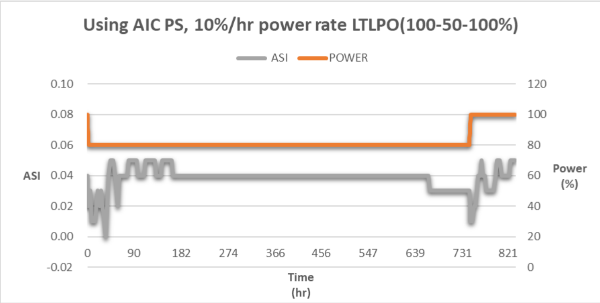

Fig.1. 10%/hr power rate LTLPO(@18GWD/MTU)

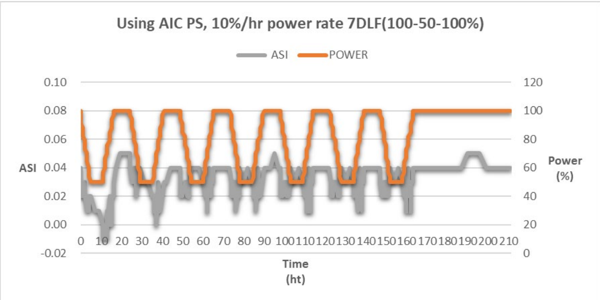

Fig.2. 10%/hr power rate 7-daily load Follow(@18GWD/MTU)

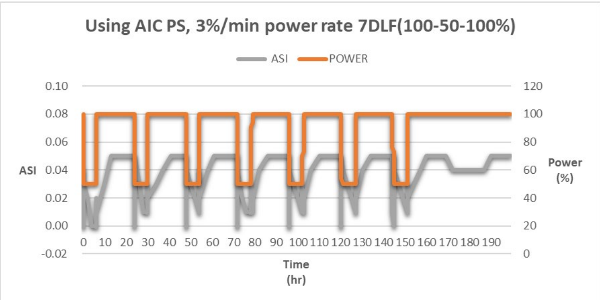

Fig.3. 3%/min power rate 7-daily load Follow(@18GWD/MTU)

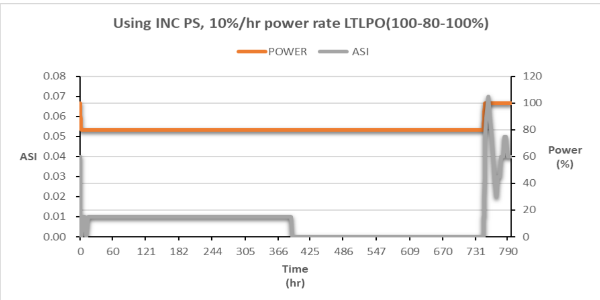

Fig.4. 10%/hr power rate LTLPO(@18GWD/MTU)

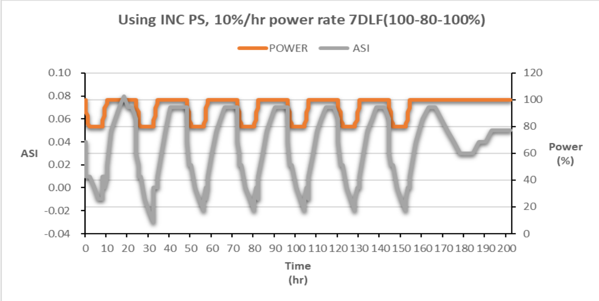

Fig.5. 10%/hr power rate 7-daily load Follow(@18GWD/MTU)

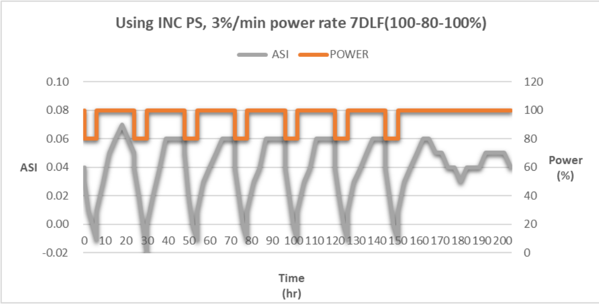

Fig.6. 3%/min power rate 7-daily load Follow(@18GWD/MTU)

3. Conclusions

As a result of the load follow operation simulated after changing the part-strength control element assemblies' absorbent in APR1400, it is confirmed that it could be applied to 18GWD/MTU depletion core at the end of the cycle. The introduction of improved absorption materials is expected to be of great help in the application of practical load follow operations in the near future.

REFERENCES

[1] STREAM/RAST-K USER's Manual

[2] Current Status of Technology Development for Flexible Operation of Planned Load Follow-up (Fall Nuclear Society, 2022).

[3] Core Operating Guidelines(WCAP-18372-P Rev.2 May 2020)