Preliminary Analysis of Daily Load-Following Operation for OPR 1000 and Soluble Boron-Free SMR using DeCART2D/MASTER Two-Step Code System

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몬테칼로 노물리 연구실

Introduction and Objective

- ❖ In Rep. of Korea, according to the 11th basic plan for long-term electricity supply and demand, a 700 MW-class small modular reactor (SMR) is scheduled to be built by 2038.
- ❖ With the advancement of global carbon neutrality policy, the share of renewable energy in the domestic energy mix will unavoidably increase significantly. Thus, It is expected that DLFO will be required.
- ❖ The ERU and EPRI URD also specify requirements for load-following performance.
- ❖ Objective
  - This study aims to investigate the daily load-following capability of (i) the OPR-1000 equilibrium core and (ii) the SBF SMR core, employing the DeCART2D/MASTER two-step core design analysis system.

Daily Load Following Operation for OPR-1000

❖ Daily Load Follow Operation(DLFO) Scenario

- The DLFO with a typical load variation scenario for Hanbit unit 3, SBF SMR were simulated by the DeCART2D/MASTER code system.
- Typical power profile: 50% power operation during low electricity demand hours from 3:00 to 9:00, gradual ramp-up to 100% power from 9:00 to 12:00, full power operation from 12:00 to 24:00 during peak demand hours, and a gradual ramp-down to 50% power from 0:00 to 3:00.(12-3-6-3)

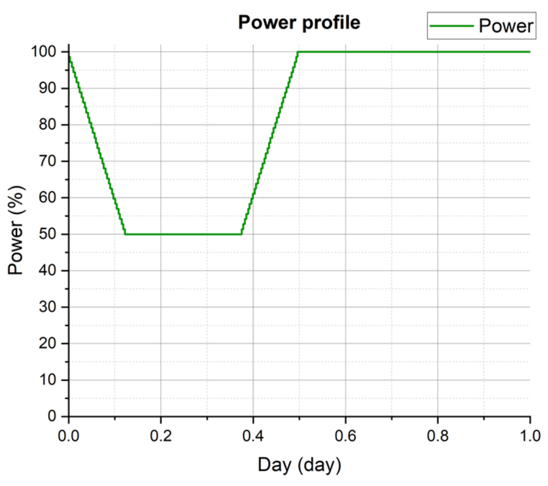

Fig. 1. Daily load following operation power profile (12-3-6-3)

❖ Daily Load Follow Operation(DLFO) Methods for OPR-1000

- The DLFO simulations was performed at near BOC (40 EFPD) of the equilibrium cycle in the Hanbit Unit 3.
- In simulating DLFO, three control mechanisms were employed to regulate reactor power: regulating banks (i.e., R1~R5), manual boron concentration adjustment, and PSCEA.
- To achieve this, Regulating Banks 5 and 4 (R5 and R4) are primarily used to achieve criticality at the desired power level using CRS card in MASTER code.
- To avoid violating the PDIL, boron concentration is manually adjusted. Furthermore, the PSCEA is used to manage the axial power distribution and ensure that AO and related parameters remain within acceptable operational limits.
- At the beginning of DLFO, the R5 regulating bank was initially inserted 10% prior to initiating the load-follow sequence, with the regulating banks then adjusted to maintain an overlap distance of 228.6 cm.

❖ OPR-1000 DLFO Results

- As power rises, the xenon concentration decreases, adding positive reactivity to the core, which must be suppressed by inserting control rods. Taking this into account, the regulating banks were adjusted in accordance with the PDIL of the OPR-1000.
- 1315 ppm of boron was injected at the start of load-following operation, and in order to maintain the regulating bank PDIL limit, the boron concentration was increased when the power returned to 100 % to offset the positive reactivity. Then it was reduced to 1356ppm.
- the PSCEA positions were adjusted to bring the axial power distribution within the allowable limit.

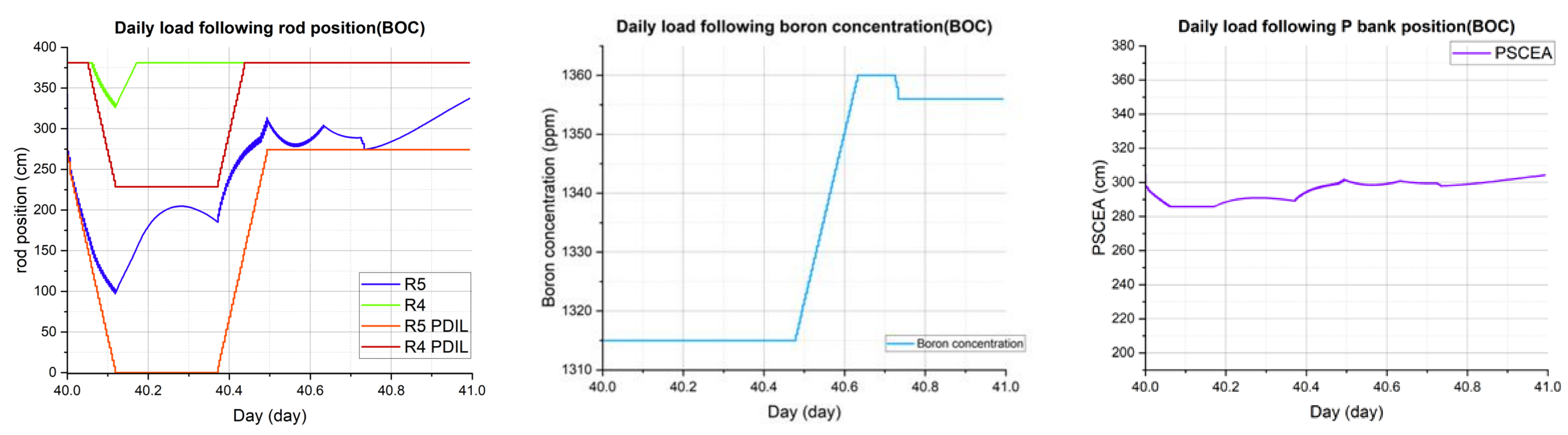

Fig. 2, 3, 4. Daily load following rod position and PDIL, boron concentration, PSCEA position at BOC

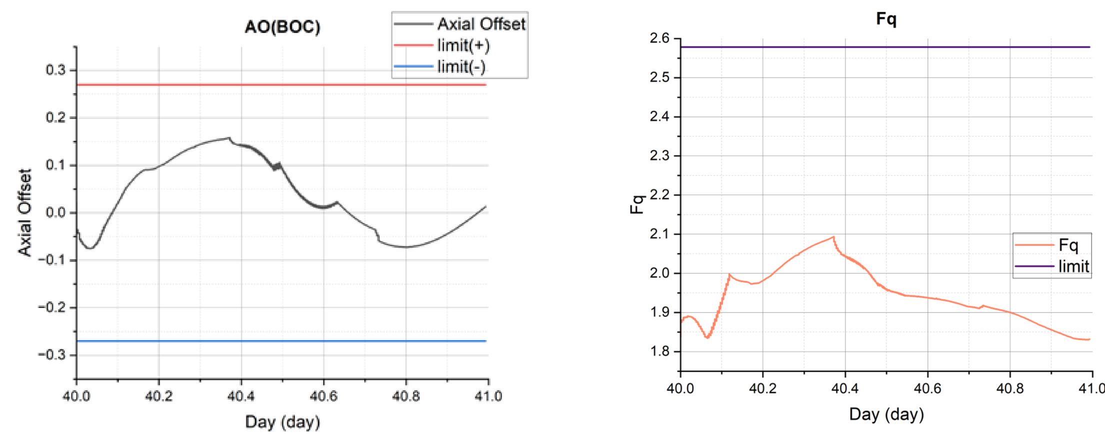

Fig. 5, 6. Daily load following AO and Fq variation at BOC

➢ It can be seen that AO and Fq are well within the limits. (AO: -0.3~0.3, Fq: <2.55)

Daily Load Following Operation for SBF SMR

❖ Daily Load Follow Operation(DLFO) Methods for SBF SMR

- Unlike the OPR-1000, the SBF SMR does not control reactivity through boron, so the reactivity must be adjusted solely with control rods.
- the CRS card in MASTER was used to create an input deck in which the regulating banks were inserted sequentially from R4 to R1, maintaining a 50% overlap interval.

❖ SBF SMR DLFO Results

- For the SBF SMR, burnup was carried out in DLFO mode at three burnup points; 40 EFPD, 230 EFPD and 330 EFPD.

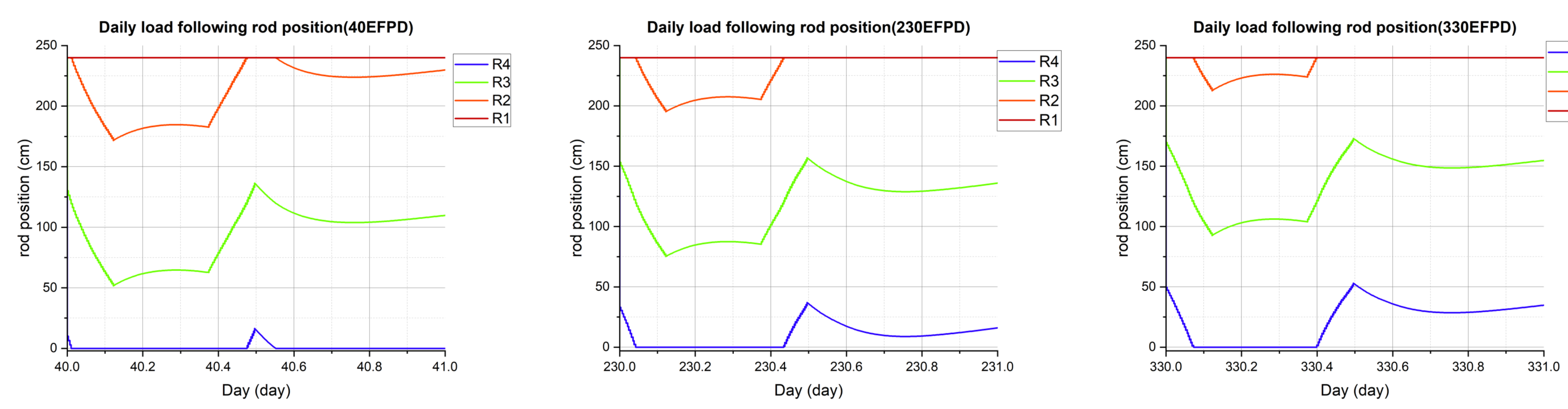

Fig. 7, 8, 9. Rod positions during daily load following operation in SBF SMR at 40, 230, 330EFPD

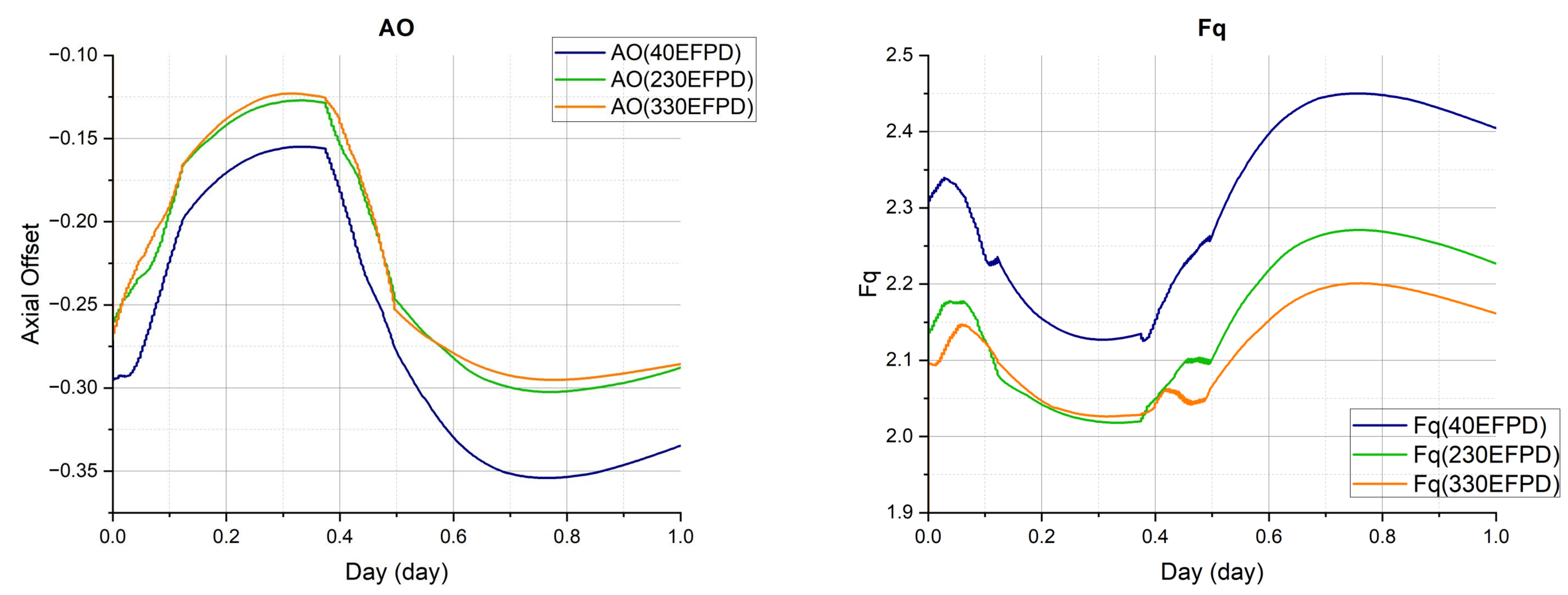

Fig. 10, 11. AO and Fq variation during DFLO in SBF SMR at three burnup points

➢ For the AO, at 40EFPD, maximum value is −0.1073 and minimum is −0.3541; at 230EFPD, maximum value is −0.0738 and minimum is −0.3024; and at 330EFPD, maximum value is −0.0878 and minimum is −0.2751.

➢ For Fq, at 40EFPD, maximum value is 2.4501 and minimum is 1.8770; at 230EFPD, maximum value is 2.2710 and minimum is 1.7733; and at 330EFPD, maximum value is 2.2010 and minimum is 1.7877.

Conclusion

- ❖ In this study, preliminary DLFO analysis were performed for both the OPR-1000 Hanbit Unit 3 and the SBF SMR using the DeCART2D/MASTER two-step code system.
- ❖ For the OPR-1000 equilibrium cycle, it was noted that the reactivity in the core was successfully controlled through adjustments of regulating bank, PSCEA, and boron concentration. Moreover, the axial power distribution was stabilized by regulating the PSCEA.
- ❖ It was confirmed that the operations of the DLFO for OPR-1000 meet the AO (-0.3 ~ 0.3) and F_q limits (< 2.55).
- ❖ For the SBF SMR, which operates without soluble boron, reactivity is only controlled through regulating bank adjustments.
- ❖ It was confirmed that the operations of DLFO for SBF SMR meet the AO (-0.3 ~0.3) and F_q (<2.55) limits which is the conventional limit for commercial PWRs as burnup progressed.