KNF-
ENG-05

Optimization of Lower Limit of RCS Flow Rate

CORE ENGINEERING DEPT. HyoSang Yoo
T. 042-868-1432 E. hsyoo@knfc.co.kr

As low leakage loading pattern is preferred for economical fuel usage, RCS(reactor coolant system) flow rate is decreased because thermal stratification of hot leg reduces operation margin. Measured average hot leg temperature is higher than the real temperature as the internal power of core increases. This makes the measured RCS mass flow rate decrease. RCS mass flow rate is calculated by heat balance method. Optimization of lower limit of RCS flow rate optimizes the RCS mass flow rate to relax the lower limit of RCS mass flow rate and to have flexibility of loading pattern for more economical fuel usage.

Description

● Background

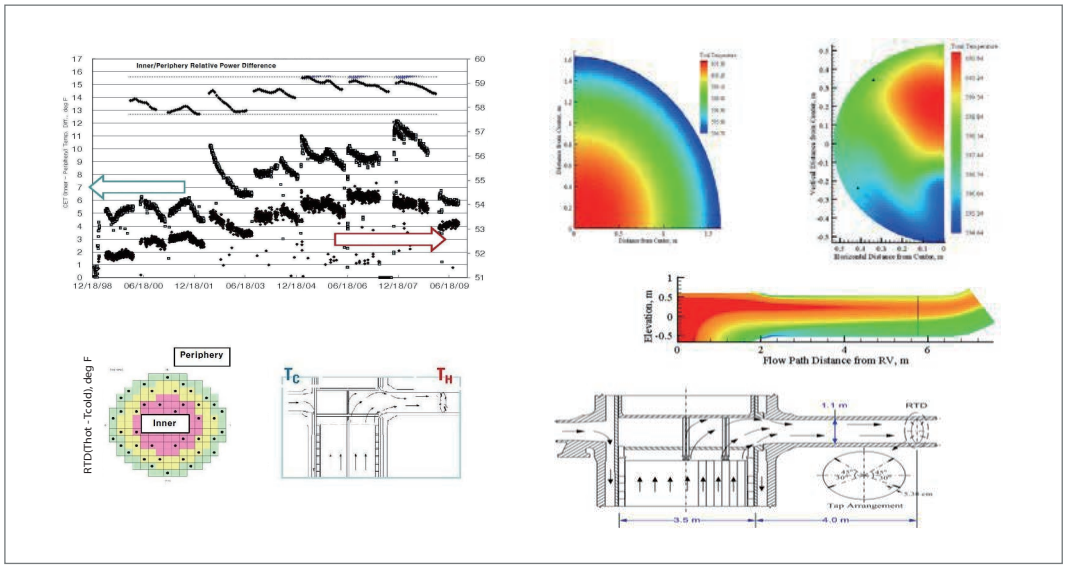
- As a result of the study of measured RCS mass flow rate of OPR1000 by heat balance method, RCS mass flow rate is decreased continuously as cycles progressed and approached to the lower limit of RCS flow rate, and there was not enough operation margin. There is a decrease in RCS mass flow rate due to thermal stratification of hot leg as low leakage loading pattern is used for more economical fuel usage, and the RCS mass flow rate is approached to lower limit of RCS flow rate. There is a need for optimization of flow rate to have operation margin.

● Cause of occurrence

- Temperature difference is increased and RCS flow rate is decreased as the cycles progress
- To have flexibility on loading pattern for more economical fuel usage
- Thermal stratification of hot leg
  - Thermal power and cold leg temperature remain unchanged as cycles progresses but hot leg temperature keeps increasing
  - Increase in internal power of core increases the exit temperature inside the core
  - Measured average hot leg temperature is higher than the real temperature as the exit temperature inside the core increases
  - RCS mass flow rate is calculated by heat balance method. When core thermal power is consistent, the RCS mass flow rate is decreased as the hot leg temperature is increased.
  - About 1°F temperature difference between hot leg and cold leg makes about 2% flow rate change.
- Flow rate measured by heat balance method
  - Core power = Specific heat · mass flow rate · (Hot leg temperature – Cold leg temperature)
- As low leakage loading pattern is used, increase of core exit temperature due to increase in power of core interior makes decrease of RCS flow rate

● Purpose

- There is a decrease in RCS mass flow rate due to thermal stratification of hot leg as low leakage loading pattern is used for more economical fuel usage, and the RCS mass flow rate is approached to lower limit of RCS flow rate.
- There is need for relaxation of lower limit



of RCS mass flow rate through optimization of lower limit of RCS mass flow rate as low leakage loading pattern is used for more economical fuel usage.

● Necessity

- Resolution of limitation of reactor operation margin caused by decreased measured RCS flow as low leakage loading pattern is used for more economical fuel usage
- To have flexibility on loading pattern
- To prevent the shortening the cycle length

● Principle

- Optimize the lower limit of RCS mass flow rate
  - Change lower limit to more than 95% of nominal design flow rate instead of more than 100% of nominal design flow rate
- Safety evaluation of core and system due to change in lower limit of RCS mass flow rate
  - Nuclear design and safety analysis are performed using typical loading pattern with 100% nominal design flow rate and 95% nominal design flow rate
  - About 3.5% COLSS DNBR margin decrease is expected if flow rate decreases 5%

Distinctiveness

● Characteristics

- Relaxation of lower limit of RCS mass flow rate through optimization of lower limit of RCS mass flow rate. Decrease of RCS mass flow rate due to thermal stratification of hot leg as low leakage loading pattern is used
- Ensured operation margin through optimization of limit of RCS mass flow rate and flexibility of loading pattern
- Ensured through optimization of limit of RCS mass flow rate
- Ensured operation margin without hardware change

● Benefits

- Improvement of 5% operation margin
- Ensured flexibility of low leakage loading pattern for more economical fuel usage
- Increased cycle length(about 5EFPD) by using low leakage loading pattern for OPR1000

Experience

- OPR1000 plants already applied
  - Hanbit Unit 3,4,5,6, Hanul Unit 3,4,5,6
- OPR1000 plants in the process of applying
  - Shin-Kori Unit 1,2, Shin-Wolsong Unit 1,2

Deliverables

- Licensing Report
- Markup for FSAR revision
- Supporting License

Technology Readiness Level (TRL)

Actual system proven through operation

Business Model

Technology Transfer
Licensing
Joint Search
Service Execution
Others