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ENG-06

# Secondary Calorimetric Power Based on Measured Steam Flow Rates Technology for APR1400

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Secondary calorimetric power based on Measured Steam Flow rates (MSBSCAL) technology which is not susceptible to fouling problem, currently used in OPR1000 nuclear power plants was expanded

## Description

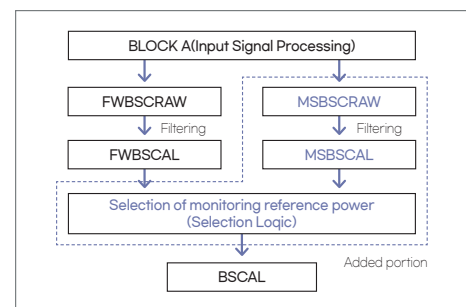
### ● Background and Necessity

- COLSS continuously monitors the licensed power using secondary calorimetric power (BSCAL) in OPR1000 nuclear power plants
- The feedwater flow is overestimated by abnormal phenomenon such as fouling in the feedwater venturi, resulting in overestimation of the reactor thermal power, resulting in reduction of the reactor power and loss of electric power
- Most of the fouling phenomenon in the feedwater flow are generated in the OPR1000 nuclear power plants. Therefore, it is necessary to apply the measurement method of the reactor thermal power using the main steam flow which is independent of the fouling phenomenon. So the methodology is developed, licensed and approved, and applied to the present OPR1000 nuclear power plants
- As the reactor power fluctuations can have a serious impact on safety as well as economy of nuclear power plant, it is necessary to apply this methodology to calculate reactor power based on the main steam flow for APR1400 nuclear power plants

### ● Principle

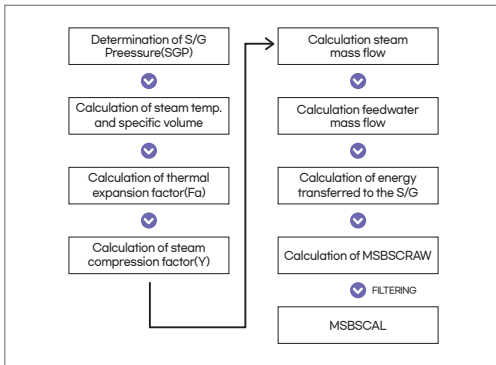
- Overview of MSBSCAL Methodology

- MSBSCAL is only applied above 95% power
- MSBSCAL is an independent and parallel with the current secondary calorimetric power based on measured feedwater flow rates(FWBSICAL)
- The main steam flow is calibrated with feed mass flow before fouling in the startup test
- Calculation of thermal power is based on main steam flow
- Application of MSBSCAL in COLSS algorithm
  - Input part, calculation of MSBSCAL part, selection BSCAL from FWBSICAL & MSBSCAL part are applied in COLSS algorithm as shown in below figure.



- Input part : Average pressure of safety channel S/G and averaged steam flow of each S/G are used for MSBSCAL calculation
- MSBSCAL calculation part : MSBSCAL calculation is added in the COLSS independently and parallel with the current FWBSICAL
  - a) Secondary Calorimetric Power based on Measured Feedwater flow rates (FWBSICAL) Calculation of secondary calorimetric power is based on the feedwater flow measured in the feedwater venturi

b) Secondary Calorimetric Power based on Measured Steam Flow rates(MSBSCAL)  
Calculation of secondary calorimetric power is based on the main steam flow measured in the main steam nozzle. Below figure shows an overview of MSBSCAL calculation process.



- Selection of BSCAL part : Operator selects the MSBSCAL selection switch as below figure. MSBSCAL is used for plant thermal power when the power is 95% or above and MSBSCAL is calculated as normal. Otherwise, FWBSCAL is selected as the plant thermal power.

Quality		Conditions		BSCAL
FWBSCAL	MSBSCAL	MSBSCAL	OPMS	
GOOD	GOOD	< 95% Power	N/A	FWBSCAL
GOOD	GOOD	N/A	RESET	FWBSCAL
GOOD	GOOD	≥ 95% Power	SET	MSBSCAL
GOOD	BAD	N/A	N/A	FWBSCAL
BAD	GOOD	≥ 95% Power	SET	MSBSCAL
BAD	GOOD	< 95% Power	N/A	BAD
BAD	GOOD	N/A	RESET	BAD
BAD	BAD	N/A	N/A	BAD

● **Work Scope**

- Extended application of the methodology to the APR1400 nuclear power plant including the revision of standard COLSS program, linkage program and confirmation of related thermal power uncertainty with approval of license.
  - Revision of COLSS Functional Design Requirement(FDR) : Revision of COLSS FDR based on above algorithm
  - BSCAL uncertainty Analysis : BSCAL uncertainty is determined from the various range of blowdown flow rates and flow configurations. BSCAL uncertainty is calculated with instrument uncertainty, uncertainty in COLSS BSCAL algorithm constants and blowdown flow measurement uncertainty.

- Generation of COLSS Test Data : The generation of COLSS Test case is performed for verification of changed COLSS algorithm using the COLSS FORTRAN code.

**Distinctiveness**

● **Characteristics**

- Established a reactor thermal power measurement technique based on the main stem flow and improvement of reliability of thermal power monitoring
- Improved a core management operation technology and core safety by adding another thermal power monitor

● **Benefits**

- Recovery of lost thermal power
  - Prevention of electrical power loss due to fouling in the feedwater venturi when MSBSCAL is applied : If the loss due to fouling is 0.5%, the expected recovery electric power of the main steam flow-based thermal power per unit is 7MWe
  - $7\text{MWe} * 1,000\text{kWe/MWe} * 24\text{hr/day} * 365\text{day} * 67.9\text{won/kWh} * 0.8(\text{availability}) = 3.33 \text{ billion won/year.unit}$

**Experience**

- 12 units in standard nuclear plants in Korea adopted this technology
- Application case for MSBSCAL
  - Continuous reduction of electric power after overhaul for Shin-kori Unit 2 cycle 3
  - Power was decreased about 7 MWe(from 1047 MWe to 1040 MWe) in the beginning of the cycle and it continues to decrease
  - Overestimation of feedwater flow: Feedwater venturi was clogged like fouling problem.
  - Plant power was recovered about 7 MWe by using MSBSCAL. Economic effect is about 3.33billion won/year

**Deliverables**

- COLSS Functional Design Requirements
- Secondary calorimetric power uncertainty analysis report
- On-line program installation test materials and reports

**Technology Readiness Level (TRL)**

Actual system proven through operation

**Business Model**

- Technology Transfer
- Licensing
- Joint Search
- Service Execution
- Others