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The Improvement of Plant Efficiency by Testing and Revising of the Reactor Thermal Power Calculation Program

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1. Introduction

Reactor thermal power is divided into two major parts, one is Primary Plant Performance Calculation(PPPC) using enthalpy gap between inlet and outlet fluid of the reactor core, another is Secondary Plant Performance Calculation(SPPC) using enthalpy gap between inlet and outlet fluid of the steam generator. Since the uncertainty of flow measurement mostly affects the result of reactor thermal power calculation, reactor power in most of Nuclear Power Plants(NPPs) is controlled by excore Nuclear Instrumentation System(NIS) based on SPPC which has less uncertainty of flow measurement by using venture-meter.

Real time monitoring system for reactor thermal power of Kori unit 3&4 has been established since 1992, and plant efficiency was improved by detecting errors and revising the program in 2012 following the engineering judgement that reactor thermal power varies according to steam generator blowdown flow change, unit conversion constant, and thermal expansion coefficient, etc.

2. Method of estimating SPPC

SPPC is calculated by summation of enthalpy in main steam and steam generator blowdown flow and subtraction of main feed water enthalpy flowing into steam generator. For calculation accuracy, various constants are used such as main feed water flow, temperature and pressure, and main steam pressure, steam generator blowdown flow, temperature and pressure and design parameters of venture-meter. The measurement uncertainty for those constants are less than 0.25%.

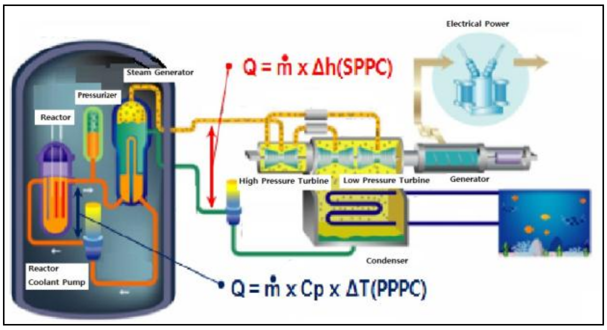

Figure 1. Method of Reactor Thermal Power Measurement

3. Verification of reactor thermal power calculation program

By verifying the operational parameters and constants, accuracy of equation, some program errors were found at the reactor thermal power calculation program in Kori unit 3&4.

3.1 An application error on specific volume of steam generator blowdown fluid

Since blowdown flow was measured at the point of steam generator blowdown line placed at the downstream of the blowdown flash tank, regenerative and non-regenerative heat exchanger, the specific volume for the blowdown flow should be used correspondent with the temperature and pressure at the point of measurement. However, by using the specific volume with the temperature and pressure at the point of main feed water line entering into the steam generator, blowdown flow was measured 15.7% lower at actual normal blowdown flow of 68ton/hr. As a result, reactor thermal power was indicated 0.092% greater resulting in 0.13% greater of reactor thermal power at the maximum blowdown flow of 130ton/hr.

3.2 An application error of differential pressure(ΔP) unit conversion constant for main feed water inlet flow

For the thermal power calculation program, ΔP unit needs to be converted into Pascal from inch H2O measured at flow instrument. From ASME Steam Table by applying conversion constant of 248.660 at 20℃ water instead of 249.089 at 4℃ of water which is applied for existing program, ΔP was decreased by 0.17%. As a result, main feed water flow was decreased by 0.085% and reactor thermal power also was decreased by 0.086%.

3.3 An application error of thermal expansion coefficient for venture-meter, measuring main feed water flow for steam generator

Since main feed water flow rate is the most crucial factor for the accuracy of reactor thermal power calculation, a venture-meter is generally utilizing as the most accurate instrument, which consists of Austenitic Stainless Steel Nozzle within Carbon Steel. According to the ASME PTC Code 19.5, Carbon Steel and Austenitic Stainless Steel have different thermal expansion coefficients. However, by applying the thermal expansion coefficient of Austenitic Stainless Steel to the both materials, the main feed water flow rate was decreased by 0.055% and reactor thermal power was under-calculated by 0.056%.

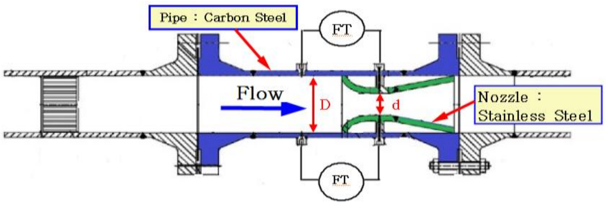

Figure 2. Feedwater Flow Measurement Nozzle

4. The result of corrective action for reactor thermal power calculation program

4.1 Simulation

The reactor thermal power for Kori unit 3&4 is calculating by two independent main computers(#1, #2), synchronized with time, using operating parameters and constants. The result below at Table 1 was achieved by sequentially correcting errors using main computer #2, while main computer #1 was under normal operation, providing operating parameters.

Power Variation Test	Reactor Thermal Power(%)		Power Variation(%)		
	Main Comp.#1	Main Comp.#2	Actual Value	Predicted Value	Deviations
Note 1	99.966	99.878	-0.088	-0.086	-0.002
Note 2	99.965	99.836	-0.129	-0.092	-0.037
Note 3	99.945	100.006	0.061	0.058	0.003
Note 4	**99.968**	**99.812**	**-0.157**	**-0.120**	**-0.037**

Table 1. Results of simulation for parameters

Note :
1. Results of correction for differential pressure unit conversion constant of main feed water inlet flow
2. Results of correction for steam generator blowdown specific volume
3. Results of correction for thermal expansion coefficient of venture-meter for main feed water flow
4. Results of correction for total errors in reactor thermal power calculation Program

The simulation results were almost the same with expectations even though there was a little deviation, because steam generator blowdown flow was slightly higher than the estimation. When all the errors were corrected, the reactor thermal power decreased by 0.157%. Therefore the generator output was increased by 1.6 MWe, based on operation of reactor at 100% thermal power.

4.2. Actual application result

First of all, the main computer #1 and #2 for Kori unit 3&4 were checked whether they were at the same condition, then the errors of reactor thermal power calculation programs in main computer #2 and #1 were corrected in order. Then main computer #1 and #2 were checked and confirmed whether in operation at the identical condition.

As a result of an actual application, reactor thermal power decreased by 0.152~0.153% and the generator output increased by 1.6 MWe while operating the reactor at 100% thermal power. The result was almost the same with the above simulation despite of a little deviation due to slightly lower steam generator blowdown flow in actual application compared to the simulation.

4.3 Kori unit 3 operational status graph after actual application

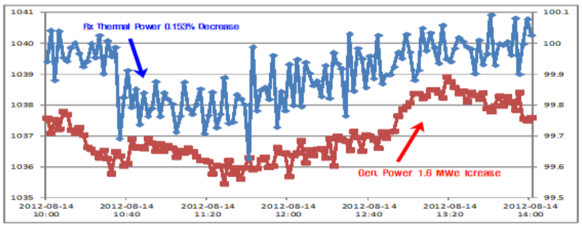

Figure 3. Kori 3 Reactor Thermal Power - Gen. Electrical Power

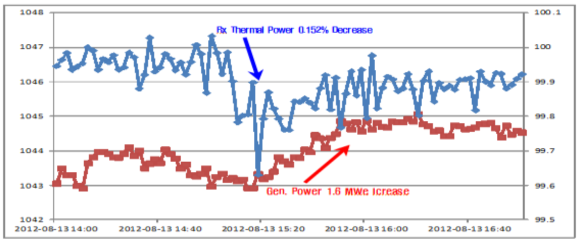

Figure 4. Kori 3 Reactor Thermal Power - Gen. Electrical Power

5. Conclusion

The reactor thermal power calculation program for Kori unit 3&4 was developed in 1992 and operated for 20 years without any correction or revision. Based on the engineering judgement that reactor thermal power varies according to change of steam generator blowdown flow, we conducted a research and found a couple of errors in steam generator blowdown specific volume, unit conversion constants for differential pressure of main feed water inlet flow, and thermal expansion coefficient of venture-meter which measures main feed water flow for steam generator. By correcting the errors in reactor thermal power program, generator power increased by 3.2 MWe for two units, Kori 3&4. Considering recent capacity factor of the plant, additional net electricity of 26,434 MWh was produced annually.

REFERENCES

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