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Evaluation of RCS flow and daily power measurement uncertainties at Kori Unit 2

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1. Introduction

As a part of reload transition safety analysis for Kori Unit 2 fuel change to other type, the instrument and controller measurement uncertainties are reviewed.

In this paper, the evaluation method of measurement uncertainty is introduced. And the measurement uncertainties of reactor coolant system(RCS) flow and daily power are evaluated. For daily power measurement uncertainty evaluation, steam generator (S/G) blowdown(B/D) system is in-serviced condition which is different from that of traditional method.

And the statuses of Nuclear Power Plant(NPP)'s RCS flow uncertainty are investigated.

2. Methods and Results

The S/G main feed water(MFW) flow, pressure, temperature, main steam pressure, Pressurizer pressure, RCS flow, hot leg(H/L) and cold leg(C/L) temperature are evaluated for RCS flow measurement uncertainty calculation. For this, the transmitter, rack in process cabinet and controller's characteristics, such as accuracy, temperature effect, pressure effect, drift and so on, are evaluated.

For daily power measurement uncertainty, the RCS flow, RCS H/L and C/L temperature are excluded and S/G B/D flow and temperature are included to RCS flow measurement uncertainty evaluation method.

2.1 *Uncertainty Evaluation*

2.1.1 The Assumptions of Evaluation

Conditions 1) and 2) below are commonly adapted for the calculation of daily power and RCS flow measurement uncertainties, but 3) ~ 6) are only for RCS flow measurement uncertainty

1) The environmental conditions for transmitter and process rack are 40 ~ 120˚F temperature, ambient atmospheric pressure and 40 ～ 60% humidity.
2) The compartment temperature of reference leg for Process Measurement Accuracy is 90 ～ 130˚F.
3) Because RCS flow is measured by elbow tap which is installed in RCS loop, flow measurement uncertainty includes that of elbow tap.
4) Because instruments are calibrated during maintenance period, sensor drift effect is not considered except special case for flow uncertainty evaluation.
5) RCS flow measurement is performed at S/G B/D isolated condition.
6) The uncertainty of Pressurizer pressure is ± 40 psi conservatively which is calculated before.

2.1.2 The Evaluation Method of Uncertainty

The method is a combination of statistical and algebraic method that uses statistical square root sum square (SRSS) method to combine random uncertainties and then algebraically combine the non-random terms.

$$CSA = \pm\sqrt{A^2 + B^2 + C^2 + (D+E)^2} \pm |F| + G - H \Lambda \quad (1)$$

Where

A, B, C : random and independent terms
D and E : random and dependent terms that are independent of term A,B,C
F : abnormally distributed uncertainties and/or bias(unknown sign)
G, H : bias with known sign

1) random independent uncertainty
   a) Primary Element Accuracy : System element accuracy that quantitatively converts the measured variable energy into a form suitable measurement, as venturi, orifice, nozzle.
   b) Process Measurement Accuracy : Due to a non-instrument related effect.
   c) Sensor Reference Accuracy : Linearity, Hysteresis and Repeatability of Sensor related accuracy.
   d) Sensor Temperature Effect : The measured result change effect due to temperature conditions are changed between the sensor calibration and measurement.
   e) Sensor Pressure Effect : The measured result change effect due to pressure conditions are changed between the sensor calibration and measurement.
   f) Rack Temperature Effect : Temperature effect of Process rack.
2) random dependent uncertainty
   a) Calibration Accuracy : Accuracy related the transmitter is calibrated as acceptance criterion.
   b) Drift : The measured result change effect between subsequent checks of the device.

c) Measurement and Test Effect : Accuracy of calibration equipments for input and output of transmitter or rack.
d) Environmental allowance : bias value to consider harsh environmental condition.

For Measurement and Test Effect combination

$$MTE = \sqrt{MTE\,1^2 + MTE\,2^2 + MTE\,3^2 + \Lambda\ \Lambda} \quad (2)$$

For Calibration Effect

$$CSA = \sqrt{(SCA + SMTE\,)^2} \ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda \quad (3)$$

For Drift Effect

$$CSA = \sqrt{(SD + SMTE\,)^2} \ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda \quad (4)$$

2.1.3 The Characteristics of the Measurement Elements

The transmitters for MFW flow, pressure and temperature, RCS flow, S/G B/D flow and temperature, RCS H/L and C/L temperature are calibrated per 18 months as calibration procedures.

The signals for MFW flow, MFW pressure and temperature, main steam pressure go to plant computer directly. Also MFW flow and pressure, main steam pressure can be taken at field installed instruments.

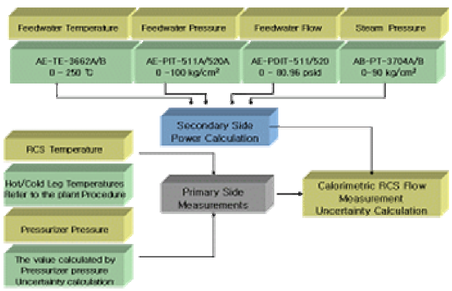

Figure 1. RCS flow measurement flow chart

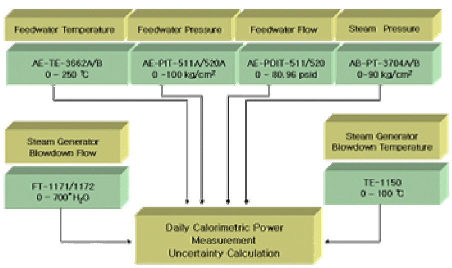

Figure 2. power measurement flow chart

The signals for RCS H/L and C/L temperature, RCS flow, S/G B/D flow and temperature go to plant computer via process rack. Also RCS flow goes to flow indicator.

2.2 The Results of Evaluation

2.2.1 RCS flow measurement uncertainty Evaluation

In Kori Unit 2, a design was changed for flow measurement that signals do not go via process rack and directly go to plant computer. This can remove process rack related uncertainties, such as rack calibration accuracy(RCA), rack drift(RD), rack measurement and test equipment(RMTE), rack temperature effect(RTE).

The uncertainty is improved from 3.0 to 2.7% because of that reason. And if RCS flow signal go to plant computer directly, the uncertainty will improve some more.

The flow measurement uncertainties are 3.5% of Kori Unit 1 and Ulgin Units 1&2 which are bigger that of Kori Unit 2.

2.2.2 Daily power measurement uncertainty Evaluation

For daily power measurement, a design was changed that signals do not go via process rack and directly go to plant computer. In Kori Unit 2, daily power measurement uncertainty is about 2.0% although steam generator blowdown system is considered which was not considered before.

The power measurement uncertainty is 2.0% in Kori unit 1 at S/G B/D isolated condition.

3. Conclusions

The RCS flow measurement uncertainty and daily power measurement uncertainty are used as initial condition for safety analysis, and the uncertainty is dependant on the characteristics of the transmitter, rack in process cabinet and controller. As process signals go to computer directly by design change which reduce process rack related uncertainties and readout error, the measurement uncertainties are reduced. And the transmitters for flow and pressure measurement were changed to Rosemount's model, so sensor uncertainties are reduced. This makes more margins for safety analysis.

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