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# Evaluation of Kori unit 3 control system Margin for Power Uprate

*In-Hwan Kim, Jae-Yong Lee and Duk-Joo Yoon*
*Korea Electric Power Research Institute, 103-16, Mun-ji Dong, Yuseong-Gu, Daejeon, 305-380, KOREA*
*Tel:042-865-5589 , Fax:042-865-5504 , Email: kimih@kepri.re.kr, jylee@kepri.re.kr*

## 1. Introduction

As a part of Power Uprate(PU) Program for Kori 3/4 and Yonggwang 1/2 Units, the controller settings of Control Rod Control System(CRCS), Over Power ΔT (OPΔT) and Over Temperature ΔT(OTΔT) system will be changed to improve system performance.

However, it is recommended to verify the effect using plant data before it is actually adapted to Nuclear Power Plants (NPPs).

In this paper, the effect is evaluated and operation data is predicted for Power Uprate.

## 2. Methods and Results

The equations are used to evaluate the control system performance before PU project is implemented. And same Kori 3 operation data is used to evaluate CRCS, OPΔT and OTΔT system before and after Power Uprate.

In OPΔT and OTΔT operation margin(OM) evaluation, the evaluated and measured data before Power Uprate are used to predict measured data in order to compare with evaluated data after controller settings change.

### *2.1 CRCS Performance Evaluation*

#### *2.1.1 The Method of Evaluation*

The Control Rod has moved unexpectedly during steady state condition. The optimization process in the Control Rod controller settings is studied to prevent this unexpected motion.

The settings of lead/lag( $\tau_3/\tau_4$) and lag( $\tau_5$) for Reactor Coolant System(RCS) average temperature (Tavg), power deviation cutoff point($K_1$) will be changed from 80/10, 5, 1 to 40/10, 10, 2, respectively.

The equation (1) is used to evaluate controller setting change effect.

$$T_E = T_{REF}\left(\frac{1}{1+\tau_2 s}\right) - T_{AVG}\left(\frac{1+\tau_3 s}{1+\tau_4 s}\frac{1}{1+\tau_5 s}\right)$$

$$-\{(Q_N - Q_{TBN})\left(\frac{\tau_7 s}{1+\tau_7 s}\right)(K_1)\}\{Q_{TBN}K_2\}\Lambda \quad (1)$$

#### *2.1.2 The Results of Evaluation*

The temperature difference( $T_E$ ) which controls Control Rod is significantly affected by the Tavg controller settings (lead/lag, lag) which amplify Tavg.

If controller settings are changed as mentioned above, the maximum and minimum temperature differences are reduced by about 1.0°F and stabilized.

Figure 1 shows Control Rod Control Signal before and after settings are changed.

From this result, it can be predicted that CRCS will be stabilized after Power Uprate.

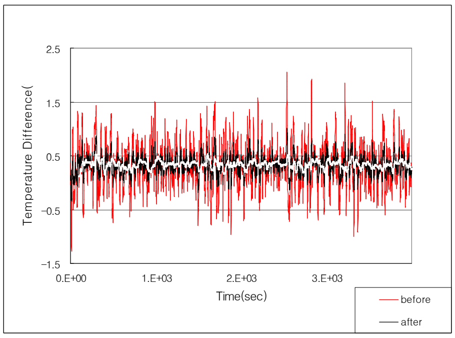



Figure 1 CRCS performance before/after settings changed

### *2.2 OTΔT System Performance Evaluation*

#### *2.2.1 The Method of Evaluation*

If Departure from Nucleate Boiling(DNB) is taken place in reactor core region, fuel can be damaged by the high temperature due to the heat transfer reduction. The OTΔT system is used to prevent DNB by RCS pressure, temperature, hot and cold leg temperature and axial power tilt control.

The actual RCS hot and cold leg temperature difference(ΔT) should not greater than the setpoint which is calculated to prevent DNB.

And the settings of lead/lag( $\tau_1/\tau_2$) for measured ΔT , $(K_1)$ for nominal ΔT, $(K_2)$ and $T'$ for Tavg will be changed from 8/3, 1.379, 0.021, 588.5 to 10/3, 1.137, 0.025, 587, respectively.

The equation (2) is used to evaluate OTΔT setting change effect.

$$OT\,\Delta T\left(\frac{1+\tau_1 s}{1+\tau_2 s}\right)\left(\frac{1}{1+\tau_3 s}\right) \le$$

$$\Delta T_0\{K_1 - K_2\left(\frac{1+\tau_4 s}{1+\tau_5 s}\right)[T\left(\frac{1}{1+\tau_6 s}\right) - T']$$

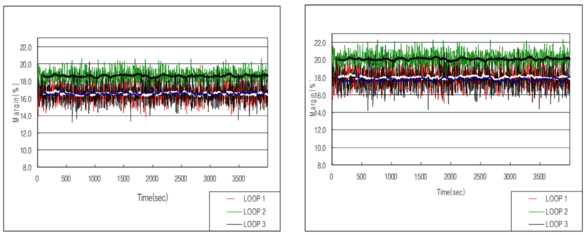
$$+ K_3(P - P'') - f_1(\Delta I)\}\Lambda \quad (2)$$

#### *2.2.2 The Results of Evaluation*

The operation margin is significantly affected by the ΔT channel settings(lag, lead/lag) which amplify measured ΔT. And RCS nominal and operation temperature difference( $T_{ER}$ ) also affects operation margin by amplified lead/lag setting.

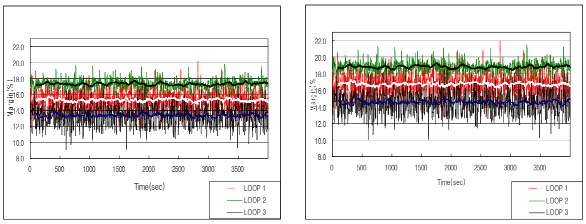
The predicted measured margin is improved by about 1.0% and minimum margin is around 10% with this method. Figure 2 and 3 show evaluated/measured operation margin before and after settings are changed.

As a result, it can be predicted that OTΔT will improve operation margin for safety operation in Power Uprate.




a) Before b) After

Figure 2 OTΔT evaluated OM with settings change




a) Before b) After(Predicted)

Figure 3 OTΔT measured OM with settings change

*2.3 OPΔT System Performance Evaluation*

*2.3.1 The Method of Evaluation*

If the reactor generates more power than designed, the fuel rod may be damaged because the linear power density and RCS temperature increase above the safety limit. The OPΔT system is used to insure fuel rod integrity by RCS temperature, hot and cold leg temperature. The actual RCS ΔT should not greater than the setpoint which is calculated to prevent overpower generation.

And the settings of lead/lag( $\tau_1 / \tau_2$ ) for measured $\Delta T$ , $(K_4)$ for nominal $\Delta T$, $(K_6)$ and $T'$ for Tavg will be changed from 8/3, 1.09, 0.001635, 588.5 to 10/3, 1.093, 0.002486, 587, respectively.

The equation (3) is used to evaluate OPΔT setting change effect.

$$OP \ \Delta T \left(\frac{1+\tau_1 s}{1+\tau_2 s}\right)\left(\frac{1}{1+\tau_3 s}\right) \le$$

$$\Delta T_0 \{ K_4 - K_5 \left(\frac{\tau_7 s}{1+\tau_7 s}\right)\left(\frac{1}{1+\tau_6 s}\right) T -$$

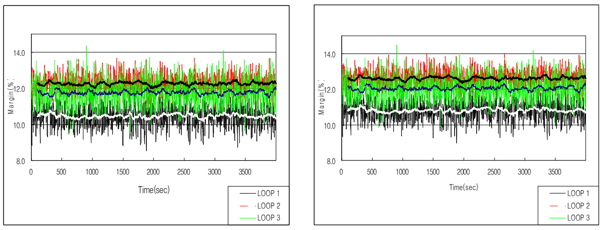
$$+ K_6 \{ T \left(\frac{1}{1+\tau_6 s}\right) - T'' ) - f_2(\Delta I)\} \wedge \quad (3)$$

*2.3.2 The Results of Evaluation*

The operation margin is mostly affected by ΔT channel settings(lag, lead/lag) which amplify measured ΔT. But RCS Tavg does not affect operation margin because rate/lag does not amplify input signal. The same method is used as OTΔT to predict measured OM. It is nearly the same as measured OM of the settings are not changed, ie, average and minimum margin is around 10% and 8% .

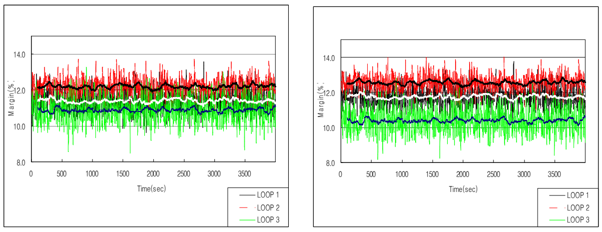
Figure 4 and 5 show evaluated/measured operation margin before and after settings are changed.

From this result, it can be predicted that OPΔT will not affect safety operation in Power Uprate.




a) Before b) After

Figure 4 OPΔT Evaluated OM with settings change




a) Before b) After(Predicted)

Figure 5 OPΔT Measured OM with settings change

## 3. Conclusions

The results of the control system performance evaluation with Kori 3 operation data show that the CRCS is stable, and the OPΔT and OTΔT operation margin are acceptable in channel setpoint changed condition.

Finally, it can be predicted that the CRCS, OPΔT and OTΔT will be acceptable for Power Uprate operation.

## REFERENCES

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