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Operating Margin Analyses in Large Load Rejection and Reactor Trip Transients after Power Uprate of UCN 1&2

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1. Introduction

Korean nuclear power plants have been performing power uprating projects from Kori 3&4 to UCN 1&2 Units since 2004. Kori units 3&4 and YGN units 1&2 successfully increased the plant licensed power by 4.5 percent several years ago. UCN 1&2 kicked off a project to increase the power by 4.5 percent in July 2009. This has resulted in changes to major design and operating parameters, as shown in Table 1, and in particular reduced the steam dump capacity (SDCAP) from 85% to 80% of the turbine steam flow at full power due to an increase of steam flow. The reduction of SDCAP deteriorates heat removal capability in large load rejection, and therefore it is necessary to determine whether a reactor trip will occur. The proportional band (PB) of the steam dump control system affects the departure of the nucleate boiling ratio (DNBR) operating margin under large load rejection transients. In the present study we find the optimal value of the PB by analyzing the setpoint sensitivity in order to improve the reduced DNBR margin by SDCAP in large load rejection transients. UCN units 1&2 have experienced large load rejection (LLR) transients related to house load operation three times from 2004 to 2010. Operating data from plant occurrences of LLR at UCN 1&2 showed that the steam generator (SG) level and OTDT are limiting values with respect to a reactor trip. However, reactor trip has never occurred in LLR. The SG level high and low reactor trip setpoints have been widened because the SG will be replaced. Therefore, we do not evaluate this SG setpoint, as the plants will be operated smoothly after power uprating. We find that the PB affects the DNBR setpoint after power uprating. We establish a design scheme to smoothly transmit the electricity from the turbine to the house load without reactor trip at large load rejection.

2. Methodology for Steam Dump Control System Design

In order to determine the optimal steam dump control system controller setpoints, the transients are analyzed using the LOFTRAN computer code. Design transients considered to evaluate these setpoints are 10% step load change, 5%/min. ramp load change, large load rejection, and reactor trip, which are called condition I transients [1]. Among these design transients, the 95% large-load rejection transient was chosen to determine modulating controller setpoints, and the reactor trip transient was chosen to determine quick open controller setpoints, because these transients are more limiting than any others [1].

TABLE 1. Major Operating Parameters at Full Power Before and After Power Uprating

Parameter	Before Power Uprating	After Power Uprating	Analysis Results
NSSS Power (MWt)	2785	2910	2910
Thermal Design Flow, m^3/sec	17.015	17.015	17.015
Reactor Coolant pressure, MPa	15.5	15.5	15.5
RCS Coolant Avg. Temperature, °C	304.6	306.7	306.7
SG Steam Pressure, MPa	5.77	6.67	6.67
SG Steam Temperature, °C	273	273.8	273.8
Steam/Feedwater Flow, 10^3 kg/sec	1.512	1.594	1.594
Feedwater Temperature, °C	219	222.8	222.6
Steam Dump Capacity*, %	85	80	80

2.1 Modulating Controller

The modulating controller is designed to control the reactor power, average RCS temperature, RCS pressure and main steam pressure without large oscillations. This controller is also designed to minimize the amount of steam dump, prohibit reactor trips, and prevent actuation of the steam generator safety valve when a condition I transient occurs[1]. In these analyses, a 95% load rejection transient is used for the design transient. This 95% load rejection transient will be evaluated in order to determine whether the requirement of the design transient is met or not when the steam dump capacity has been reduced due to the power uprate. During these transients, the OTDT reactor trip margin and SG level low-low reactor trip margin are specifically checked to confirm that there is an adequate operating margin, because they are limiting values [1].

2.2 Quick Open Controller

The quick open controller is designed to prevent both steam generator safety valve actuation resulting from excessive reactor residual heat removal and safety injection due to low pressurizer pressure and low steam-line pressure resulting from excessive cooling[1]. It is also designed to control the average RCS temperature, RCS pressure, and main steam pressure without large oscillation when a turbine trip occurs [1]. In order to verify the appropriateness of these setpoints, the reactor trip transient was analyzed.

3. Results and Discussion

Figs. 1~3 show RCS transients. If the PB decreases, the steam dump control system becomes more sensitive and the RCS operating parameters such as temperature and pressure may oscillate. Fig. 2 shows the reactor coolant average temperature when using various PB. The PB must be maintained above 15 so that the plant will avoid these unfavorable oscillations, as they are detrimental to smooth plant operation. They are described in the figures as OTDT operating margins representing the minimum DNBR during 95% load rejection for the various PB.

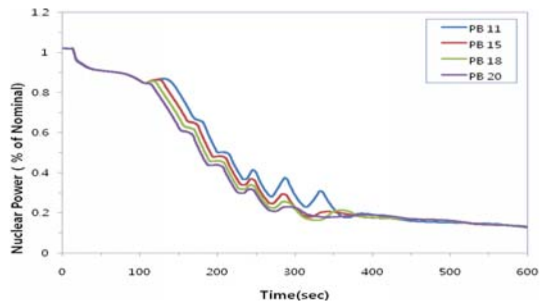

Fig. 1 Nuclear Power in Large Load Transients

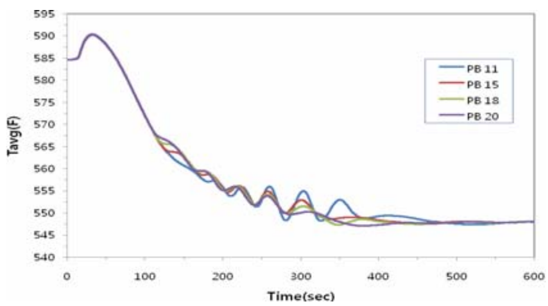

Fig. 2 Average Temperature in Large Load Transients

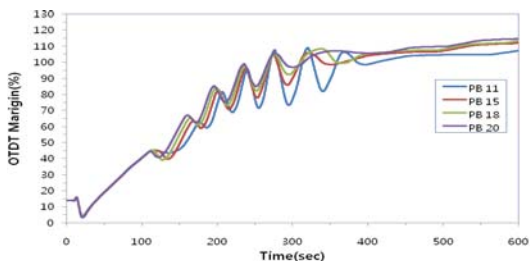

Fig. 3 OTΔT Margin in Large Load Transients

A reactor trip is analyzed to verify the appropriateness of the quick open controller. In these analyses, we assessed code runs of various setpoints for the lead-lag controller (LLC) of low steamline pressure safety injection (SI) actuation and verified that the steamline pressure did not reach the SI actuation signal after the reactor trip, as shown in Fig. 4.

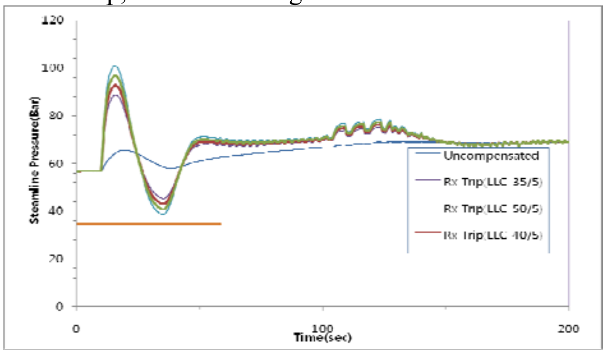

Fig. 4 Margin-to-SI Actuation by Steamline Low Pressure after Reactor Trip

4. Conclusions

Steam dump control system setpoints have been analyzed for various PB and these setpoints can maintain sufficient operating margins when condition I transients occur. However, when the PB is reduced below 15, the reactor coolant operating parameters oscillate with high amplitude due to frequent opening and closing of the steam dump valve. In order to optimally operate the steam generator control system, we recommend these setpoints be maintained at above 18 for smooth plant operation without oscillation of the main operating parameters. The plants did not reach reactor trip setpoints under a 95% load rejection transient after power uprating in UCN 1&2. Also, this paper verified that the steamline pressure did not reach the SI actuation signal after reactor trip transients. In conclusion, the operating margin after 4.5% power uprating is appropriate under large load rejection and reactor trip transients in UCN 1&2.

REFERENCES

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[3] UCN 1&2 PCWG Parameters to support a 6% Power Uprate, 2010

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