Simulation of Three Main Feedwater Pump Operation for SKN 1&2 and SWN 1&2

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1. Introduction

A concept of three main feedwater pump operation is adopted as an improved design feature in Shin-Kori Unit 1&2 (SKN 1&2) and Shin-Wolsong Unit 1&2 (SWN 1&2). To evaluate the three main feedwater operating condition, a feedtrain model is developed and included in the KOPEC Integrated Systems Performance Analysis Code (KISPAC) [1]. The power levels at which the second and the third pumps are to be in-service are determined from the code simulation. Also, plant responses at a loss of one or two main feedwater pump(s) are simulated with the KISPAC code.

2. Feedtrain Model Description

The developed feedtrain model for SKN 1&2 and SWN 1&2 is a node and flowpath model to calculate the flow through the flowpath. Figure 1 is a model configuration of the feedtrain for SKN 1&2 and SWN 1&2. The model accounts for the momentum equation across each flowpath and the mass conservation law at each node. The equations are linearized and form a matrix equation with unknown variables of pressure and flowrate. A matrix solution technique is used to simultaneously solve for pressure and flow throughout the feedtrain.

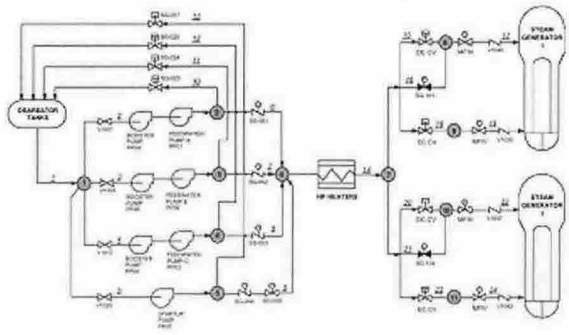

Figure 1. Node and flowpath model for the feedtrain model

Heat addition through the HP heater is modeled proportional to the turbine power having first order lag function to represent the thermal capacitance of the heater. Pumps and valves are modeled as control devices adding or losing pressure through the flowpath depending on their control signals.

The advantage of the developed feedtrain model is that it can be applied to two or three main feedwater pump system and it gives more accurate solution compared to the current feedwater model in the KISPAC code which calculates feedwater flow using simplified physical model without node and flowpath.

3. Simulation Results

The developed feedtrain model is merged into KISPAC code to simulate steady state and transient plant responses. Code inputs for all major plant systems including RCS, pressurizer, feedwater system, steam generator, steam line, and control systems, are prepared using design data for SKN 1&2 and SWN 1&2. Each main feedwater pump has 55% flow capacity of rated feedwater flow in the design [2,3].

3.1 Determination of Power for Pump Addition

The second main feedwater pump is normally in-service at 50% power in the Korea Standard Nuclear Power Plant (KSNP), which has 65% main feedwater pump capacity in design and two main feedwater pumps operating at rated condition. It is determined so as to give appropriate pressure differences across the main feedwater control valves before and after the pump addition. When the pump is added at too low power, the pressure difference after the addition is high and the valve integrity may be threatened. When the pump is added at too high power, the pressure difference before the addition is low and control capability in feedwater flow is lost.

Table 1. Pressure Difference across the Main Feedwater Control Valves depending on Plant Conditions

Reactor Power	3 Pumps Operating	2 Pumps Operating	1 Pump Operating
100 %	75 psid	40 psid	Impossible
90 %	80 psid	40 psid	Impossible
80 %	100 psid	45 psid	Impossible
75%	105 psid	50 psid	Impossible
70 %	110 psid	60 psid	Impossible
60 %	125 psid	90 psid	Impossible
50 %	-	105 psid	15 psid
40 %	-	120 psid	40 psid
35%	-	115 psid	60 psid
30 %	-	110 psid	75 psid

The recommended timing of pump in-service to the system is when the pressure difference across the valve is about 50 psid from the operational experiences of the KSNP. Table 1 shows the simulation results by KISPAC code for the pressure difference across the main feedwater valve at various power and number of operating main feedwater pump combinations. The results indicate that the second pump is recommended to start about 35~40% power and the third pump is about 70~75% power. However, the final decision of pump in-service time needs the consideration for pump efficiency and the consequences of loss of a operating main feedwater pump event.

3.2 Simulation for Loss of Pump(s) Transient

SKN 1&2 and SWN 1&2 are designed to continue full power operation upon loss of one main feedwater pump during three pump operating condition. At loss of two pumps, which means one pump trip during two pumps operation or simultaneous two pumps trips during three pumps operation, Reactor Power Cutback System (RPCS) and following turbine setback/runback is actuated to prevent reactor trip depending on power level. The target power of RPCS is 75%, same as KSNP, and turbine setback/runback is reduced to 50%, within 55% of one main feedwater pump capacity, from 60% of KSNP. The limiting case for loss of one pump is at full power operation condition. For loss of two pumps, there are two limiting cases. One is at full power with RPCS actuation. The other is just below 75%, at which RPCS (actually CEA drop) is not actuated. Figure 2 shows the wide range steam generator level behaviors during the transient cases mentioned above which is simulated by KISPAC code.

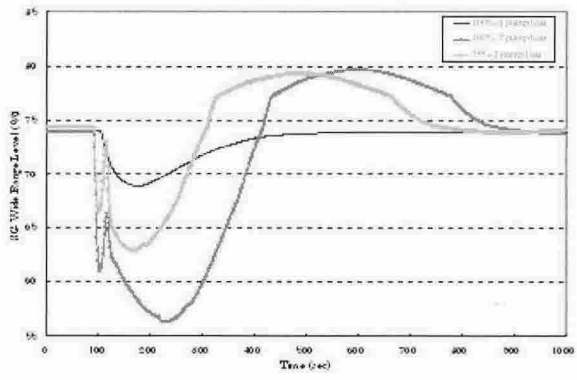

Figure 2. SG level transients during loss of main feedwater pump(s) events

As the main feedwater pump trips, steam generator levels decrease due to reduced flow. The Feedwater Control System (FWCS) increases the feedwater flow and the steam generator levels come back to normal level. The reactor trip setpoint for the low steam generator level is about 45% (wide range, preliminary) for SKN 1&2 and SWN 1&2. Figure 2 shows that there is a little margin to low steam generator level trip upon the loss of pump(s) event.

4. Conclusion

A feedtrain model for operation of three main feedwater pumps was developed and merged into KISPAC code. From the KISPAC simulation, it is recommended to start the second main feedwater pump at 35~40% power and third pump at 70~75% power. Also, loss of one or two main feedwater pump events can be accommodated in SKN 1&2 and SWN 1&2 design. However, it should be noted that actual plant responses may be a little different depending on the as-built design of SKN 1&2 and SWN 1&2.

REFERENCES

[1] Technical Manual for KISPAC, KOPEC, 1999.
[2] Preliminary Safety Analysis Report for SKN 1&2, KHNP.
[3] Preliminary Safety Analysis Report for SWN 1&2, KHNP.