Transient Impact Analysis for Input Sensor Malfunction of Main Feedwater Common Header Pressure for APR1400

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Introduction

During power operation, a malfunction of a main feedwater common header pressure (MFHP) input sensor can occur in APR1400.

For controlling steam generator (SG) level in APR1400, feedwater control system (FWCS) uses various input parameters including MFHP. According to the design of FWCS, two MFHP signals are averaged and utilized for the speed compensation logic of main feedwater pump (MFWP) in normal condition. However, if one of two input sensors sends bad signal, the other value of fine input sensor is used automatically.

The problem is when one of the input sensors is not sending bad signal but showing a malfunction such as oscillation or sending inappropriate value, which actually can happen during the operation of APR1400. In this case, the distorted average value is used in FWCS without signal transferring to the fine input sensor and affect operation of the plant, mainly SG level control.

Therefore in this study, an analysis for this case has been performed to evaluate the impact of a transient to the plant operation and to verify whether the plant can be controlled properly.

Control Logic of FWCS

The FWCS receives steam header pressure, MFHP, and steam flow input signals and generates MFWP speed bias signal as shown in Fig. 1. Therefore, malfunction of MFHP input sensor causes speed change of MFWP.

Also, since FWCS controls downcomer feedwater control valve (DFCV), economizer feedwater control valve (EFCV) and MFWP speed simultaneously as the major target, EFCV position is also changed to regulate the SG level to its setpoint. DFCV position does not change as it is fixed at 50% position when the reactor power is over 20%.

Due to these control interactions described above, behaviors of major plant parameters including SG level vary and are controlled.

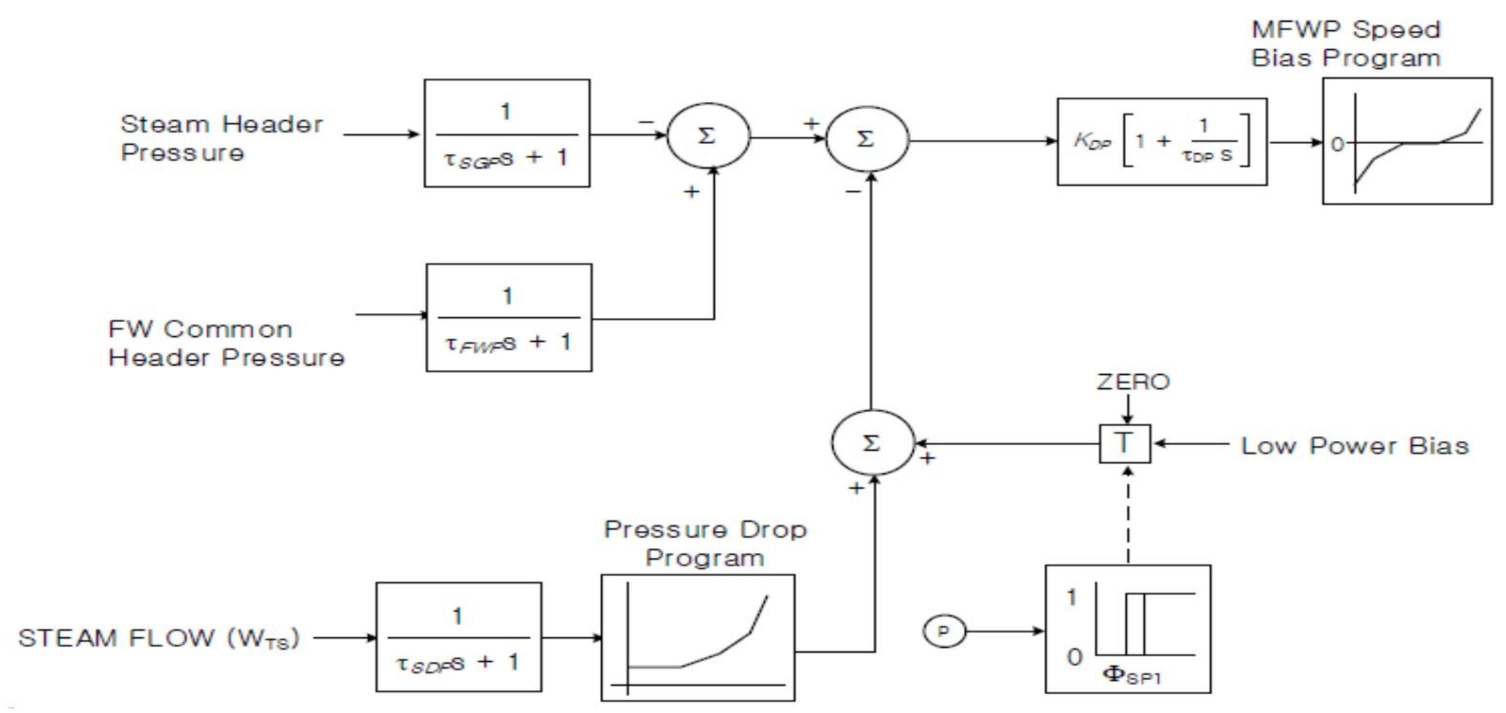

Fig. 1. Simplified MFWP Speed Compensation Logic

Analysis Methodology

◈ Computer Codes

To simulate the intended transient, the KEPCO E&C integrated system performance analysis code (KISPAC) was utilized. The KISPAC is a best-estimate simulation code to analyze the performance of plant including NSSS control systems and has been utilized in actual plant design. Fig. 2. shows the KISPAC primary loop configuration and includes the node and flow path designations.

◈ Initial Condition and Assumptions

Nominal design value is used as initial condition for analysis. In actual operation, this transient can be mitigated by manual operation of the operator by transferring channel. Therefore, in this study, automatic operation by the NSSS control systems after initiating of the transient is assumed. In addition to maximize the impact of the transient, the value of failed input sensors of MFHP is assumed to be zero.

◈ Node and Flow Path Diagram

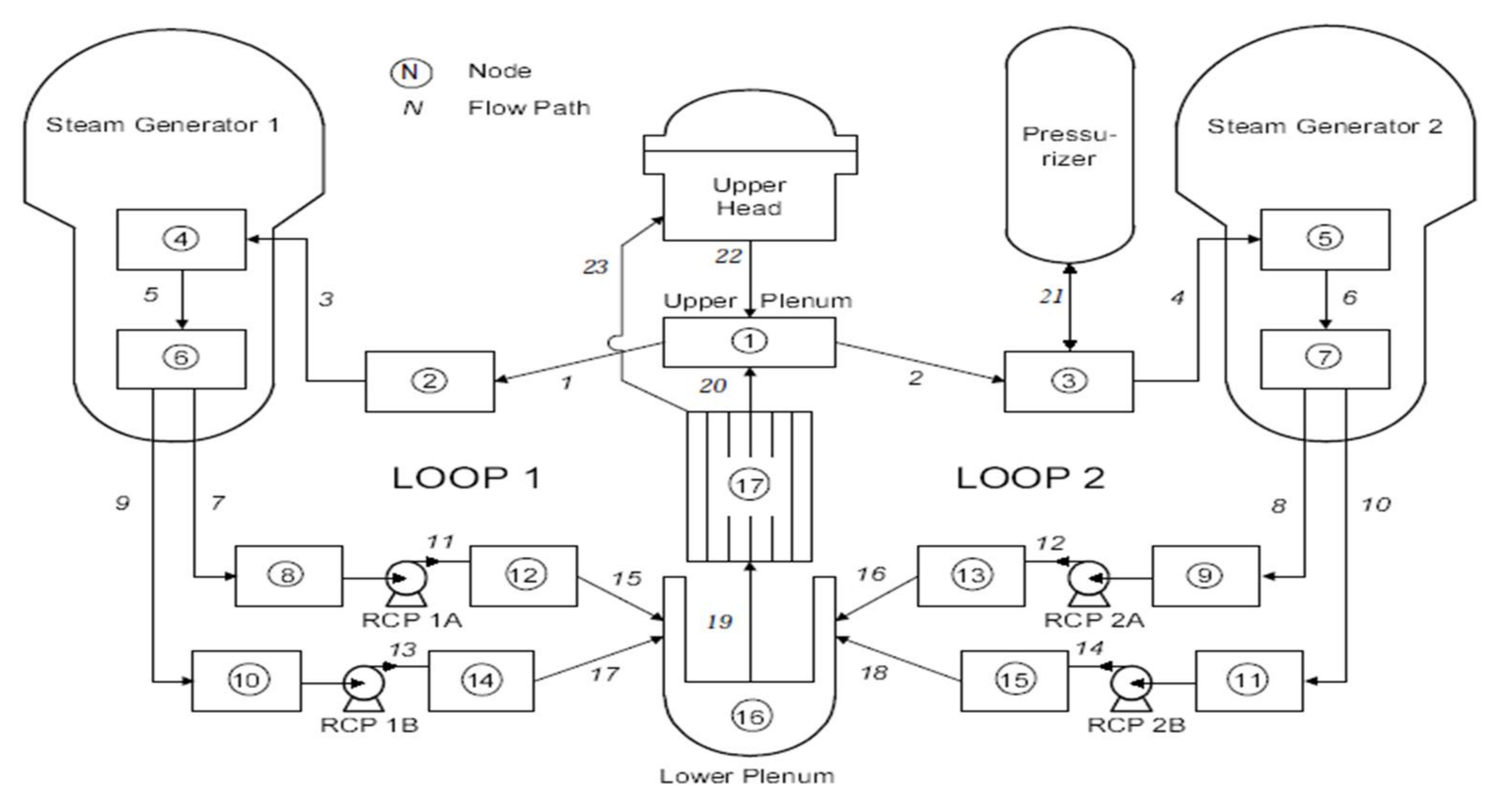

Fig. 2. Node and Flow Path Diagram for the KISPAC

Analysis Results

The behaviors of major parameters for the transient analysis are shown in Fig. 3 through Fig. 10.

As described previously, a malfunction of an MFHP input sensor caused increasing of MFWP speed, resulting in increases of main feedwater flow and SG level consequently. The position of EFCV was decreased to compensate the increasing of SG level. Due to increased and stabilized MFWP speed, MFHP was also increased and stabilized. Primary system parameters such as reactor power, pressurizer pressure, and level were mostly stable.

After the transient, all major parameters reached a new stable state due to control of NSSS control systems and there was no significant impact on the plant operation.

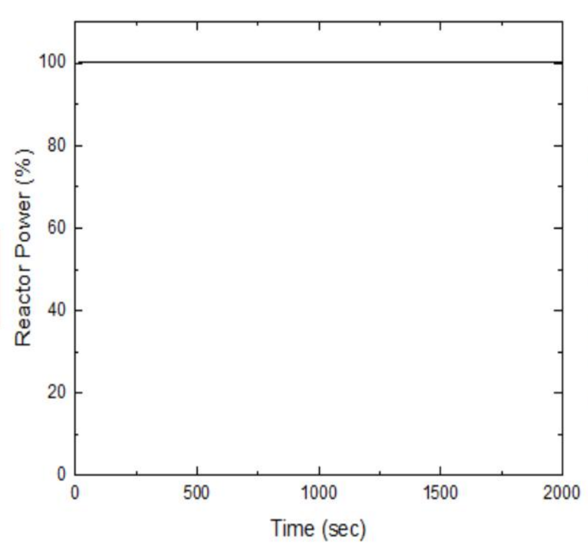

Fig. 3. Reactor power

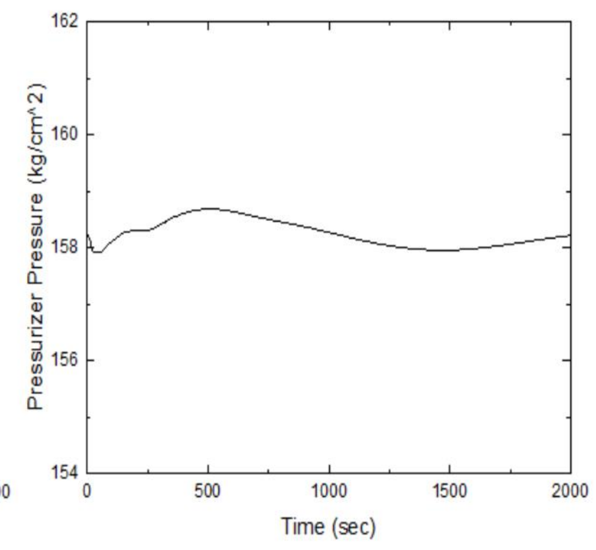

Fig. 4. Pressurizer pressure

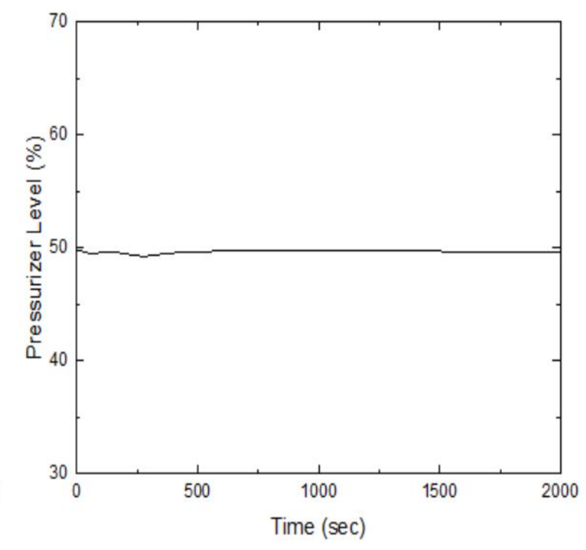

Fig. 5. Pressurizer level

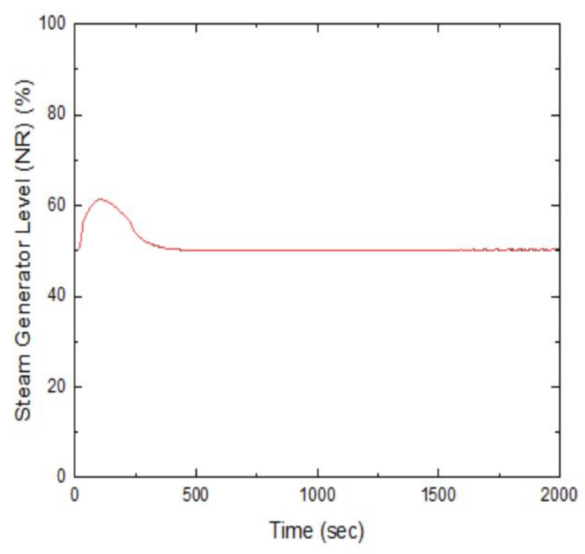

Fig. 6. SG level (Narrow range)

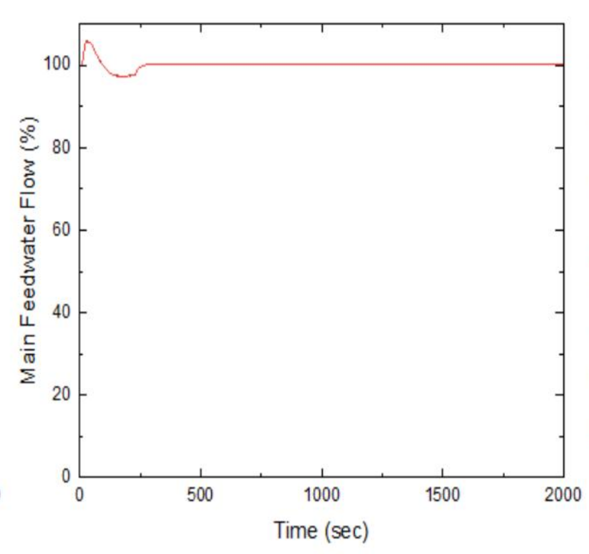

Fig. 7. Main feedwater flow

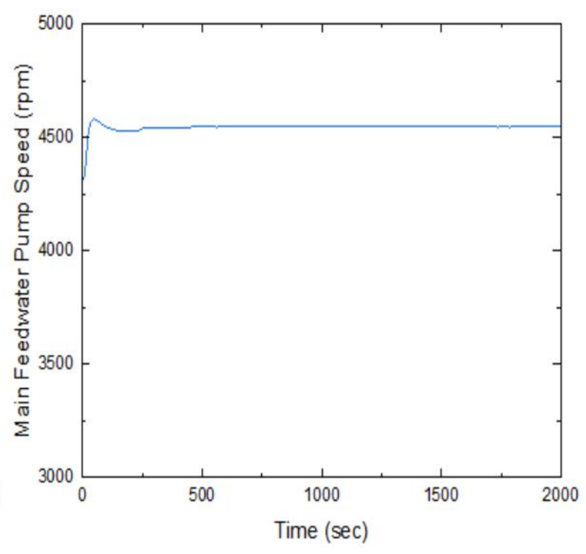

Fig. 8. MFWP speed

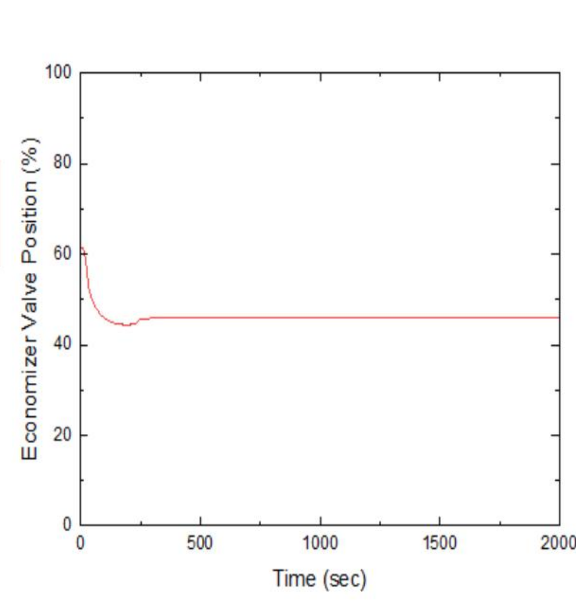

Fig. 9. EFCV position

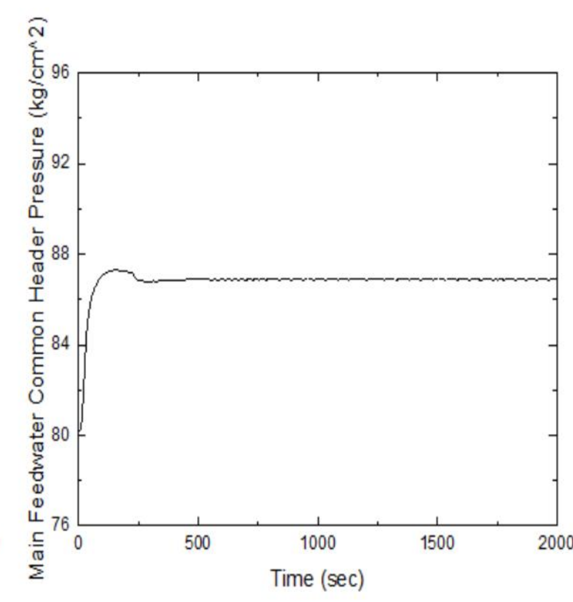

Fig. 10. MFHP

Conclusions

In case that one of the MFHP input sensors malfunctions without sending bad signal, automatic channel transferring does not happen and distorted average value of MFHP affects operation of the plant.

Thus, in this study, transient analysis for this case has been performed to evaluate the impact of a transient to the plant operation and to verify if the plant can reach a new stable state. To simulate the transient, KISPAC was used with conservative assumptions.

Consequently, it is concluded that small transient could occur in the secondary system shortly after initiation of this malfunction. However, the NSSS control systems including the FWCS control the plant appropriately and recover the plant to a stable condition.

In conclusion, there was no significant impact on the plant operation in case of a malfunction of the MFHP input sensors.