Development of Integrated Valve Control Algorithm of Feedwater Control System for APR1400

See Chae Jeong *, In Ho Song, Myeong Hoon Lee
KEPCO Engineering & Construction Co., 111, Daedeok-daero 989, Yuseong-gu, Daejeon, 34057
**Corresponding author: scjeong@kepco-enc.com*

1. Introduction

Performance of steam generator(SG) water level control system, which is called feedwater control system(FWCS), of APR1400 is very important for the stable operation. However, the oscillation of SG water level has been increased due to the bigger stiction behavior of the economizer feedwater valve at the full power steady state operation of APR1400. In this paper, development of integrated control algorithm of the economizer and downcomer valves to resolve large oscillatory behavior of SG water level and its application result are described.

2. Control Stability of SG Water Level

The FWCS receives SG water level, feedwater flow, and steam flow input signals and generates the economizer valve, downcomer valve and main feedwater pump speed demand signals to maintain the SG water level around the level setpoint.

The FWCS changes between high and low power control modes at 20% of reactor power. In low power mode, the SG water level is controlled with downcomer valve while the economizer valve is fully closed. In high power mode, the level is controlled with economizer valve and the downcomer valve position is fixed at 50%. Because the flow capacity of downcomer valve is about 1/6 of the economizer valve, fine control can be provided with the downcomer valve in the low power range(Fig. 1).

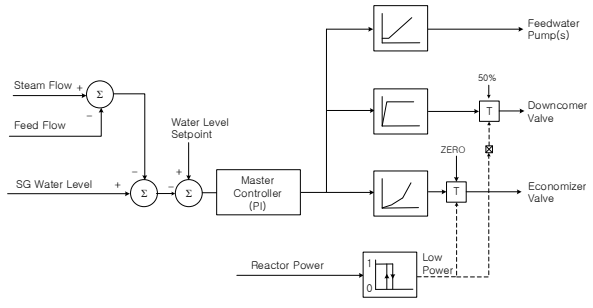

Fig. 1. Major control algorithm of APR1400 FWCS

At the high power steady state operation of APR1400, the SG water level shows continuous ±2.5% oscillation as shown on Fig. 2. The amplitude of level oscillation was observed increased than the reference plant. If amplitude of oscillation is increased, it may result in negative effects such as shortening the life of economizer valve by long term spurious movements and unstable calculation of the secondary calorimetric power which may challenge reduction of the operational margin of the plant[1].

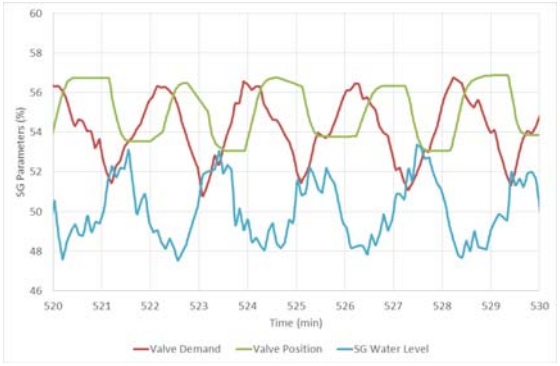

Fig. 2. Operational data of the SG level control of the first APR1400 unit at 90% reactor power

3. Modeling of the Economizer Valve Stiction Characteristics

To provide fundamental resolution for the oscillation issue, the oscillatory behavior of the SG water level was modeled first, and then control algorithm to enhance the stability of the level control was developed by using this model.

It was analyzed that the stiction of economizer valve is the root cause of level oscillation shown on Fig. 2 [2]. To perform accurate modeling of economizer valve stiction characteristics, the APR1400 NPA (Nuclear Plant Analyzer)[3] was used.

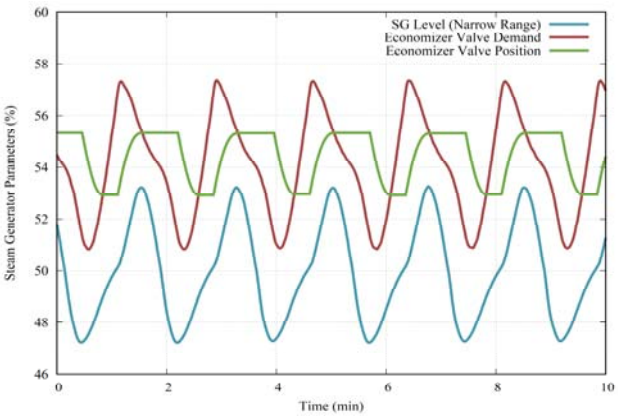

Fig. 3. Modeling result of economizer valve stiction characteristics

Fig. 3 shows the analysis result of developed economizer valve stiction model. The model was optimized to match with operational behavior of the site as much as practical. The modeling shows certain amount of differences on amplitude and period of parameter oscillations compared to site data, but it was evaluated acceptable to derive new control algorithm to stabilize the oscillation behavior.

4. Integrated Control Algorithm of Economizer and Downcomer Valves

After completion of economizer valve stiction modeling, a new control algorithm has been developed as shown on Fig. 4 to achieve stable control of the SG water level. The key feature of new control algorithm is a hysteresis function added after the economizer valve position demand signal to minimize the movement of the economizer valve in the high power control mode. By doing this, the fine controllability of SG water level will be lost so that it is necessary to use other available control device for the fine control of feedwater flow.

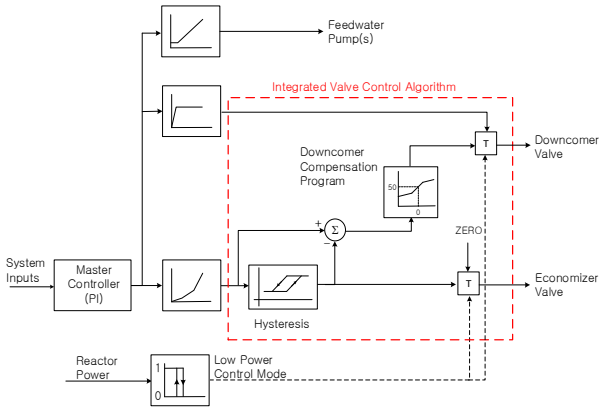

Fig. 4. The integrated valve control algorithm

The downcomer valve which was operated at the fixed position of 50% has been newly assigned for the fine control of feedwater. The concept of the downcomer valve control is to provide continuous control of feedwater flow by compensating the differences between the demand signal and the hysteresis output signal for the economizer valve.

The setpoint set of added compensation program of the downcomer valve on Fig. 4 was derived based on that the flow capacity of the economizer valve which is several times greater than the downcomer valve. The hysteresis setpoint was set with estimated value of the economizer valve stiction shown on Fig. 2.

With the integrated valve control algorithm and newly generated setpoints, the SG water level shows very stable behavior as shown on Fig. 5.

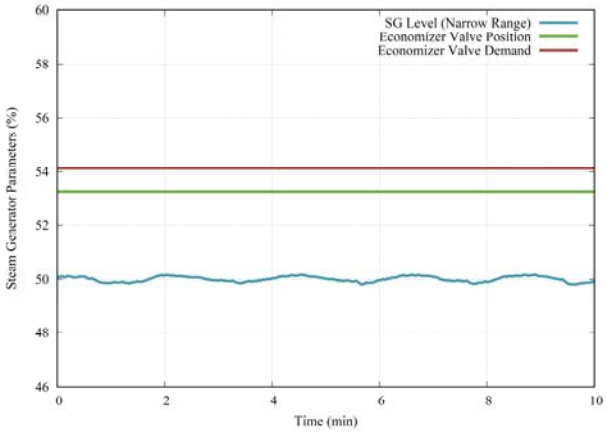

Fig. 5. Analysis result by applying integrated valve control algorithm

5. Conclusions

Increased oscillation amplitude of the SG water level of APR1400 caused by bigger economizer valve stiction was observed. To provide fundamental resolution for this oscillation issue, the stiction characteristics both of the economizer and downcomer valves has been modeled to get the similar dynamic behavior of site operational data. After then, integrated control algorithm of the economizer and downcomer valve has been developed and analysis result of its application shows acceptable stability of the SG water level.

This integrated valve control algorithm can be applied to APR1400 and OPR1000 plants to achieve stable control of the SG water level, to enhance integrity of the economizer valve, and to increase stability of secondary calorimetric power calculation.

REFERENCES

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