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Development of Integrated Control Algorithm of Steam Generator Level for the Nuclear Power Plants

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1. Introduction

- Performance of feedwater control system(FWCS) is very important for stable operation of the nuclear power plants.
- For APR1400, relatively large oscillation of SG water level has been observed at the full power steady state operation.
- Integrated control algorithm of the economizer(E/C) and downcomer (D/C) valves has been developed to resolve large oscillatory behavior.

2. Control Stability of SG Water Level

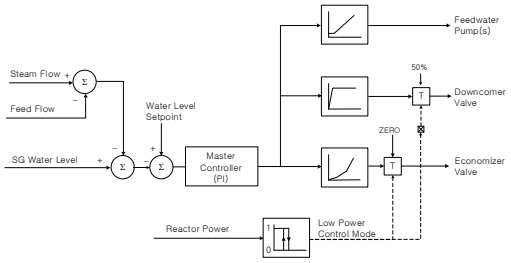

Fig. 1. Schematic Functional Diagram of APR1400 FWCS

- FWCS changes between high and low power control modes at 20% of reactor power.
- In high power control mode, the SG water level is controlled with E/C valve while the D/C valve is fixed at 50% position.
- The flow capacity of D/C valve is about 1/6 of the E/C valve so that D/C valve has advantages for the fine controls

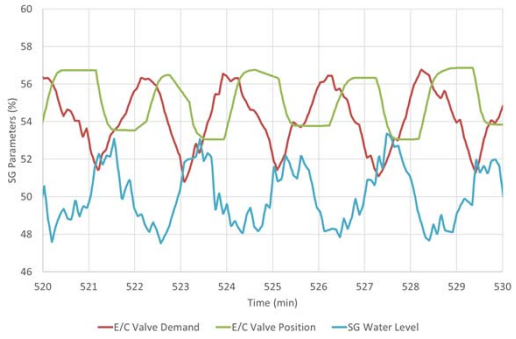

Fig. 2. Operational data of the SG level control of the first APR1400 unit at 90% reactor power

- At the high power steady state operation of the APR1400, the SG water level shows continuous ±2.5% oscillation (Fig. 2).
- Due to the increased oscillation compared to the reference plant, it may result in following negative effects:
  - Shortening the life of economizer valve by long term spurious movements
  - Unstable calculation of the secondary calorimetric power which may challenge reduction of the operation margin of the plant

3. Modeling of the Economizer Valve Stiction Characteristics

- The oscillatory behavior of the SG water level was modeled by using APR1400 Nuclear Plant Analyzer(NPA).
- Similar dynamical behavior has been obtained by applying appropriate amount of valve stiction for the E/C valve (Fig. 3).

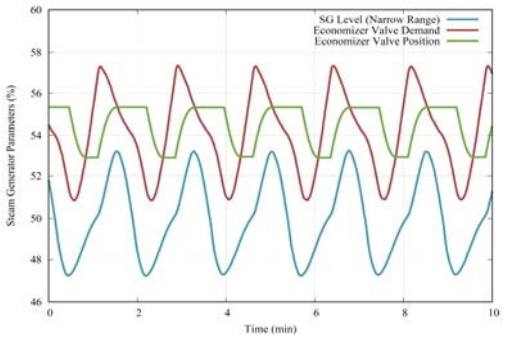

Fig. 3. Result of modeling based on the dynamics of E/C valve stiction

4. Integrated Control Algorithm of E/C and D/C Valves

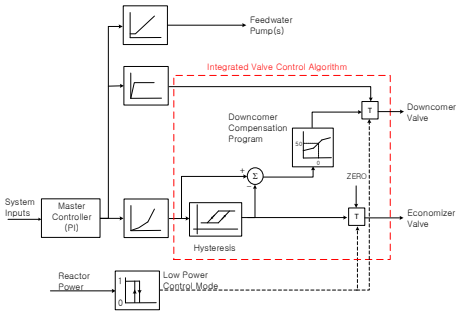

Fig. 4. The integrated control algorithm of E/C and D/C valves

- A hysteresis function was added after the E/C valve demand to minimize fine movements of the E/C valve with adjustable value.
- For the fine control, the D/C valve is used to compensate demand deviation of the E/C valve caused from newly added hysteresis.
- The D/C valve compensation is calculated based on the differences between the E/C valve demand and the output signal of hysteresis

5. Result and Conclusion

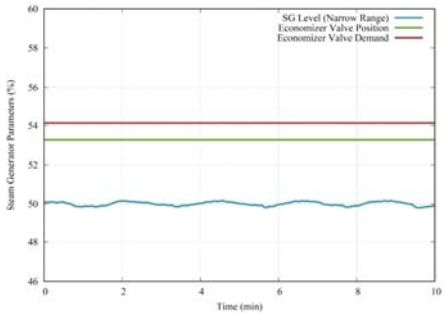

Fig. 5. Analysis result by applying integrated valve control algorithm

- Analysis results show that S/G water level can be stabilized by applying the integrated valve control algorithm with setpoint optimization (Fig. 5)
- This algorithm can be applied to APR1400 and OPR1000 plants to achieve stable control of the SG water level, to enhance integrity of the E/C valve, and to increase stability of secondary calorimetric power calculation.