Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Optimization for the Parameters of Feedwater Control System for OPR1000 Nuclear Power Plants

Ung Soo Kim*, In Ho Song, Jong Joo Sohn and Eun Kee Kim
NSSS Engineering Department, KOPEC, 150, Deokjin-Dong, Yuseong-Gu, Daejeon, KOREA
**Corresponding author: uskim@kopec.co.kr*

1. Introduction

The control systems for the nuclear steam supply system (NSSS) make the nuclear power plant (NPP) operate efficiently under transient conditions as well as steady state conditions. The control performance of the NSSS control systems depends on their own control algorithms and relevant parameters such as gain values, time constants and so on. Currently, the values of these parameters are determined based on sensitivity studies using system simulation computer code and engineering judgments.

In this study, the optimization for the parameters of the feedwater control system (FWCS) is performed to provide it with a better control performance. The optimization objective is to minimize deviation of the steam generator (SG) water level during transients. In this case, analytic objective function does not exist and the responses to input can be evaluated by computer simulations only. Therefore the simulation optimization methodology [1] is used and the response surface methodology (RSM) [2, 3] is adopted as the simulation optimization algorithm. As a result, the control performance of the FWCS is remarkably improved.

2. Backgrounds

2.1 Simulation Optimization

The simulation optimization is the process of finding the best input variable value among all possible inputs without explicitly evaluating each input. As shown in Fig. 1, the output of a simulation model is input to an optimization algorithm to provide a feedback on the progress of the search for the optimal solution. This feedback in turn guides a next input to the simulation model.

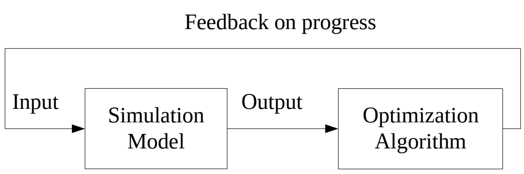

Fig. 1. A simulation optimization process.

2.2 Response Surface Methodology

The RSM is a procedure for fitting a series of regression models to the output variable of a simulation model by evaluating it at several input variable values and optimizing the resulting regression function. The process starts with a first order regression function as the equation (1) and the steepest ascent/descent method [3]. After reaching the vicinity, a higher degree regression function as the equation (2) is employed.

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i \tag{1}$$

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k}\sum_{j=1}^{k} b_{i,j} x_i x_j \tag{2}$$

Where,
Y : response
x_i : design variables
b_i, $b_{i,j}$: regression coefficients

3. Optimization for the Parameters of Feedwater Control System

3.1 Feedwater Control System

The FWCS for the Ulchin NPP unit 5 and 6 is chosen for the study. The function of the FWCS is to control the SG water level. The parameters to be optimized in the FWCS are the master PI controller gain K and reset time constant τ as shown in Fig. 2.

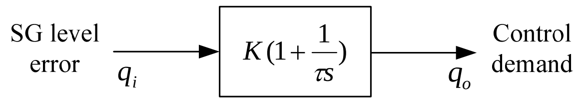

Fig. 2. A typical model for FWCS master PI controller.

The gain K is given as a piecewise linear function according to the reactor power. Also the reset time τ has different values corresponding to the reactor power.

3.2 Optimization for Parameters

The optimization for the gain and reset time is done for two regions. The one is for the high reactor power region (≥ 20%). The other is for the low reactor power region (< 20%).

The optimization objective is to minimize the SG level deviation from the target setpoint (44%) during transients. The objective functions are relationships between the SG level deviation and the parameters of the master PI controller. These objective functions are not available in the form of analytic equations and can only be evaluated by computer simulations. For computer simulations, the KISPAC [4], which is one of the system simulation computer codes for the design and performance analyses of actual NPPs, is utilized.

The following four transients are selected as simulation cases for optimization. The first three ones are for the high power and the last one is for the low power:

(a) Power ramp down from 100% to 20%
(b) Load rejection to house load 5%
(c) Loss of a main feedwater pump
(d) Low power oscillation (5%-18%-5%)

Through this work, the parameters of the master PI controller are optimized as Table I.

Table I: Optimization result

Parameter	Existing	Optimization
Low power τ (sec)	600.00000000	260.26386860
High power τ (sec)	100.00000000	32.88918393
Gain at 5 %	0.20000000	0.20000000
Gain at 8 %	0.20000000	0.33030291
Gain at 12 %	0.20000000	0.23995807
Gain at 16 %	0.20000000	0.35962611
Gain at 19 %	0.20000000	0.03818895
Gain at 20 %	0.20000000	0.83117131
Gain at 40 %	0.41800000	0.99508727
Gain at 60 %	0.61700000	0.80204109
Gain at 80 %	0.68300000	0.82751407
Gain at 100 %	0.80000000	0.97849428
Gain at 120 %	0.80000000	0.97849428

The SG level behaviors during above four transients are shown in Fig. 4. As shown in Fig. 4, the degree of the SG level variation is minimized and it can be known that this parameter optimization provides optimal performance to the FWCS.

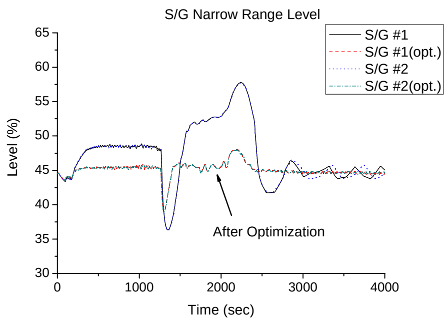

Fig. 4(a). Power ramp down from 100% to 20%.

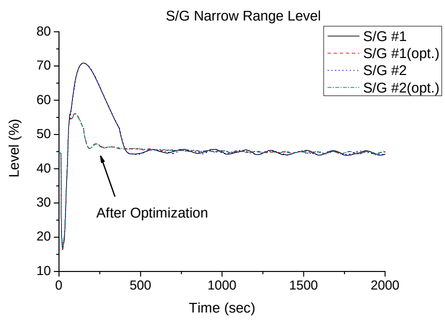

Fig. 4(b). Load rejection to house load 5%.

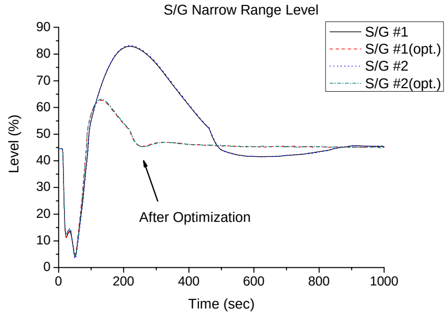

Fig. 4(c). Loss of a main feedwater pump.

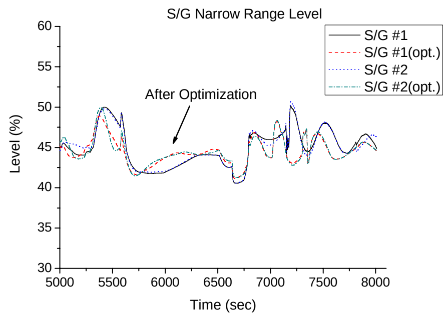

Fig. 4(d). Low power oscillation (5%-18%-5%).

4. Summary and Conclusions

In this work, the parameters of the FWCS are optimized. The objective functions for the optimization are relationships between the SG level deviation and the parameters of the FWCS. Because these objective functions are not available in the form of analytic equations, the simulation optimization methodology is utilized and the RSM is adopted as the optimization algorithm. From the optimization, the FWCS becomes to have the optimal performance on the SG level control and consequently the control performance of the FWCS is remarkably improved. Also, it is concluded that this parameter optimization method can be applied to the other NSSS control systems and actual design of NPPs.

REFERENCES

[1] Y. Carson, A. Maria, Simulation Optimization: Methods and Applications, Proceedings of the 1997 Winter Simulation Conference, pp.118-126, 1997.
[2] H. Gonda Neddermeijer, Gerrit J. Van Oortmarssen, Nanda Piersma, Rommert Dekker, A Framework for Response Surface Methodology for Simulation Optimization, Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, USA, Dec. 2000, vol.1, pp.129-136, 2000.
[3] Raymond H. Myers, Douglas C. Montgomery, Response Surface Methodology: Process and Product Optimization Using Designed Experiments, John Wiley & Sons, 1995.
[4] Technical Manual for the KISPAC, KOPEC, August, 1999.