Option Study on SMART-P Feedwater Flow Rate Control

Han-Ok Kang, Juhyeon Yoon
Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon, hanokang@kaeri.re.kr

1. Introduction

Feedwater flow rate of SMART-P is a leading control parameter for other system parameters such as reactor power and steam pressure. Wide operating range of flow rate (turn-down ratio) is requied to cover start-up/cooldown operation modes as well as power generation mode. Stable flow control is mandatory for the reliabe normal power operation. Furthermore, fast and robust is also required for the emergency situation.

To have a better knowledge of the feedwater flow rate control and interface requirements for practical design of feedwater control system, a MMS model of the feedwater control system has been developed. This model is described herein, from the feedwater pumps to the front of steam pressure control sytem, and representative results of the model calculations are presented.

2. Methods and Results

In this section some of the techniques used to model the feedwater control system are described. The MMS model includes feedwater pumps, feedwater control valves, steam generator, and steam lines.

2.1 MMS Model

MMS (Modular Modeling System) is a Windows NT based visual software system for modeling the dynamic characteristics of power plant systems and studying various design, performance, and operation aspects [1]. KAERI are currently utilizing the MMS plant model to perform various scooping analyses and to design and to test the control logics of the plant [2].

Figure 1 shows the MMS model used to test the feedwater control system in this study. Only significant components for the feedwater control are included in the model and other components such as steam pressure control system and condenser are substituted as boundary conditions. The steam pressure control system also regulates steam flow rate and have a chance to interact with feedwater control system, which requires including the steam pressure control system for the overall plant analysis. However our objective is only for feedwater flow control in this study so constant steam pressure is assumed for the boundary condtion. The MMS modules for feedwater pumps, startup feedwater pump, feedwater control valve, steam generator, and steam lines are shown the figure 1.

Basically the feedwater control system is composed of control valve itself, actuator, and controller. Though variable feedwater pump speed is one possible candidate for the flow rate control, it requires inefficient inductor system so feedwater pumps are assumed to operate with constant speed. Three differenct options are considered in this study. The first and simplest way is to use only one control valve with feedback control from measured flow rate signal. The second is to use a feedwater control valve and a throttling valve in series. The stem postion of feedwater control valve is proportional to required flow rate directly. The throttling valve regulates the the pressure drop through the feedwater control valve in the constant value. The third is to introduce a small additional valve which takes charge of the low flow rate regime. The valves for the rated condition and for the startup condtion are combined in a row.

Figure 1 shows the model for the first option and other models have been developed separately. Valve flow coefficients, actuator parameters, and tunning values for the controller are optimised to satisfy the design requirement as conventional procedure [3]. Table 1 shows important valve and controller parameters for the analysis.

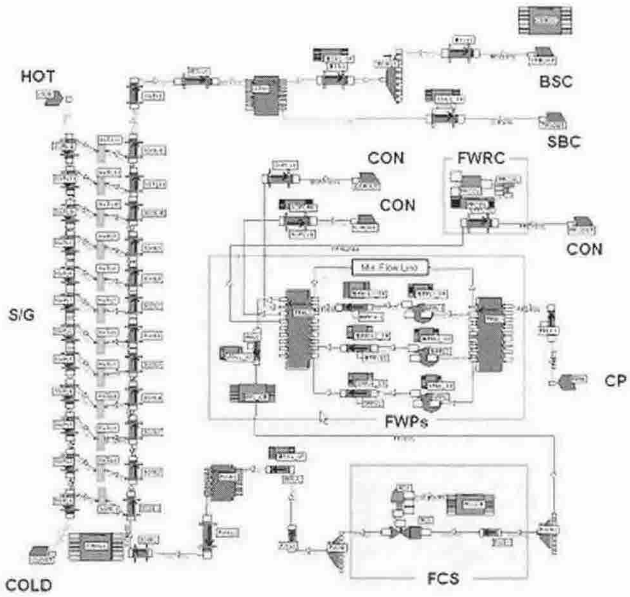

Figure 1. MMS model for the feedwater control with single valve.

Table 1. Important valve and controller parameters

Parameters	Values

Valve flow characteristics	Equal percentage
Actuator type	Pneumatic
Actuator stroke time	5 sec
Actuator total hysterisis	1 %
Valve DP ratio	23 %
PI controller proportional gain	0.005
PI controller integral gain	0.0025
Valve stem postion for rated condition	0.8
Turn down ratio	20

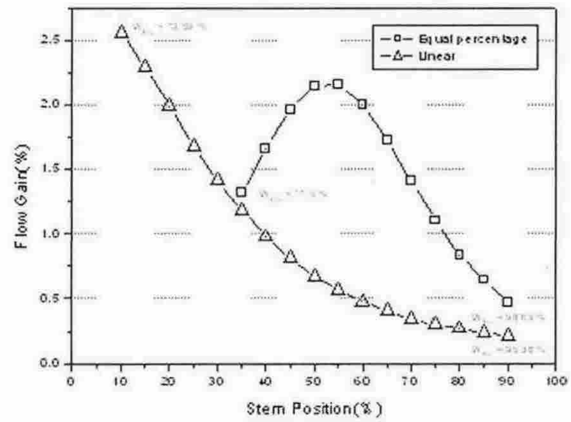

Figure 2. Flow-gain curve

2.2 Results

There exist two possible selections for feedwater control valves. One is linear flow characteristic and other equal percentage. The selection depends on system curve and feedwater pump characteristic. Figure 2 shows flow-gain curve for the SMART-P with two valve flow characteristics. The figure shows that we can obtain narrow variatoins of flow gain and stem position for the case of equal percentage flow characteristic valve, which are recommanded features for the stable control.

Power decreasing senario is simulated with different feedwater control system options, which is shown in the figure 3. First feedwater flow rate is decreased to from 100 % to 20 %. Then startup feedwater pump is turned on and feedwater pump off. After the steam pressure setpoint is reset to 1.6 MPa, feedwater flow rate is decreased to 5 %. Three figures are for the single control valve, the serial configuration with throttling valve, and the parallel installation with low flow capacity valve. For the first case, single valve has to take a charge of whole range of operation. Flow oscillation is shown for the low flow condition with second case. This flow oscillation is due to delayed correction of pressure drop through the feedwater control valve. Main feedwater control valve is substituted into smaller valve at 350 sec for the third case.

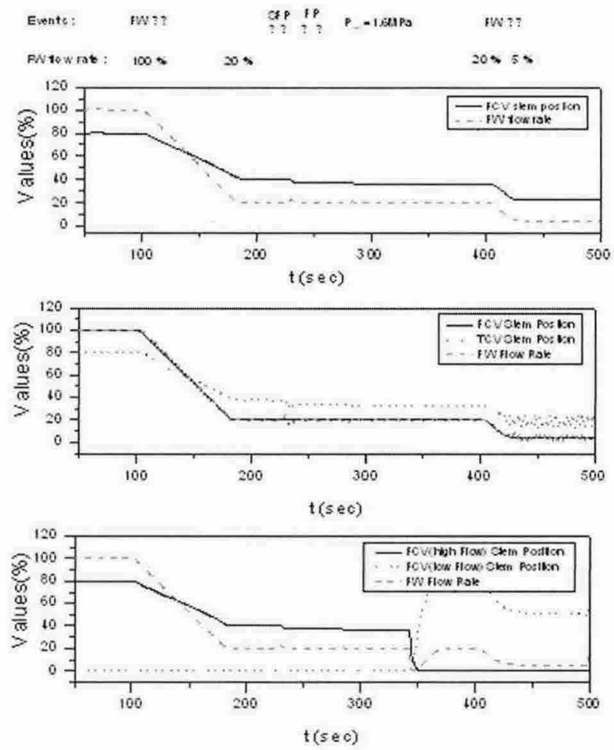

Figure 3. Flow rates and stem postion for power decreasing operation with three different feedwater control system options.

Some flow transient occurs during control valve alternation, which can be avoided through control logic refinement.

3. Conclusion

To have a better knowledge of the feedwater flow rate control and the interface requirements for practical design of feedwater control system, a MMS model of the feedwater control system has been developed. Basic flow-gains are compared for the different valve flow characteristics. Merits and demerits for different valve configurations are also discussed with power decreasing senario.

ACKNOWLEDGEMENT

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