MSSV Modeling for Wolsong-1 Safety Analysis

Bok Ja Moon [a*], Chul Jin Choi [a], Seoung Rae Kim [a]
[a]*KEPCO E&C, 150 Dukjin Dong Yuseong Gu Daejeon Si*
[*]*Corresponding author: bjmoon@kepco-enc.com*

1. Introduction

The main steam safety valves (MSSVs) are installed on the main steam line to prevent the over-pressurization of the system. MSSVs are held in closed position by spring force and the valves pop open by internal force when the main steam pressure increases to open set pressure. If the overpressure condition is relieved, the valves begin to close.

For the safety analysis of anticipated accident condition, the safety systems are modeled conservatively to simulate the accident condition more severe. MSSVs are also modeled conservatively for the analysis of over-pressurization accidents. In this paper, the pressure transient is analyzed at over-pressurization condition to evaluate the conservatism for MSSV models.

2. Analysis and Results

In this section over-pressurization accident to be analyzed is described and several MSSV models are presented. And the pressure transients are compared between applied MSSV models.

2.1 Over-pressurization Condition

For the evaluation of MSSV models, the system pressure transient following loss of class IV power is simulated for Wolsong-1 Nuclear Power Plant (NPP). The primary heat transport pumps and feedwater pumps are tripped on a loss of class IV power and the pressure begins to increase. The turbine governor valve is closed and condenser discharge valves and atmospheric steam discharge valves are conservatively assumed to be closed. The Reactor Regulating System (RRS) is assumed to be frozen and Liquid Relief Valves (LRVs) are not credited. The second shutdown system number 2 (SDS2) is assumed to be effective. The analysis is performed with the CATHENA thermal hydraulic computer code[1].

2.2 MSSV models

Four MSSVs are installed on each steam line and the open set pressures of each valve are 5.11, 5.17, 5.20 and 5.24 MPa(a) respectively in Wolsong-1 NPP.

Model A shown in Figure 1 is the conceptual opening characteristics of MSSVs. The valves pop open to 70% of full lift when the system pressure increases to P_{set}. And the valves open fully when the steam pressure increases to accumulation pressure P_{acc} which is 3% of set pressure above P_{set}. As the steam pressure decreases, the valves start to close linearly to 70% of full lift until the steam pressure decreased to P_{reseat} which is 95% pressure of P_{set}. The valves close completely at P_{reseat}. If the system is over-pressurized again, MSSVs open again in accordance with opening characteristics explained above.

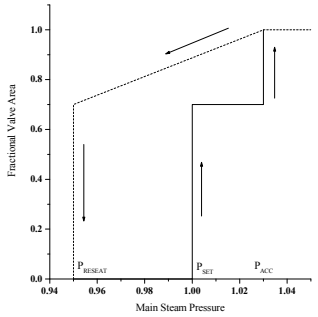

Figure 1 MSSV Open Characteristics – MODEL A

The spring-loaded valve does not open exactly as the characteristics of MODEL A. Once the valve starts to open at set pressure by spring force, the force continuously lifts the valve and the valves fully open after all. And the valves remain at full open position until the steam pressure decreases to reseat pressure. MODEL B is established based on the realistic MSSV open characteristic as shown in Figure 2. 3% uncertainty is conservatively applied to open and reseat set pressure. As MSSV performance is tested periodically to check the open and reseat pressure, this model is considered as conservative and realistic.

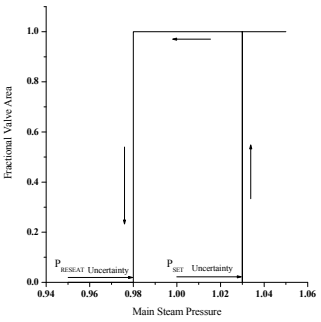

Figure 2 MSSV Open Characteristic – MODEL B

MODEL C shown in Figure 3 is a conservative model established for Wolsong-1 safety analysis of over-pressure accident. The valves start to open at set pressure and linearly open in proportion to steam pressure until the pressure reaches to the accumulation pressure. Four MSSVs are assumed conservatively to

open at maximum set pressure 5.24 MPa(a) simultaneously whereas MSSVs open in order of set pressures.

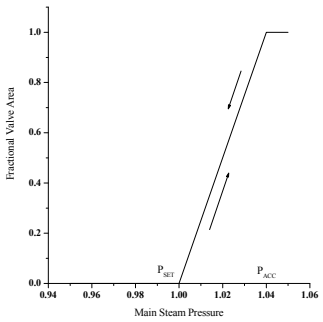

Figure 3 MSSV Open Characteristic – MODEL C

2.3 Effects of MSSV models

The pressure of steam generator increases on a loss of class IV power and reaches MSSV open set pressure. As steam discharges through MSSVs, the pressure of the steam generator decreases.

Figure 4 shows the steam pressure and corresponding MSSV lifting behavior simulated using MODEL A. One MSSV opens at set pressure, 5.11 MPa(a) and remains at 70% of full lift because the pressure does not increase to 103% of set pressure and the valves repeat lifting around the set pressure as expected in Figure 1.

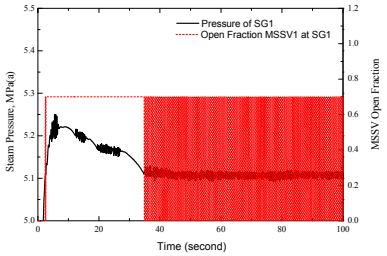

Figure 4 MSSV Open Fraction and Flow for MODEL A

Figure 5 is for the case of MODEL B. One MSSV opens at 5.26 MPa(a), including 3% uncertainty to 5.11 MPa(a) of set pressure, and remains at full open position until the pressure decreases to reseat pressure, 98% pressure of set pressure obtained by adding 3% uncertainty.

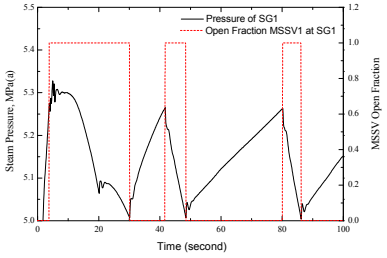

Figure 5 MSSV Open Fraction and Flow for MODEL B

All MSSVs of MODEL C start to open at maximum set pressure, 5.24 MPa(a) and the open area linearly increases or decreases as a function of main steam pressure. Thus, the steam pressure and valve open area change very smoothly as shown in Figure 6.

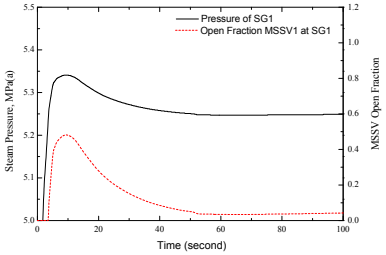

Figure 6 MSSV Open Fraction and Flow for MODEL C

The main steam pressure transients are compared in Figure 7 between 3 MSSV models. The peak pressure of MODEL C is the highest among the results. Though MODEL B is realistic with considering 3% uncertainty, its peak pressure is lower than the result of MODEL C. The system pressure of MODEL A shows the lowest peak pressure.

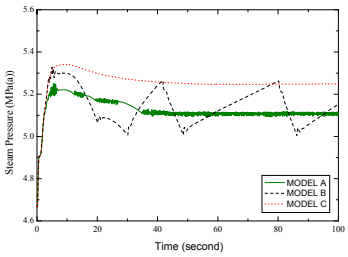

Figure 7 Steam Pressure Transients for 3 MSSV Models

3. Conclusions

The feasibility study for various MSSV models has been performed for Wolsong-1 safety analysis. The MSSV models which were applied to over-pressurization accident analysis are based on conceptual, realistic and conservative open characteristics. The CATHENA code well simulates MSSV actuation and the MSSV model applied to Wolsong 1 safety analysis gives conservative results compared to conceptual model and realistic model conservatively established including 3% uncertainty.

REFERENCES

[1] CATHENA MOD-3.5d/Rev 2 Input Reference," 153-112020-UM-001, Rev.0, 2005.