Study on the Opening Characteristics of MSSV

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1. Introduction

Nuclear power plants have safety valves on the main steam lines to protect overpressure of the secondary system of the plants. The safety valves are designed to open and relieve excess pressure from the main steam lines and to reclose in order to prevent further release of steam after normal conditions have been restored. In safety analysis, the opening and closing characteristics of MSSV is usually modeled in two types. One is pop-up model and the other is step-change model. In this paper the two models are compared to see the effects on the pressures of the primary and the secondary systems.

2. Methods and Results

In this section the models of opening and closing characteristics of MSSV are described. To examine the effects of the models, a loss of condenser vacuum (LOCV) event, which is the limiting event in regard of pressure, has been analyzed for a typical OPR1000 plant.

2.1 Step-change Model

The pressure accumulation in a safety valve is the overpressure between when the valve initially opens and where its flow capacity is rated. In typical OPR1000 plants, MSSVs are assumed to reach rated capacity at 3% accumulation and reclose on 5% blowdown.

In order to model the accumulation and blowdown of the valve, step-change model has been generally used. When the pressure of main steam line reaches opening set pressure, P_{set}, the valve partially opens to reach 70% of its rated capacity. With the accumulation of 3% of set pressure, the valve fully opens. This opening characteristics and set pressure of the valve are presented in Table 1 and Fig. 1, where set pressures are typical opening set pressures for MSSVs of OPR1000 plants. In safety analysis, 4% of set pressure is included as drift and measurement uncertainties.

Table 1: Opening set pressures

	Set Pressure	Set Pressure in Safety Analysis
1st Bank	1250 psig	1314.7 psia
2nd Bank	1290 psig	1356.3 psia
3rd Bank	1300 psig	1366.7 psia

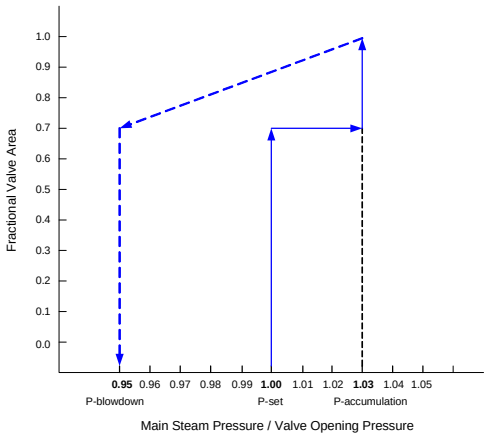

Fig. 1. Opening characteristics curve of MSSV for step-change model

2.2 Pop-up Model

In the pop-up model, the MSSV pops open after some delay at the pressure of the valve's opening set pressure. The delay time is provided by the manufacturer of the valve and is usually within 100 *msec*. The opening characteristics curve is described in Fig. 2. Set pressures are the same as in the step-change model as shown in Table 1 and the delay time is separately considered in safety analysis.

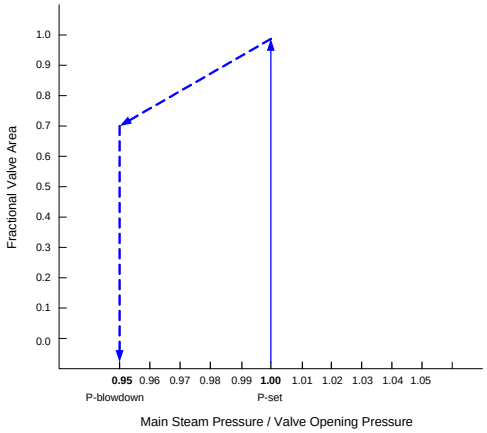

Fig. 2. Opening characteristics curve of MSSV for pop-up model

2.3 LOCV Analysis Results

The LOCV event has been analyzed to see the effects of the opening characteristics curve of MSSV using RETRAN-3D computer code. The event is chosen because it is the limiting event in regard to overpressure of the primary system and the secondary system of the plant.

The peak pressure analysis cases in the primary and secondary systems are separately analyzed because the initial conditions that lead to peak pressure are different for the primary and secondary systems[1,2]. Two cases of LOCV event are selected after sensitivity analysis. In the peak pressure case of the secondary system, the pressurizer pressure control system is conservatively assumed to operate automatically in order to maximize the pressure of the secondary system. For both cases step-change model and pop-up model are used separately to simulate the MSSV responses.

Results of case studies are described in Table 3, Fig. 3 and Fig. 4. As shown in Table 3 and Fig. 3, the peak pressure of the primary system is not affected by the opening characteristics models of MSSV, because the peak pressure of the RCS occurs before the MSSVs open in this case.

For the peak pressure case of the secondary system pressurizer PSVs do not open and reactor trip occurs relatively later than that of the RCS peak pressure case. So the pressure of the steam generator for the SG peak pressure case is higher than that of the RCS peak pressure case. As shown in Table 3 and Fig. 4, SG peak pressure using pop-up model is less than that of using step-change model. This is due to the fast full open property of the pop-up model. Thus, by adopting the pop-up model, the secondary system can have more margin for maximum pressure.

Table 2. Initial conditions for peak pressure cases of the primary and secondary systems

	RCS Peak Pressure Case	SG Peak Pressure Case
Power	102 %	102 %
PZR Level	52.6 %	21.9 %
PZR Pressure	2250 psia	2000 psia
Core Inlet Temperature	564.5 F	570.0 F
RCS Flow	100 %	95 %
SG Level	35 %	79 %
PZR Spray	Manual	Automatic

Table 3. Results of case studies for peak pressure

	Step-change Model	Pop-up model
RCS Peak Pressure	2704 psia at 7.3 sec	2704 psia at 7.3 sec
SG Peak Pressure	1408 psia at 22.3 sec	1379 psia at 21.35 sec

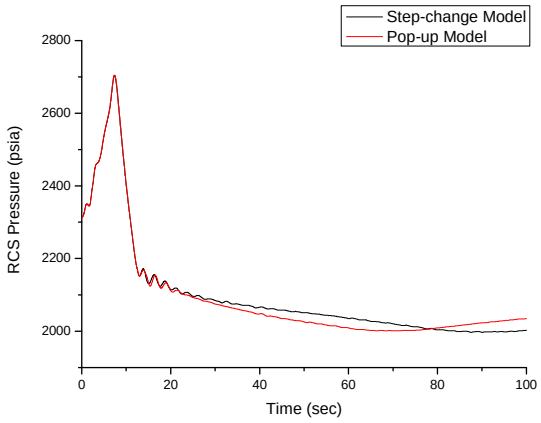

Fig. 3. Comparison of the peak pressure case of the primary system

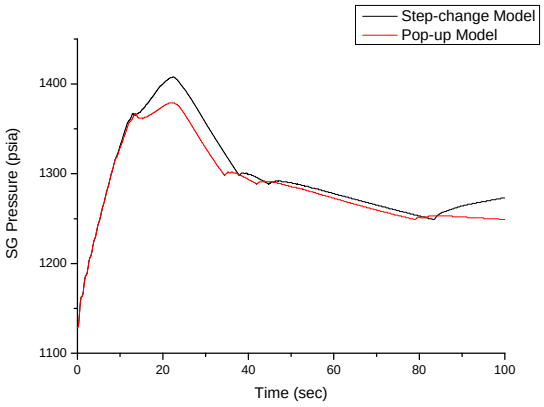

Fig. 4. Comparison of the peak pressure case of the secondary system

3. Conclusions

Pop-up model of the MSSV is compared with step-change model. Thus far, step-change model has been generally used to simulate the MSSV response of the OPR1000 plants. But with the view point of current safety standards[1,2] this model may be not adequate to simulate the MSSV responses. Pop-up model shows better results than step-change model, and is more realistic since one of features of safety valve is fast opening. By using the pop-up model the secondary system can have more margins in pressure.

REFERENCES

[1] Safety Review Guidelines for Light Water Reactors (Rev. 3), “15.2.1-3 Loss of External Load; Turbine Trip; Loss of Condenser Vacuum”, KINS, 2009

[2] NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plant: LWR Edition (Rev.2), “15.2.1-15.2.5 Loss of External Load; Turbine Trip; Loss of Condenser Vacuum; Closure of Main Steam Isolation Valve (BWR); and Steam Pressure Regulator Failure (Closed)”, USNRC, 2007.