Performance Evaluation for Overpressure Transient at Reactor Coolant System of SHINKORI 3/4 NPP by Loss of Turbine Load

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1. Introduction

NPP should sustain the integrity of reactor coolant pressure boundary (RCPB) to prevent the release of radioactive material. According to KEPIC MN-7000, NPP should have facilities to maintain the pressure inside the RCPB lower than 110% of design pressure during overpressure transients. [1] Hence, commercial NPP include depressurization-devices such as pressurizer safety valve and main steam safety valve with reactor protection system.

In SINKORI 3/4 NPP (SK34), first commercial APR1400-type plant, the depressurization devices have distinguishing features. Fig. 1 shows schematic diagram for pilot operated safety relief valve (POSRV) as pressurizer safety valve of SK34. [2] The valve includes two spring loaded safety valve (pilot valve) to set up the opening/closing pressure of main valve. And main valve operates with delay time after opening/closing of pilot valve. Main steam safety valve (MSSV) of SK34 is so-called IAD-type valve, for which opening set pressure was defined by manufacturer as initial audible discharge whereas previous definition was popping point. The design features for POSRV and MSSV should be considered in detail at transient analysis.

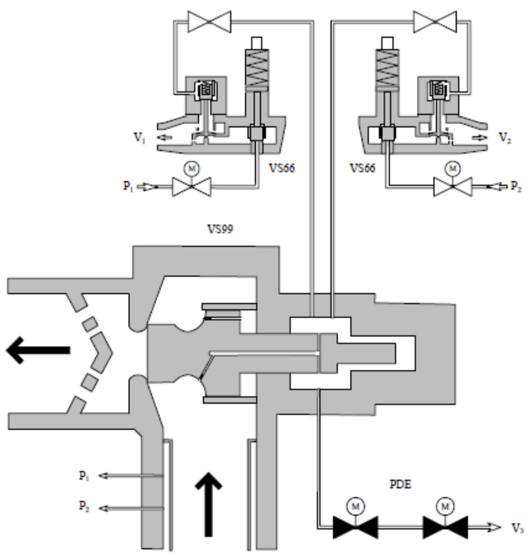


Fig. 1. Schematic diagram of pilot operated safety relief valve (POSRV)

The objective of this study is to evaluate the performance of SK34 for overpressure transient with conservative conditions and to identify significant parameters with sensitivity study.

2. Analysis Methodology

When any overpressure transient occurs, POSRV and MSSV should have enough capacity to relieve coolant or steam with excess enthalpy to atmosphere or other system. Therefore, the input model needs to be composed of the worst combination of input variables. This section describes the assumption and features of input model to result in conservative output in viewpoint of overpressure in RCS of SK34.

2.1 Assumptions

The following assumptions were considered to maximize the pressurization rate in this study.

- With initiating event, reactor coolant system and main steam system is at 102% of rated power with considering uncertainty.
- The reactor is tripped by second safety class trip signal according to standard review plan [3]
- Moderator temperature coefficient is zero.
- Doppler coefficient is a minimum negative number.
- After turbine is tripped, the flow by letdown and charging system and pressurizer spray and the operation of turbine bypass control system, power cutback system and feedwater control system were not considered.

2.2 Input Modeling

The input model for analysis includes the features on reactor trip signal and operation of safety valves together with assumptions.

Standard review pan [3] require reactor trip by second safety class trip signal. Therefore, pressurizer high pressure trip signal generated in reactor protection system was neglected and secondary pressurizer high pressure trip signal generated in core protection calculation system was applied to this analysis. And then the value of the trip set point includes uncertainties.

According to final safety analysis report (FSAR) and technical specification (TS), the allowance of the opening pressure of POSRV and MSSV is 1.5% and 3% and additive uncertainty maintain lower than 0.5% and 1% respectively. [2] And popping pressure is higher than the opening set pressure up to 10 psia because the opening set pressure for MSSV of SK34 means the initial audible discharge according to the suggested definition of opening set pressure. Those were considered in the input model because the factors could increase the peak value of RCS pressure.

Other considerations in input model were the immediate closing or turbine stop valve and feedwater isolation valve at the initiating event, modeling of structure and pipe adjacent to coolant and steam with heat capacity, segmentation of main steam header and connecting pipes for pressure or density wave transfer.

3. Results and Discussions

The calculations about overpressure transients were performed using the standard input model of SK34 for MARS-KS. [4] At each calculation, after initial condition was obtained by steady state calculation, overpressure transient was calculated initiating loss of turbine load. And the effect of parameters on overpressure was investigated from sensitivity study on some parameters

3.1 Steady State Calculation

In general, major initial parameters to affect overpressure in RCS are pressure and level of water in pressurizer. Thus, steady state calculations were performed under some selected conditions from 2175 psia to 2325 psia as pressurizer pressure and from 21% to 60% as pressurizer level. The range of pressurizer pressure and level is based on technical specifications of SK34 and measurement uncertainty.

Table I: Comparison of steady state result with FSAR

Operating Parameter	SK34 FSAR	This Study (100% power)
Primary System		
Power	4000 MW	4000 MW
Pzr pressure	2250 psia	2250 psia
Pzr Level	8.24 m	8.31 m
Temperature(HL)	324 ^{o}C	326.75 ^{o}C
Temperature(CL)	291 ^{o}C	295.24 ^{o}C
Coolant Flow	10500 kg/s	10494 kg/s
Secondary System		
S/G Pressure	1000 psia	1006.4 psia
Steam Flow	1130 kg/s	1136.5
Heat Transfer		
Primary to tubes	4000 MW	4008.2 MW
Tubes to Secondary	4000 MW	4007.5 MW
RCP heat	17 MW	14.582

Table 1 shows the comparison of a result of steady state calculation with FSAR of SK34 at normal operating condition, at which pressurizer pressure is 2250 psia and pressurizer level is 50%. In this table, it is confirmed that the values of operating parameters from steady state calculation have similar to design values presented in FSAR.

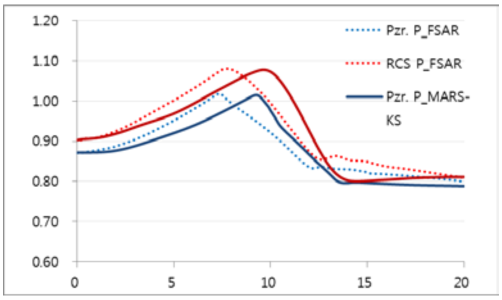
3.2 Transient Calculation

To investigate most conservative initial condition, transient calculations were performed at various initial conditions. Table II shows the RCS and SG peak pressures at various initial conditions and the maximum RCS peak pressure presents at the 2175 psia and 43%. This condition is similar to description in Reference 2. It is also confirmed from Table II that RCS and SG peak pressure is maintained lower than 110% of design pressure. Therefore, performance for overpressure protection will be satisfactory.

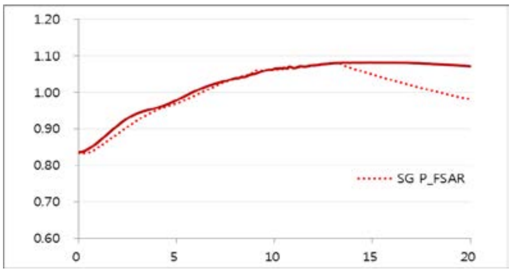
Table II: RCS and SG peak pressure at various initial conditions

Initial Pzr. Pressure [psia]	Initial Pzr. Level [%]	RCS Peak Pressure [%]	SG Peak Pressure [%]
2171.7	21.1	106.3	108.8
2170.9	31.5	106.7	108.7
2170.9	37.4	105.6	108.4
2171.8	43.1	106.8	108.1
2171.6	49.0	105.9	107.7
2171.6	63.9	106.7	106.7
2197.0	30.9	106.3	108.1
2196.9	42.7	106.4	107.5
2196.7	53.9	106.5	106.9
2243.9	30.0	106.0	107.1
2243.8	41.8	106.0	106.9
2244.0	53.1	105.9	106.7
2293.7	29.3	104.2	106.6
2293.6	41.1	104.2	106.3
2293.7	52.5	104.3	106.1

In fig. 2, the trends of RCS and SG pressure were compared to those in reference 2. Major difference is pressurization rate between two results. The lower pressurization rate in this study may be due to the difference in heat capacity of structures adjacent to fluid, heat transfer model in steam generator and etc. and further study will be needed to find out definite causes for difference.



(a) RCP discharge pressure



(b) Main steam line pressure

Fig. 2 Variation of pressure with time (a) RCP discharge pressure (b) Main steam line pressure

3.3 Sensitivity Analysis

If specific parameters are omitted or discussed deficiently in design process or changed unexpectedly during operation and maintenance, that could be affect the performance of overpressure protection. The following parameters or factors are considered in the sensitivity study.

- Loss of offsite power
- Definition of MSSV set pressure (POP & IAD)
- POSRV dead time (0.2s, 0.6s)

Table III: Variation of RCS peak pressure

	Variation of RCS Peak Pressure [psia]
Loss of offsite power	20.22
POP-type MSSV	-1.80
POSRV 0.4s dead time	5.15
POSRV 0.6s dead time	19.65

Table III shows the variation of RCS pressure peak pressure through sensitivity study. Loss of offsite power is important factor to overpressure protection as shown in this table. Trip and coastdown of reactor coolant pump lead to the reduction of heat transfer rate in steam generator. And then, accumulated heat increases the pressurization rate in primary side after reactor trip. And MSSV type and capacity also are considerable parameters. POSRV dead time shows a minor influence. However, if time of reactor trip is prior to that of MSSV opening relatively, POSRV dead time could be more significant.

3. Conclusions

In this study, we evaluated the performance of SK34 for overpressure transient with conservative conditions. From calculation results, RCS and SG peak pressure is maintained lower than 110% of design pressure under conservative conditions. Therefore, performance for overpressure protection of RCS in SK34 will be satisfactory. And we also identify significant parameters or factors in overpressure transient analysis with sensitivity study. It was confirmed that loss of offsite power could be effective to overpressure significantly and MSSV and POSRV should also be modelled appropriately in overpressure transient analysis.

REFERENCES

[1] KEPIC MN series, 2000
[2] SKR34 Final Safety Analysis Report (rev.01), KHNP, 2014
[3] Standard Review Plan, U. S. NRC,
[4] MARS-KS Manual