Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Risk Impacts of Pressurizer Safety Valve Reseat Failure

Hae Cheol Oh, Myung Ki Kim, Bag Soon Chung, Miro Seo, Jeong Heon Ha, Sung Yull Hong
Korean Electric Power Research Institute., 103-16.,Moonjidong., Yusung-Gu., Daejeon, haech@kepri.re.kr

1. Introduction

In an effort to develop probabilistic safety assessments (PSAs) that are as realistic as possible, component failure rates are traditionally based on a combination of experience, component testing, and expert judgment. During various accident sequences modeled in the PSA, the pressurizer safety valves (PSVs) of a pressurized water reactor (PWR) may cycle numerous times. The PSVs will initially relieve steam. In some longer duration accident sequences, the steam relief will eventually become liquid relief. With each cycle of the PSV, there is a probability that the safety valve will fail to reseat. The PSV failure-to-reseat results in the need for additional mitigative systems to prevent core damage. This paper describes a quantitative assessment to identify risk impacts of the failure probability due to the repeated cycling operation of PSVs (pressurizer safety valves) under severe accidents.

2. Risk impacts of PSV reseat failure

2.1 PSV re-seat failure data

Most current PSAs for the KSNP plants use a probability value of 1.5E-2 for the pressurizer safety valve failure-to-reseat [1]. The data used in these PSA is the probability of failure to re-seat per demand based on the EPRI URD[2]. No mention was made of how many demands on a PSV are made during a severe accident, nor was any distinction made on whether or not water was being discharged.

Several test series (EPRI 1982, and Dresser, 1996) were carried out in order to assess pressurizer safety valve performance. The tests include steam tests and water tests of PSVs. Analysis of the test results for PSVs suggests probabilities of failure to reseat after passing steam of 2.7E-2 per lift, and 1.1E-1 per lift after passing liquid[3].

In order to estimate the likelihood of failure using these data, it is necessary to determine the number of demands (valve lifts) during the severe accident. MAAP code can be used to identify PSV lifts that lead to water or two-phase flow. As mentioned above, PSV failure probability increases significantly when sub-cooled water flowing in to the valve. Once the number of valve lifts, the type of fluid being passed in a given lift, and the failure probabilities of failure to re-seat per demand are known, revised estimates of valve failure probability can be made. Then, revised values for risk impacts can be obtained.

The conditional probability of PSV stuck open is determined as follows;

$P_{fail,PSV} = 1 - P_{success} = 1 - (P_{s,steam})(P_{s,water})$
$= 1 - [1 - (f_{steam})^{n\_steam}] [1 - (f_{water})^{n\_water}]$

where, $P_{s,steam}$ and $P_{s,water}$ are the probabilities that the PSV would re-seat successfully after being challenged by steam or water, n_steam and n_water are the numbers of steam and water challenges to the PSV and f_{steam} and f_{water} are the failure probabilities per demand, respectively.

The results of MAAP code run for the postulated SBO accident are shown figure 1 and figure 2 [3]. There are 9 stem lifts and 8 water/two phase lifts. These values are obtained from figure 2. The revised PSV reseat failure probability is 0.69 and this is obtained from the above equation, the number of lifts from the MAAP code results for the repeated cycling operation ,and PSV test results for the steam and water.

2.2 Initiating events related to the PSV fail- to- reseat

In order to identify the risk impacts of the PSV failure data due to the repeated cycling operation, the application status of PSV fail to reseat event in the KSNP PSA model like Ulchin 5,6 PSA was examined. The initiating events related to the PSV reseat failure were identified as the SBO and ATWS events.

2.2.1 SBO initiating event

If the AFW TDP fails to start and deliver feedwater to the steam generator following SBO (Station Blackout) event, secondary steam removal through MSSVs or ADVs will continue until the SGs will dry out in about 1 hour. The RCS pressure and temperature will increase due to loss of RCS heat removal. When the RCS pressure reaches the PSV set-point, RCS inventory will be lost through the PSV repeated cycling operation.. The core will eventually be uncovered. The probability of this sequence was estimated as the below of cut-off value. Therefore, this sequence tree was not developed in detail in the KSNP PSA models.

2.2.2 ATWS initiating event

ATWS (Anticipated Transient Without Scram) event is the only initiating event which involves the heading of PSV reseat failure.

The ATWS is potentially a severe event in which the RCS goes through a pressure excursion due to an imbalance between the core heat generation and RCS heat removal. If the pressurizer safety valves that lifted to relieve pressure in the pressure peak during the early stage of the transient do not reseat, a medium LOCA occurs. The accident progression after failure of the PSV to reseat is similar to the medium LOCA progression. PSV reseat failure heading is shown in figure 3. The frequencies of the ATWS- 31, 32 and 33 sequences in figure 3 were directly proportional to the PSV reseat failure probability.

2.3 Risk impacts of PSV reseat failure data

The risk assessment for the PSV reseat failure was performed. When 0.69 was applied as the PSV reseat failure data instead of 1.5E-2/demand, the mean core damage frequency was increased from the 7.27E-6 per reactor year to 7.30E-6 per reactor year. It is about 0.4 % increase. Results of a sensitivity study show only small increments in risk impact even though the probability of PSV fail to re-seat is increased as the order of magnitude, considering the repeated cycling operation. The principal reason for this is that the contribution of sequences PSV re-seat failure for overall core damage frequency is very low.

In the view point of the LERF , Failure of a PSV to re-seat results in risk reduction, because much of the fission product inventory flows to the containment building. Moreover, the likelihood of tube rupture following the high pressure transient events such as ATWS and SBO is reduced because the reactor coolant system (RCS) temperature and pressure are reduced.

3. Conclusions

The assessment of risk impact caused by the probability change of PSV re-seat failure was performed. It is identified the PSV reseat failure probability is increased if the repeated cycling operation is considered as realistic as possible. Nevertheless, the overall risk impact due to the PSV reseat failure was negligible.

REFERENCES

[1]Ulchin Unit 5&6 PSA Report, June, 2002

[2]EPRI ALWR URD vol II, "PRA Key Assumptions and Ground Rules" 1995

[3]EPRI TR-106194 "Risks from Severe Accidents Involving Steam Generator Tube Leaks or Ruptures", October, 1997

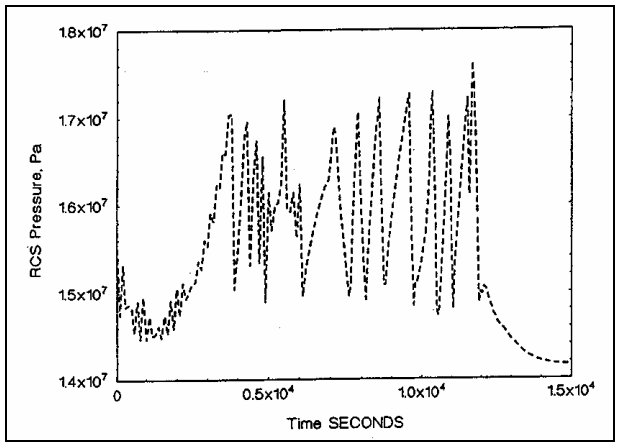

Figure 1. RCS pressure during SBO accidents

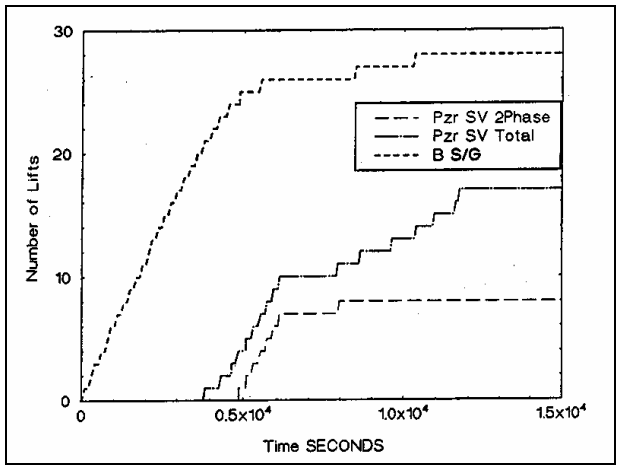

Figure 2. PSV lifts during SBO accidents

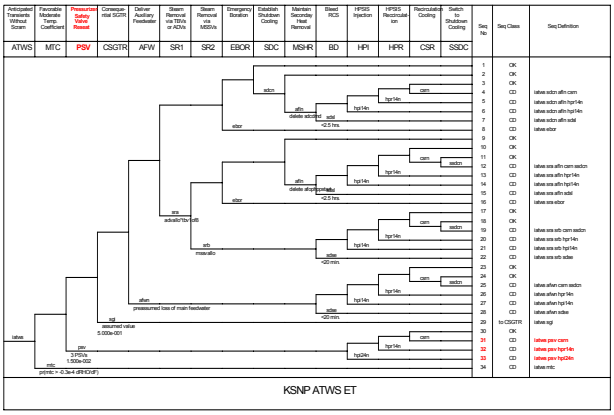

Figure 3. ATWS Event Tree in the KSNP PSA