Comparison of the LDLB Event Analyses by using the MEDUSA and CESEC-III Codes

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1. Introduction

MEDUSA, which is being developed by Korea Power Engineering Company (KOPEC) as a system code, is applied to the analysis of Letdown Line Break (LDLB) event for UCN 3&4 plants. The MEDUSA computer code solves the compressible three dimensional, two-fluid, three-field equations for two-phase flow. The three fields represent the vapor field, the continuous liquid field, and the liquid drop field, respectively. The conservation equations for each of the three fields are solved using a semi-implicit finite-difference numerical technique. MEDUSA permits the user to nodalize a wide variety of geometries encountered in nuclear reactor system, using the concept of section, channel, and gap[1-3]. The results are then compared with those calculated by CESEC-III, a licensing analysis code used for Optimized Power Reactor 1000(OPR1000).

The comparative simulation is performed as an effort to verify MEDUSA as a system analysis code to predict the thermal hydraulic response accompanied by the transient event, and also to check its modeling capability of the components such as pressurizer heaters, charging pumps, Regenerative Heat Exchanger(RHX), *etc*.

2. Analysis Methodology and Results

2.1 Description on LDLB event

The double-ended break of the letdown line outside containment, upstream of the letdown line control valve was assumed as Letdown Line Break(LDLB) event because it is the largest line and results in the largest release of reactor coolant outside the containment.

LDLB event cause a decrease in Reactor Coolant System (RCS) inventory and pressure. When in the automatic mode, the Pressurizer Pressure Control System (PPCS) and Pressurizer Level Control System (PLCS) respond to decrease of pressurizer pressure and level by actuating pressurizer backup heaters and charging pumps respectively. The LDLB event causes a reactor trip on low pressurizer pressure, and Letdown Isolation Valves(LIVs) are closed automatically, thereby terminating any further release of primary fluid outside the containment, subsequently, High Pressure Safety Injection(HPSI) is actuated at about 30 seconds after reactor trip.

2.2 Initial conditions and major assumptions

For the comparison purpose, the same initial conditions are applied for both the MEDUSA and CESEC-III analyses. Initial core power is 2815 MWt. The initial letdown and charging flow, pressurizer pressure, pressurizer level, reactor coolant flow rate, and steam generator level are at full power steady state condition. The setpoint of low pressurizer pressure reactor trip is assumed to be 1762 psia. The break is assumed to be the full cross-sectional area(double-ended) pipe break, size of 2.24 in^2, and all control systems are assumed to be in the automatic mode to maximize the total primary mass release through the break.

2.3 Results

Figure 1 shows the comparison between pressurizer pressure predicted by MEDUSA and CESEC-III.

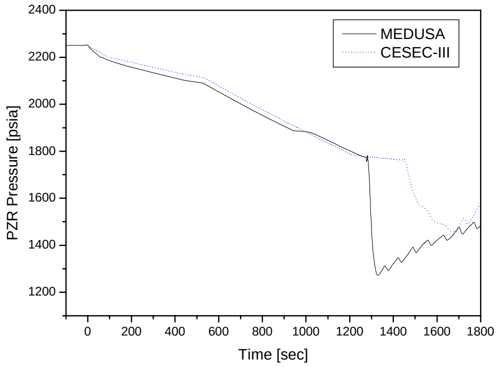

Figure 1. Pressurizer pressure

The LDLB event decreases pressurizer pressure to the pressurizer backup heater actuation setpoint. At around 65 seconds, when the backup heater is turned on, the decreasing rate of pressrurizer pressure is abruptly reduced. Then the pressure decreasing rate is maintained at the reduced level, until the pressurizer backup heater is turned off for the protection of itself at around 530 seconds, when pressurizer level reaches the level setpoint corresponding to volume of 404 ft^3, which results in a rapid decrease in pressurizer pressure again. As shown in the figure, overall trend of pressurure pressure predicted by MEDUSA is very similar to the CESEC-III analysis results before the reactor trip. However the reactor trip times are different. In the CESEC-III analysis, reactor trip occurred at around 1450 seconds due to the pressurizer low pressure. On the other hand, in the MEDUSA analysis, reactor trip occurred at around 1280 seconds, at which pressure drastically drops to around 1300 psia. Then the pressure gradually increases again due to safety injection.

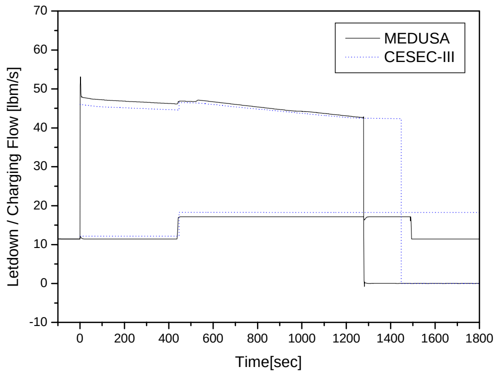

Figure 2. Letdown / Charging flow

Figure 2 shows the variation of letdown and charging flow rate. The LDLB event decreases pressurizer pressure and level, and actuates the third RHX charging pump by pressurizer low level setpoint at around 450 seconds. The abrupt increase of charging flow rate at that time is due to the additional charging pump actuation. From that time on, the heat transfer through RHX is enhanced by the increased charging flow rate. Consequently, letdown flow, which is limited by the critical flow rate at the break, is slightly increased due to the reduced enthalpy at the exit of RHX. Then the letdown flow rate is gradually decreases until letdown isolation, since the event continues to decrease the coolant enthalpy and pressure. LIVs are closed, after the safety injection actuation signal occurs at around 1280 seconds. After safety injection, the pressurizer water volume is recovered, as shown in Figure 3, and the third RHX charging pump is turned off at around 1500 seconds. Overall trend of critical flow through the break and charging flow is very similar to those predicted by CESEC-III, except the reactor trip time.

The variation of other major thermal hydraulic parameters such as primary temperature, secondary pressure, and steam generator steam flow show good agreement between CESEC-III and MEDUSA analyses.

3. Conclusion

A comparative LDLB simulation is performed for OPR1000(UCN 3 and 4), using the MEDUSA and CESEC-III codes. The transient analysis results from the MEDUSA show good agreement with those predicted by the CESEC-III code, except the reactor trip time, which seems due to conservatism involved in CESEC-III.

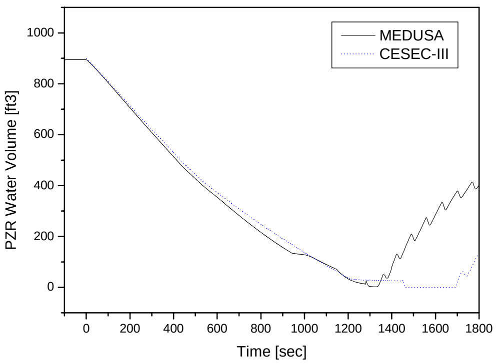

Figure 3. Pressurizer water volume

Based on this, it can be concluded that MEDUSA is applicable to the analysis of thermal hydraulic response to LDLB accident. Moreover, the MEDUSA code is expected to be useful to find additional safety margin, with more realistic simulation of two phase flow and relevant phenomena.

REFERENCES

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