RETRAN Model of SBLOCA Benchmark

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(Comparison with WFLASH)

SONGS 1

NMNan 3/24/58 Approval

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1. ABSTRACT

The current Safety Injection System at SONGS 1 depends on the operation of a number of hydraulically actuated valves. It is of interest to improve this system and increase its reliability. The RETRAN model of SONGS 1 was chosen to simulate a Small Break LOCA (SBLOCA) to evaluate the upgraded Safety Injection (SI) system. This model needed to be validated prior to the evaluation of the upgraded system. This report describes the validation effort.

The RETRAN base model of SONGS 1 has been modified to simulate a SBLOCA for the existing SI system. The RETRAN model was benchmarked by comparing its results with Westinghouse's results for the SBLOCA simulation performed with the WFLASH code. The break sizes considered were: 3, 4, and 6 inch diameter breaks at the cold leg nozzle of Loop B. In each case the transient was simulated beyond the time of the clearing loop seal and core uncovery/recovery. RETRAN results were in excellent agreement with those of WFLASH (1) for the same break sizes. The evaluation of the upgraded SI system is discussed in a separate document (2).

2. INTRODUCTION

The Safety Injection System at SONGS 1 is different from most other PWR's, since it uses the Feedwater pumps. Upon receiving a Safety Injection Signal (SIS), the feedwater pumps are realigned to take suction from the SI pumps and discharge to the RCS. This involves automatic action of several hydraulically actuated valves. It is of interest to improve the SI system and reduce its reliance on the operation of these valves. Several upgrade options were considered and needed evaluation. The RETRAN model of SONGS 1 was chosen to evaluate one of the upgrade options for the system response during a SBLOCA. However, before this evaluation is conducted, the RETRAN base model of SONGS 1 was modified and the detailed geometry of the loop seals were included in the model, and a RETRAN model of SONGS 1 for SBLOCA was developed. This model was then validated in the following manner. The currently existing SI system was included in THE RETRAN model and break sizes of 3, 4, and 6 inches were simulated. RETRAN simulation of SBLOCA for these break sizes was compared with the results of the WFLASH simulation performed by Westinghouse (1) for the same break sizes. The evaluation of the SI upgrade is discussed in Reference 2.

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3. RETRAN MODEL

The RETRAN model of SONGS 1 used to simulate a cold leg SBLOCA consists of 48 control volumes and 78 junctions. Figure 1 shows a nodal diagram of the model. Primary loops A and C are combined into an equivalent loop (right), and loop B with the cold leg break is modeled as a separate loop. The detailed geometry and the elevations of the loop seal including the lower elevation crossover leg was included in the model, since the loop seal clearing process was of interest in this analysis. Figure (2) shows the loop seal. Table 1 states the steady state initial conditions and the important assumptions made in this simulation. The break sizes of 3, 4, and 6 inches cause voiding of large sections of the primary system. The loop flow becomes stagnant, and many volumes such as the reactor vessel upperhead and the pressurizer become completely voided of liquid. A bubble rise model was extensively used in the primary system to represent voiding of a large section of RCS under fairly stagnant flow conditions. Volumes were overlapped to allow mixture level crossing the boundaries without causing numerical instability. A detailed model of the steam generator including steam separator and recirculation was used to accurately represent the distribution of coolant in the secondary system. The safety injection flow is based on the assumption that one SI train is functioning with one line injecting, one line spilling and one line blocked. Figure (3) shows the SI flow vs RCS pressure.

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This is the same SI flow model used in WFLASH. The upperhead is conservatively assumed to be initially at the same temperature as the upper plenum. A pressurizer non equilibrium model is used in this analysis. Control systems such as pressurizer pressure and level, and steam dump/bypass controls are assumed to be inoperable. The reactor is assumed to trip on the low pressurizer pressure SIS of 1750 PSIA with a one second delay. The turbine, feedwater pumps, and reactor coolant pumps are also assumed to trip on the same signal. Safety injection flow is assumed to reach the RCS 20 seconds after SI actuation. Steam safety valves are assumed operable. The auxiliary feedwater system is assumed to be manually turned on with a 10 minute delay.

Table 1

Assumptions and Initial Conditions for RETRAN model

- 1. Initial power: 100% (1347 MW_t)
- 2. Break occurs at the cold leg nozzle, loop B cold leg, discharge side of the pump.
- 3. Reactor trip on low pressure SI of 1750 psia with one second delay.
- 4. RCP's trip on SIS with 1 second delay (quick trip).
- 5. Turbine trip on reactor trip signal.
- 6. Feedwater trip on SIS.
- 7. Auxiliary feedwater is manually actuated with 10 minutes delay.
- 8. Pressurizer level, hot leg and cold leg temperatures were chosen to match those used in WFLASH. (See Figures.)
- 9. Extended Henrey Fauske critical flow model was used for subcooled break flow, with a discharge coefficient of 1.
- 10. Moody's critical flow model was used for saturated break flow with a discharge coefficient of 1.
- 11. All control systems, especially the steam dump/bypass control system are inoperable.
- 12. SI flow enters RCS with 20 second delay after SIS actuation.
- 13. One SI train is operating with one line injecting, one line spilling, and one line blocked.

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4. RESULTS

Three cold leg break sizes were simulated by RETRAN, and important parameters were compared with WFLASH results given in Reference (1). The RETRAN results for the six inch break is compared in detail with WFLASH. Figures 4 through 16 provide the results for the 6 inch break. Results show excellent agreement between RETRAN and WFLASH. Figures 17 to 21 provide the results for a 4 inch cold leg break, and Figures 22 to 26 are for the 3 inch break. In the cases of 4 inch and 3 inch breaks, RETRAN results are slightly more conservative since they indicate an earlier and deeper core uncovery. A sensitivity analysis was performed to determine the reason for the difference between RETRAN and WFLASH results. It was determined that the critical flow correlations used in WFLASH were different from that of RETRAN, and that this difference made RETRAN results slightly more conservative. The RETRAN simulation of SBLOCA for all three break sizes was continued beyond the loop seal clearing, core uncovery, core recovery, and beyond the point in time where SI flow exceeded the mass flow rate through the break.

5. CONCLUSION

The RETRAN model of the SONGS 1 SBLOCA was verified by comparing its results to the results of the SBLOCA simulation performed by Westinghouse for SONGS 1 using the WFLASH code. The break sizes of 6, 4, and 3 inches diameter were simulated. Break location was at the cold leg nozzle of Loop B. The results of RETRAN were in excellent agreement with those of WFLASH. Where results were slightly different, RETRAN results were more conservative since they predicted slightly earlier and deeper core uncovery. A sensitivity analysis was performed and it was determined that the reason for the small differences in RETRAN and WFLASH results was due to the difference in break flow models used in the two codes.

It is concluded that the RETRAN model of the SONGS 1 SBLOCA is successfully benchmarked against the WFLASH code for the range of breaksizes of interest, and can simulate a cold leg SBLOCA with acceptable accuracy.

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6. REFERENCES

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- Evaluation of An Improved Safety Injection System, Using RETRAN-02/MOD 4, SONGS 1, 1-T/H-88-03, M. Motamed

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FIGURES



SONGS 1 RETRAN Nodal Diagram



RCS PRESSURE (PSIA)



Plots for 6 Inch Cold Leg Break

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Figure 6 SONGS1 SBLOCA 6 INCH BREAK PRESSURIZER LEVEL

































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Figure 12 SONGS 1 SBLOCA EXISTING SL SYSTEM 6 INCH BREAK BREAK MASS FLOW RATE





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FIGURE 13 SONGS 1 SBLOCA EXISTING SI-SYSTEM 6 INCH BREAK SI MASS FLOW RATE 1000 MASS FLOW RATE (LBM/SEC) 800 600 400 200 0 0 20 40 60 80 100 120 140 160 180 200 TIME (SEC)

RETRAN

SCE SMALL BREAK ANALYSIS SIT INCH BREAK SAFETY INJECTION MASS FLOWRATE (LU/SEC) 1001.0 900.00 800.00 /00.00 600.00 500.00 400.00 No.00 200.00 · 100.00 0.0 8.90 80.00 8.93 8.00 80.00 90.00X 200.00 100.00 0.0 TIME (SEC)

WFLASH

1.07565

fLOWBATE

MA55

14JE C110%



MASS FLOW RAIE (LEM/SEC)

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FIGURE 15

SONGS1 SBLOCA 6 INCH BREAK COLD LEG TEMPERATURE



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Figure 16 SONGS1 SBLOCA 6 INCH BREAK HOT LEG TEMPERATURE



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Plots for 4 Inch Cold Leg Break



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Plots for 3 Inch Cold Leg Break

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APPENDIX B

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