Audit Calculations of ATWS for Ulchin Unit 1&2 Power Uprate

Jun Soo Lee*, Byung Gil Huh, Yong Seog Choi, Kwang-Won Seul
Korea Institute of Nuclear Safety, 19 Gusong, Yuseong, Daejeon 305-338
K720ljs@kins.re.kr

1. Introduction

An anticipated transient accompanied by a failure in the Reactor Trip System (RTS) to shut down the reactor is defined as an Anticipated Transient Without Scram (ATWS). Under certain postulated conditions, the ATWS could lead to Reactor Coolant system (RCS) pressure boundary fracture and/or core damage. For a conventional pressurized water reactor (PWR), the temperature corresponding to the NSSC notice No.2013.09(Performance Criteria for ECCS of the Pressurized Water Reactor Nuclear Power Plants), 1204℃ and the pressure corresponding to the ASME Boiler and Pressure Vessel Code service level C stress, 221.5 bar is assumed to be an unacceptable plant condition against ATWS, above which the RCS pressure boundary could deform to the point of inoperability and the safe shutdown by injection of borated water could be challenged. Such potentially excessive RCS overpressure may occur in the ATWS initiated from a loss of heat sink.

Currently, the modification of Ulchin 1&2 operating license for 4.5% power uprate is under review [1]. In this study, the regulatory audit calculation for ATWS of Ulchin Unit 1&2 with 4.5% power uprate was performed to support the licensing review and to confirm the validity of licensee's calculation. In order to simulate the transient behavior of ATWS initiated by a loss of feed water, the systems of Ulchin Unit 1&2 was modeled with MARS-KS 1.3.

2. Modeling of Ulchin Unit 1&2

A thermal hydraulic analysis code, MARS-KS 1.3 was used to model the primary and secondary systems of Ulchin 1&2 (twin plants with the same design and geometry). The primary and secondary systems in the code input deck consist of hydrodynamic volumes including branch, annulus, and pipe, junctions, and heat structures. Steam generators were nodalized as 18 nodes, because thermal-hydraulic behavior in steam generators played a big role in the ATWS calculation. Ulchin 1&2 have a unique feature for pressure relief; three Pilot-Operated Safety Relief Valves (POSRV), and steam dump capacity (85 percent of rated turbine flow) much larger than other three-loop plants (70 percent of rated turbine flow). The various component models and the instrumentation actuation logic and setpoints are also utilized to simulate the transient behavior of the systems. In the neutron kinetics equation of MARS-KS 1.3, the moderator density coefficient is used instead of MTC. The density coefficient is easily derived from the temperature coefficient by using known reactor coolant system parameters. It is a strong function of boron concentration and somewhat weaker function of power level. Fig.1. shows the MARS modeling for Ulchin 1&2 ATWS.

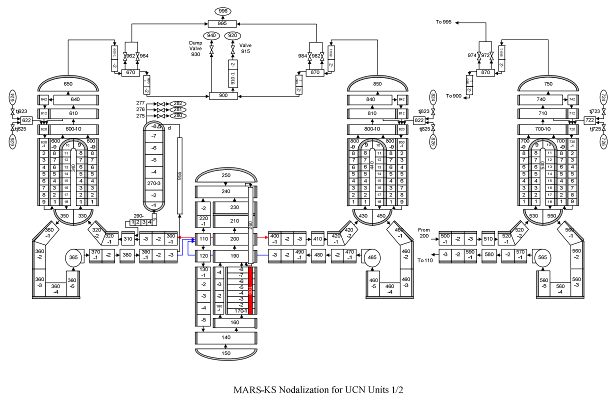

Fig.1. MARS Nodalization for Ulchin 1&2 ATWS

3. Analysis Results

A complete loss of main feedwater event, followed by a failure of reactor trip, was assumed to occur during full power operation at the time of 99% MTC in Ulchin 1&2[2]. Ulchin 1&2 AMS is actuated by SG Lo-Lo level signal with 15% NR in coincidence with a signal of low feedwater flow. Table 1 shows the basic assumptions made for the analysis.

Table.1. Basic assumption of the Ulchin 1&2 ATWS

- Initial normal full power operating early in core life
- No credit for automatic reactor trip
- No credit for automatic control rod insertion as reactor coolant temperature rises
- No credit for short and long-term operator action.\
- Full flow of Auxiliary Feed Water
- 10 % steam generator tube plugging.
- Three POSRV operable
- AMS signal generated by SG Lo-Lo level signal with 15% NR in coincidence with a signal of low feedwater flow
- Turbine trip and auxiliary feedwater actuation at 3.5 seconds and 32.5 seconds after AMS initiation respectively.

Fig.2., Fig.3. and Fig.4. show the calculated reactor coolant system temperature, pressurizer level and reactor core power, respectively. As shown in these figure, for ~ 20 sec, RCS temperature of the after SPU case increased steeply and it affected the volume of the RCS inventory, so pressurizer level increased. While RCS temperature increased, reactor core power decreased steeply by insertion of the negative reactivity. For ~240 sec, reactor core power decreased below 15%, so RCS temperature and pressurizer level started to decrease. As shown in these graphs, calculated results followed the general ATWS analysis results. For before SPU case, RCS temperature, pressurizer level and reactor core power changed by same trend.

Fig.5. shows the calculated pressure of the pressurizer for two cases, before and after power uprating. As shown in this figure, for ~ 20 sec, pressure of the after SPU case started to increase steeply and for ~ 240 sec, it reached the peak pressure(200.4 bar). And for initial ~ 40 sec, pressure of the before SPU case increased by same trend and it reached the peak pressure(184.8 bar). Pressurizer pressure due to power uprating increased by 15.5 bar, but it was still sufficiently low than the limit Pressure (221.5bar).

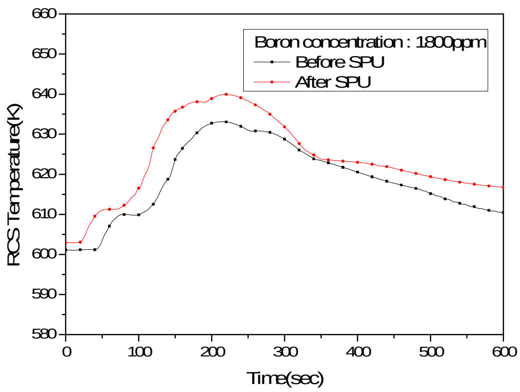

Fig.2. Reactor Coolant System Temperature

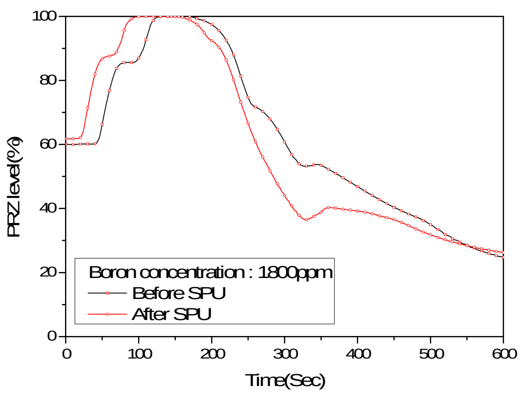

Fig.3. Pressurizer level

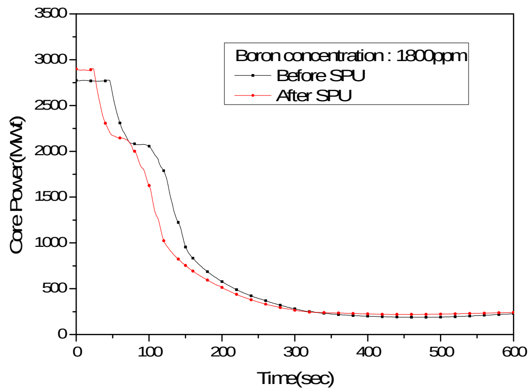

Fig.4. Reactor Core Power

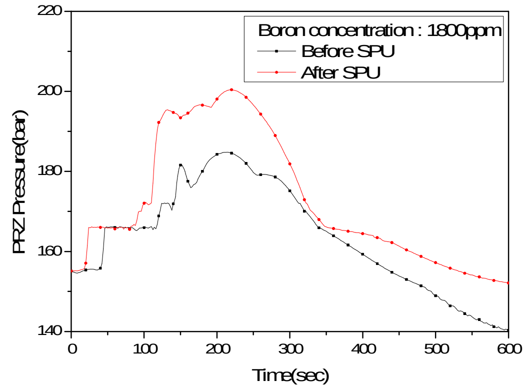

Fig.5. Pressurizer Pressure

3. Conclusions

In this study, the regulatory audit calculation of ATWS for Ulchin 1&2 with 4.5% power uprating and 99% MTC in the specific cycle designs was performed. It is conformed that the analysis results of ATWS for Ulchin 1&2 power uprate meets the RCS pressure acceptance criteria.

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