Analysis of SBLOCA with SI Fail using GPWR and review of the possibility of using GPWR

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1. Introduction

Recently, the nuclear industry has been actively conducting research to utilize the 4th industrial revolution technologies such as artificial intelligence and big data. These researches require diverse and a large amount of nuclear power plant operation data. However, utilizing actual power plant operation data is limited in terms of security. To compensate for these weaknesses, it is necessary to produce data and develop scenarios using simulators. Therefore, this study analyzed the differences between the APR1400 reactor type and the Generic PWR (GPWR) simulator and examined the similarity of the power plant behavior according to the progress of the SBLOCA with SI Fail accident. Based on the results, the possibility of utilizing GPWR in terms of applying the 4th Industrial Revolution technology was derived.

2. Methods and Results

2.1 GPWR Model

All domestic simulators of the APR1400 model were developed with WSC's 3KeyMaster tool. The GPWR used in this study is a generic model for PWRs developed by WSC with the 3KeyMaster tool, and the main parameters of the GPWR and APR1400 are shown in Table 1. As shown in Table 1, the main primary parameters such as core power and average temperature are very similar between the APR1400 and GPWR. However, there are some differences that are unique to the APR1400 design, such as the Direct Vessel Injection and In-containment Refueling Water Storage Tank. Fig. 1 provides an overview of the GPWR model.

2.2 Analysis scenarios and Assumptions

Using GPWR, the SBLOCA with SI FAIL scenario was performed during the analysis of multiple failure accidents, which is one of the main issues in the accident management plan, and the accident mitigation was examined by assuming the same operator actions as the APR1400 type. The analysis scenarios performed in this study are shown in Table 2, assuming operator actions such as stopping the RCP and opening the MSADV.

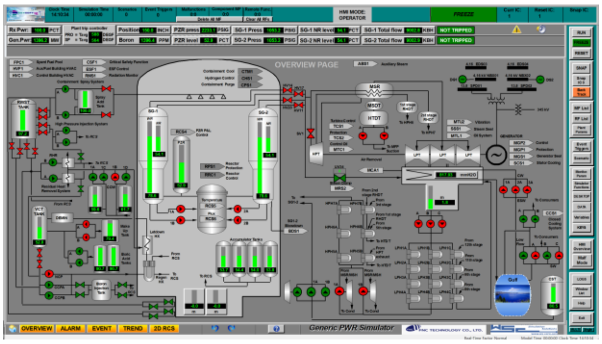

Fig. 1 GPWR Overview

Table 1. GPWR and APR1400 Specifications

RCS	GPWR	APR1400
Configuration	2 loops, 4 Reactor Coolant Pumps, 2 Steam Generators	2 loops, 4 Reactor Coolant Pumps, 2 Steam Generators
Reactor core power	3983 MWt	3983 MWt
Pressurizer pressure	158.2kg/cm2 (2250 psia)	158.2kg/cm2 (2250 psia)
Hot leg temperature	325°C (617°F)	324°C (615°F)
Coolant inlet temperature	292.6°C (558.8°F)	291°C (555°F)
Average temperature rise in vessel	32.4°C (58.2°F)	34°C (62°F)
Average temperature in vessel	309.2°C (588.5°F)	308°C (586°F)

Table 2. Analysis scenarios and sequence

Time(s)	Event
0.0	2” break in cold leg
201.0	Reactor trip Turbine trip
209.0	SIAS (Assuming complete loss of safety injection)
304.0	Pressurizer depletion
801.0	RCP Shutdown (Assuming 10 minutes after reactor shutdown)
1,800.0	Rapid depressurization Using MSADV (1 MSADV fully open per steam generator)
1,852.0	MSIS
1,966.0	Start SIT Injection
2,092.0	Shutdown cooling entry condition reached

2.3 Analysis Results

RCS rupture flow after the initial 2-inch break, resulting in a decrease in PZR pressure and pressure level. About 200 seconds after the accident, reactor trip and turbine trip occur, and a safety injection signal is generated as the pressurizer pressure decreases. However, based on the assumptions, the safety injection is completely lost and not injected. Pressurizer water level depletes due to continued loss of coolant flow, and all RCPs are tripped by operator action 10 minutes after reactor trip. 30 minutes after the accident, operator opened one MSADV per steam generator to perform rapid depressurization and cooling. As a result, the pressure of the pressurizer and steam generator is reduced, and the level of the steam generator is also reduced due to the release of steam through MSADV. When the primary pressure is reduced below the SIT pressure through rapid depressurization, the SIT begins to be injected. With SIT injection, the RCS is cooled and reaches the shutdown cooling entry condition. Fig. 2 to Fig. 7 shows the trend of analysis results for major parameters.

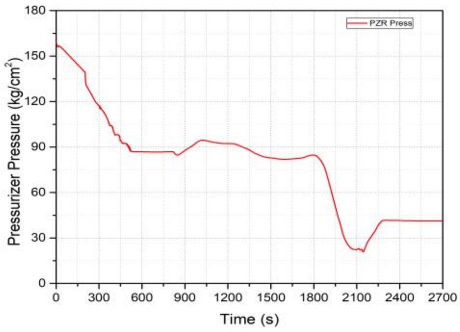

Fig. 2 Pressurizer Pressure

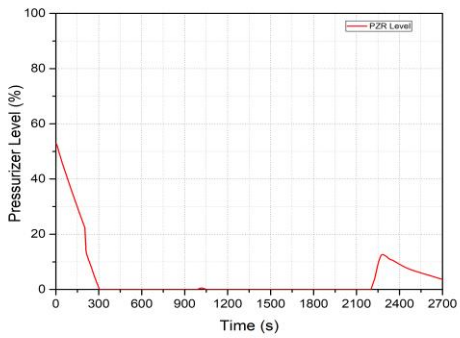

Fig. 3 Pressurizer Level

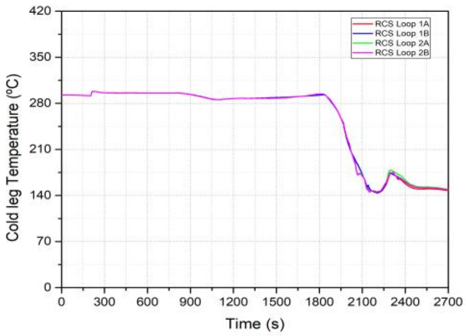

Fig. 4 RCS Cold Leg Temperature

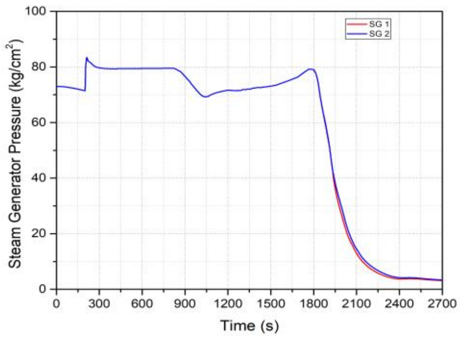

Fig. 5 SG Pressure

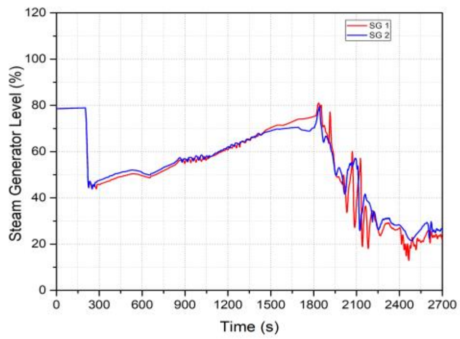

Fig. 6 SG Level

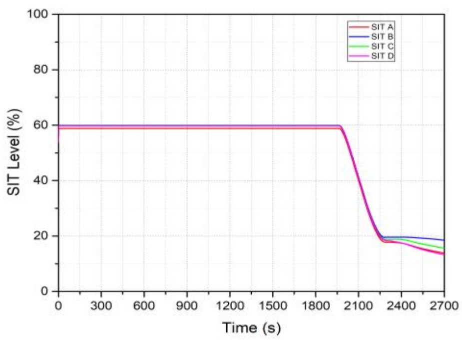

Fig. 7 SIT Level

3. Conclusions

For the SBLOCA with SI FAIL scenario, the analysis was performed assuming the same operator actions as the APR1400. As a result of the analysis, it was confirmed that the entry conditions of the shutdown cooling system were reached through the primary depressurization and cooling according to the operator actions. GPWR has differences according to its own design in terms of systems compared to APR1400, but it has been confirmed that the overall plant behavior is similar. In addition, it was confirmed that the accident mitigation strategy of the APR1400 was also effective in GPWR. Accordingly, in terms of the application of the 4th industrial revolution technology, GPWR is expected to be used in various ways, such as scenario development and confirmation of the validity of operator actions.

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