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Verification of the EOP Diagnostic Rules for the SLOCA Event Using the MARS3.0 Code

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1. Introduction

Emergency operating procedures (EOPs) in nuclear power plants are used to control the plant to a safe and stable condition when an event that requires automatic or manual reactor trip occurs. Before taking recovery actions, the operators have to diagnose the occurred event(s) using the diagnostic rules of the EOP, which is very crucial for a successful management of the event.

In particular, the diagnosis of the occurring event at an early stage of an event progression is more important for a flowchart-based diagnostic procedure such as in the CE-type emergency operating procedures (EOP), which generally guides operators to a recovery procedure on the basis of an initially performed event diagnosis. But, at an early stage of an event progression there may be a variety of plant situations present that cause a diagnostic ambiguity, such as the phenomena of symptom masking or vagueness or the possibility of the symptom recovery to a normal state at the time of an operator's event diagnosis, which arises from the behavioral characteristics of the plant systems' various responses in combination with a specific initiating event.

Thus, a verification study was raised to check the appropriateness of the diagnostic rules of the YGN EOP for the small loss of coolant accident (SLOCA) event. The approach taken for the study is to analyze the dynamic behaviors of the diagnostic parameters during the anticipated period of the operator's diagnosis time using the thermal-hydraulic (T/H) computer code, MARS3.0 [Ref. *], as the break size of the SLOCA event is increased (e.g., 1.1 in., 1.4 in., and 1.9 in.) under a realistic operative status of related plant systems.

2. Thermal-hydraulic Analyses and Results

Thermal-hydraulic analyses are performed using the best estimate thermal-hydraulic analysis code, MARS3.0, in the event of small break loss of coolant accident (SLOCA) at the cold leg of the YGN nuclear power plant. The MARS3.0 nodalization used for the modeling of the Korean standard nuclear power plant is shown in Figure 1.

The SLOCA is assumed to occur at the discharge volume of the RCP in one of the cold leg of loop B in Figure 1. The reactor and turbine trip when the pressure in the pressurizer is lower than 12.828 MPa (1860 psia). One RCP in each loop trips when the pressurizer pressure is lower than 11.866 MPa within 2 minutes after reactor trip. Charging flow is supplied to the cold leg of loop B after the accident. The high pressure safety injection (HPSI) starts when the pressurizer pressure is lower than 12.145 MPa. The HPSI water is supplied to the four cold legs from the refueling water storage tank (RWST) at 50 ^{o}C, and the HPSI fails when water inventory in the RWST is exhausted.

The SG main feed water is isolated after reactor trip, and auxiliary feed water is supplied when SG low level signal is actuated. The SG secondary system is cooled by means of automatic steam dump through the turbine bypass valve. The main steam safety valve is in automatic mode, and the atmospheric dump valve is closed. The containment is assumed to be in constant pressure and temperature throughout the accident.

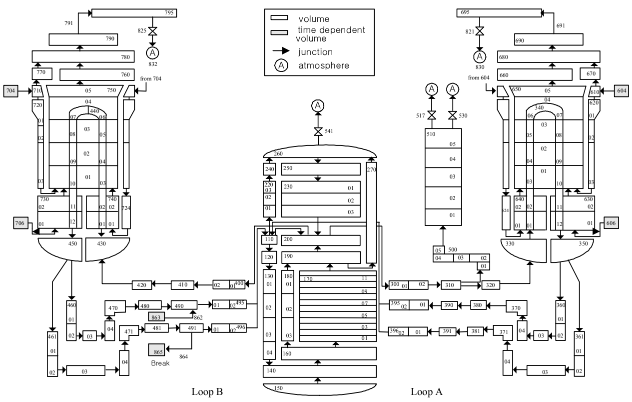

Figure 1. MARS3.0 nodalization for modeling of the YGN plant

Figure 2 and Figure 3 show the results of the thermal-hydraulic code analysis for the RCS sub-cooled margin and the SG pressure, under the break sizes of 1.1, 1.4 and 1.9 inches at the cold leg (CL), respectively. According to the results, for the break size of CL 1.1 inches, the RCS sub-cooled margin is maintained above 15 ^{o}C for the whole diagnosis time after a reactor trip. For the break size of CL 1.4 inches, the margin is in an increasing trend and arrives at 15 ^{o}C at around 600 seconds. Finally, for the break size of CL 1.9 inches, the trend is also in an increasing mode even though the value is lower than 15 ^{o}C. If we apply the rule literally, the full range of a SLOCA can be considered to be in a mismatched condition with the diagnostic rules of the EOP because the diagnostic rule asks 'is the RCS sub-cooling > 15 °C and not rising?' to determine the LOCA event.

The pressures of the steam generators turned out to be in a decreasing trend throughout the range of a SLOCA under this thermal-hydraulic condition, as shown in Figure 3. Therefore, the rule is considered to be mismatched for the SLOCA range. This phenomenon is interpreted as that the full operating status of the high-pressure safety injection (HPSI) system has the capability to cooldown the reactor.

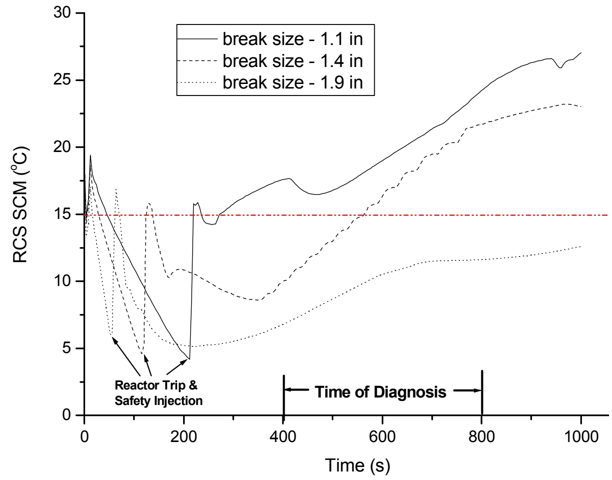

Figure 2. The Trend of the RCS Sub-cooled Margin

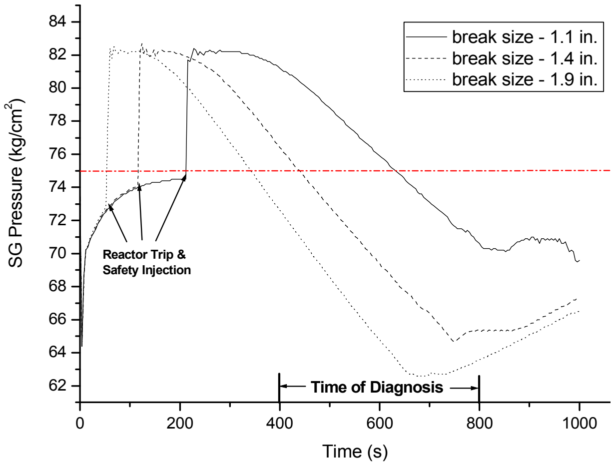

Figure 3. The Trend of the SG Pressure

3. Conclusion

A verification study was performed to check the appropriateness of the diagnostic rules of the YGN EOP for the small loss of coolant accident (SLOCA) event using the MARS3.0 code. According to the thermal-hydraulic analysis results, the RCS sub-cooled margin and the SG pressure showed a mismatch with the diagnostic rules of the EOP, respectively. Therefore, appropriate countermeasures should be developed in order to eliminate or reduce the potential for a misdiagnosis of the occurring events and its consequences to a plant safety.

REFERENCES

[1] KHNP, The emergency operating procedures of the Yonggwang 3&4 NPPs, 1998.

[2] KAERI, MARS 3.0 Code Manual. KAERI/TR-2811, 2004.