Passive Decay Heat Removal Strategy of Integrated Passive Safety System (IPSS) for SBO-combined Accidents

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1. Introduction

The safety of an advanced pressurized water reactor (PWR) is surely higher than that of nuclear power plants which have been operated until now. Considering the core damage frequency, the differences are shown. Therefore, the weak points of nuclear safety would be in outmoded nuclear power plants like the Fukushima reactors.

One of the systems for the safety enhancement is integrated passive safety system (IPSS) proposed after the Fukushima accidents [1]. It has the five functions for the prevention and mitigation of a severe accident. Passive decay heat removal (PDHR) strategy using IPSS is proposed for coping with SBO-combined accidents in this paper. The two systems for removing decay heat before core-melt were applied in the strategy. The accidents were simulated by MARS code [2]. The reference reactor was OPR1000, specifically Ulchin-3 and 4. The accidents included loss-of-coolant accidents (LOCA) because the coolant losses could be occurred in the SBO condition. The examples were the stuck open of PSV, the abnormal open of SDV and the leakage of RCP seal water. Also, as LOCAs with the failure of active safety injection systems were considered, various LOCAs were simulated in SBO. Based on the thermal hydraulic analysis, the probabilistic safety analysis was carried out for the PDHR strategy to estimate the safety enhancement in terms of the variation of core damage frequency. AIMS-PSA developed by KAERI was used for calculating CDF of the plant. [3].

2. Passive Decay Heat Removal Strategy

In the current emergency operating procedure (EOP), turbine-driven auxiliary feedwater pumps (TDP) were mainly tried to be recovered in the cases of the failures of EDGs and AAC power source. According to that, the provision of external water injection was proposed [4]. However, it has demerits of small capacity for supplying water. Also, in the case that the offsite condition is inaccessible, it cannot be properly used. Otherwise, steam generator gravity injection system (SGGI) for passive decay heat removal (PDHR) in IPSS has sufficient capacity for the designed safety duration time for SBO. Also, it has high accessibility and maintenance due to the installation besides containment. The design concept of SGGI-PDHR is shown if Fig. 1.

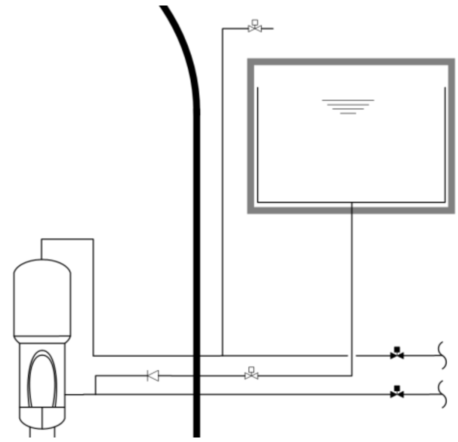

Fig. 1. Design of SGGI-PDHR in IPSS

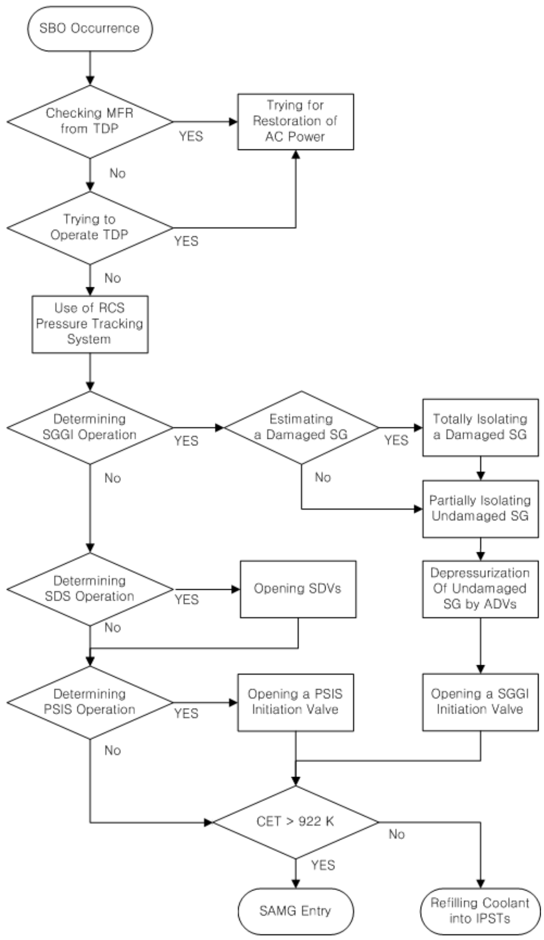

Fig. 2. Flowchart of PDHR strategy

The operation of SGGI has to be initiated before the sufficient depressurization in the secondary side using atmospheric dump valves (ADVs). Before the operation of passive safety injection system (PSIS), the necessity of safety depressurization has to be estimated according to the pressure in reactor coolant system.

3. Simulations of Accidents

Fig. 3 shows the mass flow rate from the external tank to an intact steam generator after the depressurization of the SG. In spite of the indirect cooling by the secondary side, the assumed loss of coolant decreased the reactor core water level after the designed time of 8 hours.

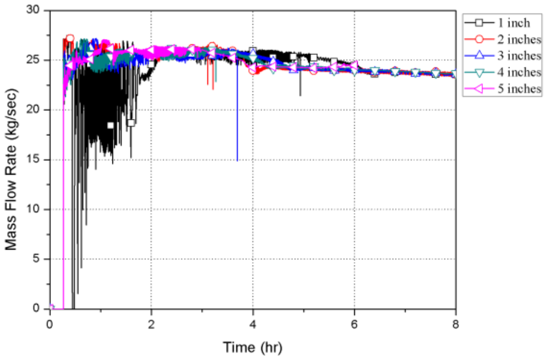

Fig. 3. Mass flow rate of SGGI-PDHR in IPSS

For LBLOCAs, the sufficient depressurization in reactor coolant system is needed for passive injection from the external water tank. Also, the pressure in containment is the key parameter about the pressure difference. The containment can be cooled by passive containment cooling system (PCCS) or vented by containment filtered venting system for preserving the integrity of containment.

PSIS can inject the coolant into reactor vessel in SBO with large break LOCA under the assumption that containment is cooled by PCCS. The mass flow rates in various LOCAs are shown in Fig. 4. It can remove the decay heat for the designed time as well.

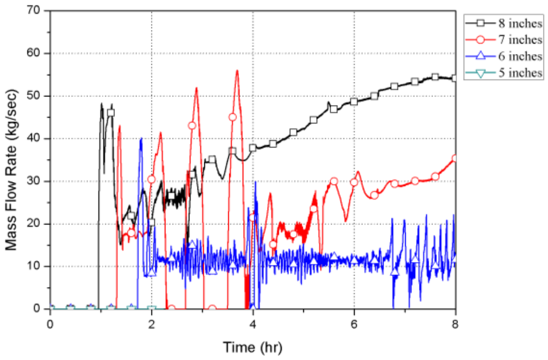

Fig. 4. Mass flow rate of PSIS in IPSS

4. Probabilistic Safety Analysis

The function of SGGI in IPSS was quantitatively analyzed for two accidents which were loss of offsite power (LOOP) and loss of feedwater (LOFW). The SGGI for PDHR could be used in the failures of the auxiliary feedwater supply when the depressurization by ADVs succeeded. When one IPSS was applied, the CDF value of LOOP decreased by about 70 %. With the application of two IPSS, the CDF decreased by about 80 %. The decrease about LOFW was bigger than those about LOOP as SGGI aimed at injecting water into the intact steam generator. The Fussell-Vesely importance of human error to initiate the operation of SGGI was estimated to be higher than the other basic events in SGGI.

5. Conclusions

The IPSS was applied in the PDHR strategy which was developed in order to cope with the SBO-combined accidents. The estimation for initiating SGGI or PSIS was based on the pressure in RCS. The simulations for accidents showed that the decay heat could be removed for the safety duration time in SBO. The increase of safety duration time from the strategy provides the increase of time for the restoration of AC power. The strategy can be applied in the integrated procedure of EOP and SAMG as the follow-up item of the Fukushima accidents. Also, it can be independently used for the mitigation steps in SAMG

REFERENCES

[1] S.H. Chang, S.H. Kim, J.Y. Choi, Design of integrated passive safety system (IPSS) for ultimate passive safety of nuclear power plants, Nuclear Engineering Design 260, 104-120, 2013.

[2] J.J. Jeong, et al., Development of a multi-dimensional thermal-hydraulic system code, MARS 1.3.1. Ann. Nucl. Energy 26 (18), 1611-1642, 1999.

[3] S.H. HAN, et al., Improved Features in a PSA Software AIMS-PSA, Korean Nuclear Society, Spring Meeting, Pyeongchang, Korea, 2010.

[4] S.W. Lee, et al., Extended Station Blackout Coping Capabilities of APR1400, Science and Technology of Nuclear Installations, vol. 2014, Article ID 980418, 10 pages. doi:10.1155/2014/980418.