Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

SBO Simulations for Integrated Passive Safety System (IPSS) Using MARS

Sang Ho Kim*, Sung Yeop Joung and Soon Heung Chang
Dept, Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology
373-1, Guseong-dong, Yuseong-gu, Daejeon, 305-701, Republic of Korea
**Corresponding author: proton@kaist.ac.kr*

1. Introduction

The current nuclear power plants have lots of active safety systems with some passive safety systems. The safety of current and future nuclear power plants can be enhanced by the application of additional passive safety systems for the ultimate safety. It is helpful to install the passive safety systems on current nuclear power plants without the design change for the licensibility. For solving the problem about the system complexity shown in the Fukushima accidents, the current nuclear power plants are needed to be enhanced by an additional integrated and simplified system.

As a previous research, the integrated passive safety system (IPSS) was proposed to solve the safety issues related with the decay heat removal, containment integrity and radiation release [1]. It could be operated by natural phenomena like gravity, natural circulation and pressure difference without AC power. The five main functions of IPSS are: (a) Passive decay heat removal, (b) Passive emergency core cooling, (c) Passive containment cooling, (d) Passive in-vessel retention and ex-vessel cooling, and (e) Filtered venting and pressure control.

The purpose of this research is to analyze the performances of each function by using MARS code. The simulated accident scenarios were station black-out (SBO) and the additional accidents accompanied by SBO.

2. Concept of IPSS Design

The concept of integrated passive safety system (IPSS) which we proposed can be achieved by the application of one or two big tanks outside containment shown in Figure 1. It is a system that one source can make a role of multiple safety functions for preventing and mitigating each problem in accidents. The specific design of integrated passive safety system consists of integrated passive safety tanks (IPSTs), pipes, sprays, valves, heat exchangers and filtered venting system. IPSTs are installed on any high place like the top of auxiliary building for high head. The number of IPST can be one or more for the designed thermal power and the condition of a nuclear power plant.

IPSS proves the ultimate safety by supplementing original safety systems in preparation for natural disaster and severe problems like a massive tsunami. Accordingly, the functions performances of IPSS are analyzed under the assumption that the original systems are failed to operate. A pressurized water reactor (PWR) is illustrated as a representative reactor type to show an application example of IPSS in Figure 1.

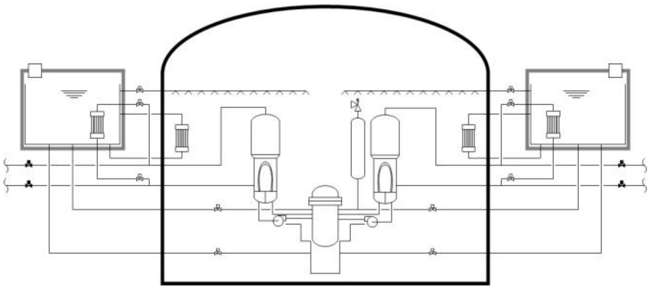

Fig. 1. Integrated Passive Safety System in OPR1000

3. Case Studies by MARS

3.1 Station Black-Out (SBO)

SBO is defined as the complete loss of AC electric power to the essential and nonessential switchgear buses in NPPs [2]. There are lots of SBO scenarios dependent on the success or the failure of each scenario step. In the case of OPR1000, the severest SBO scenario is caused by the failure of turbine driven pumps and the failure of early AC power restoration. SBO can cause the core damage and containment failure in spite of the reactor trip.

In order to prove the performance of IPSS PDHR in SBO, MARS (Multi-dimensional Analysis of Reactor Safety) code has been used for the basic simulations [3]. The reference reactor is set to OPR1000 as a Korean representative reactor.

First of all, the SBO scenario which can cause the core damage was simulated under the simple assumption about the initiation of some components. Secondly, the SBO scenario with the success of turbine driven pumps (TDPs) operation was simulated. Finally, for the comparison of the results from the current system, the SBO scenario with the operation of IPSS PDHR was simulated by MARS. The passive steam generator injection from IPST into steam generators as the second method of IPSS PDHR was used with the installation of IPSS in OPR1000 shown in Figure 2.

The assumption that IPST was installed on the top of the auxiliary building outside the containment was applied to the simulations related with the elevation difference for water injection from IPST. The top level of the auxiliary building was set for 30.5m from the ground. Also, the water inventory of an IPSS was set for 2000 ton.

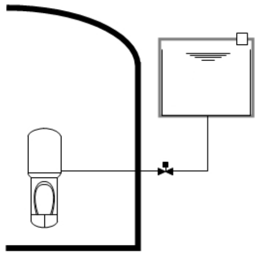

Fig. 2. Second Concept of PDHR System in IPSS

The mass flow rate formed by the water level difference between the water level in IPST and that of the SG is presented in Figure 3 with the comparison of those from TDPs and MDPs simulated for the current system. The injection can be done from the pressure decrease of the secondary side with the open of MSSVs or ADVs.

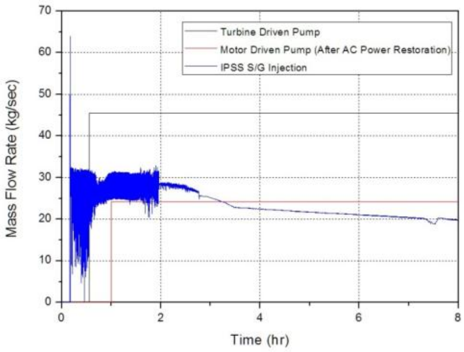

Fig. 3. Mass Flow Rate from Feedwater Backup Systems

Even if the mass flow rate decreases because of the water level decrease in IPST, the decay heat can be removed by the direct SG injection for eight hours shown in Figure 4. It is simulated that the case with IPSS can cool the core faster than that with TDP if the operation of IPSS PDHR is initiated. The case with IPSS will not cause the pressure increase of RCS due to the simple and fast operation.

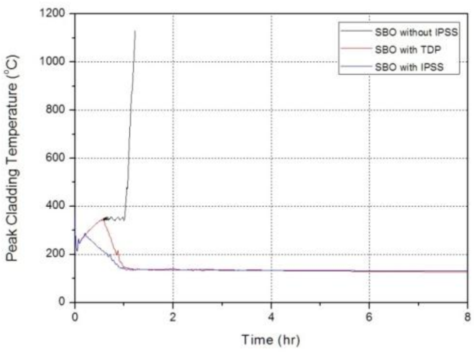

Fig. 4. PCT with and without IPSS PDHR

3.2 SBO with MFLB

The main feedwater line break (MFLB) causes that one line for PDHR cannot be available. In Korea, APR+ adopted the concept of PAFS on the secondary circuit. The application possibility has been positively reviewed and estimated [5]. In SBO with MFLB, the passive SG injection for the PDHR of IPSS in OPR1000 was simulated.

The results show that supplying the water into one steam generator is sufficient to remove decay heat by forming the natural circulation in a loop of RCS. It also means the redundancy concept for IPSS could be achieved in a case that one IPSS fails if two IPSS are installed.

3.3 SBO with LBLOCA

The concept of passive ECCS was newly proposed in the previous paper [1]. In a case of LBLOCA, the pressure of RCS sharply decreases. Therefore, the injection from IPST into RPV is possible due to the water level difference. The results show that the temperature of core can be decreased by gravity injection.

4. Conclusions

By using the MARS code as a system code, the accidents with the performance of IPSS functions were simulated. IPSS is designed for the ultimate safety, not basis safety. Accordingly, it does not replace the current safety systems. It supplements the current safety systems and proves the ultimate safety with lots of passive functions. It contains the multiple barriers by itself. The estimation of specific design parameters for each component and overall analyses are the future works of the research

REFERENCES

[1] S.H. Chang, S.H. Kim, J.Y. Choi, Integrated Passive Safety System (IPSS) for Ultimate Safe Nuclear Power Plants. Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 17-18, 2012.

[2] USNRC, NRC Regulations 10 CFR 50.2, 1956.

[3] 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.

[4] S.H. Chang, H.C. NO, W.P. Baek, S.I. Lee, S.W. Lee, Conceptual design of CARR passive PWR 1300MWe (CP1300). Nuclear Engineering International, February, 1997.

[5] Y.J. Cho, et al., Analytical studies of the heat removal capability of a passive auxiliary feedwater system (PAFS). Nucl. Eng. Des., 2012, http://dx.doi.org/10.1016/j.nucengdes.2012.03.046

[6] S.W. Lee, W.P. Baek, and S.H. Chang, Assessment of Passive Containment Cooling Concepts for Advanced Pressurized Water Reactors, Annals of Nuclear Energy 24, 467-375, 1997.