Nucl Eng Technol 47 (2015) 443–453

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.journals.elsevier.com/nuclear-engineering-and-technology/

Original Article

DEVELOPMENT OF AN OPERATION STRATEGY FOR A HYBRID SAFETY INJECTION TANK WITH AN ACTIVE SYSTEM

IN SEOP JEON and HYUN GOOK KANG[*]

Nuclear and Quantum Engineering Department, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon 305-701, South Korea

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form
22 December 2014
Accepted 24 January 2015
Available online 1 April 2015

Keywords:
Hybrid safety injection tank
Operation strategy
Passive system

ABSTRACT

A hybrid safety injection tank (H-SIT) can enhance the capability of an advanced power reactor plus (APR+) during a station black out (SBO) that is accompanied by a severe accident. It may a useful alternative to an electric motor. The operations strategy of the H-SIT has to be investigated to achieve maximum utilization of its function. In this study, the master logic diagram (i.e., an analysis for identifying the differences between an H-SIT and a safety injection pump) and an accident case classification were used to determine the parameters of the H-SIT operation. The conditions that require the use of an H-SIT were determined using a decision-making process. The proper timing for using an H-SIT was also analyzed by using the Multi-dimensional Analysis of Reactor Safety (MARS) 1.3 code (Korea Atomic Energy Research Institute, Daejeon, South Korea). The operation strategy analysis indicates that a H-SIT can mitigate five types of failure: (1) failure of the safety injection pump, (2) failure of the passive auxiliary feedwater system, (3) failure of the depressurization system, (4) failure of the shutdown cooling pump (SCP), and (5) failure of the recirculation system. The results of the MARS code demonstrate that the time allowed for recovery can be extended when using an H-SIT, compared with the same situation in which an H-SIT is not used. Based on the results, the use of an H-SIT is recommended, especially after the pilot-operated safety relief valve (POSRV) is opened.

Copyright © 2015, Published by Elsevier Korea LLC on behalf of Korean Nuclear Society.

1. Introduction

The Fukushima accident was not managed properly because of a lack of mitigation systems and strategies against a long-term station black out (SBO) [1]. The application of passive features has been suggested for properly mitigating another severe accident because passive systems do not require external energy supplies and passive safety features can increase the diversity of mitigation techniques [2,3]. For this reason, passive safety features have become an important issue in the nuclear field, and a substantial number of studies related to passive safety have been performed [4–6].

A conventional nuclear power plant (NPP) is primarily composed of active systems; thus, conventional operating

* *Corresponding author.*
E-mail address: hyungook@kaist.ac.kr (H.G. Kang).

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

http://dx.doi.org/10.1016/j.net.2015.01.008

1738-5733/Copyright © 2015, Published by Elsevier Korea LLC on behalf of Korean Nuclear Society.

procedures focus on the operation of active systems. When a passive safety system is added to a NPP, a new operation procedure is needed for the effective use of the passive system alongside the active system. This process is essential to enhance the safety of NPPs. However, only a few studies in the nuclear field have addressed the operation strategies of passive systems. Therefore, the operation strategy for a passive system should be studied further.

A previous study suggested the principle of a hybrid safety injection tank (H-SIT) system to enhance the ability of accident mitigation [7]. Many researchers have worked on H-SIT systems for the development of passive safety. In brief, the H-SIT is a new design concept for a passive safety injection system. The H-SIT system can inject water by using the pressure from nitrogen gas as a normal SIT in low-pressure accidents such as a large-break loss-of-coolant accident (LOCA). The H-SIT system can also inject water by using gravitational force in over-pressure accidents such as a SBO. The term "over-pressure" means that the pressure inside a reactor vessel is higher than the injection pressure of the safety injection pump (SIP). In over-pressure accident scenarios, the SIP cannot inject water because the SIP shut-off head has a limitation. The H-SIT is the only system that can inject water without depressurization in over-pressure accidents. Thus, this function of the H-SIT is critical. To drive the H-SIT in an over-pressure scenario, the battery-driven isolation valves open, and the pressure of the H-SIT is then balanced with the pressure of the reactor coolant system (RCS) through the pressure-equalizing pipe. This pipe is situated between the H-SIT and the pressurizer (PZR). The process for driving the H-SIT can be conducted in any pressure range, which includes the over-pressure situation. Thus, when the pressure is balanced, the emergency core cooling water can be injected by using the gravitational force in all scenarios such as the over-pressure scenario. Fig. 1 presents the outline of the H-SIT system.

A H-SIT can be used with an active injection system to increase the diversity of the safety system. A H-SIT is also planned to adjust to the advanced power reactor plus (APR+). Therefore, developing an H-SIT operation strategy is a suitable example of establishing the parallel operation of passive and active systems. Hence, this study focused on developing a methodology for constructing an operations strategy of an H-SIT, and using it to construct an actual operations strategy. In section 2, several technical methods are presented for the development of scenarios in which an H-SIT is suitable. In section 3, a timing effect analysis is performed for the specific scenarios that were determined in section 2. The scenario was analyzed using the thermal-hydraulic code and by calculating the recovery probability. This study suggests an effective strategy for the operation of an H-SIT in a conventional NPP and explains how that strategy is developed logically.

2. Scenario development

The H-SIT is primarily used in over-pressure accidents, which occur when many abnormal conditions coincide. Thus, these accidents are complicated to analyze. In this accident

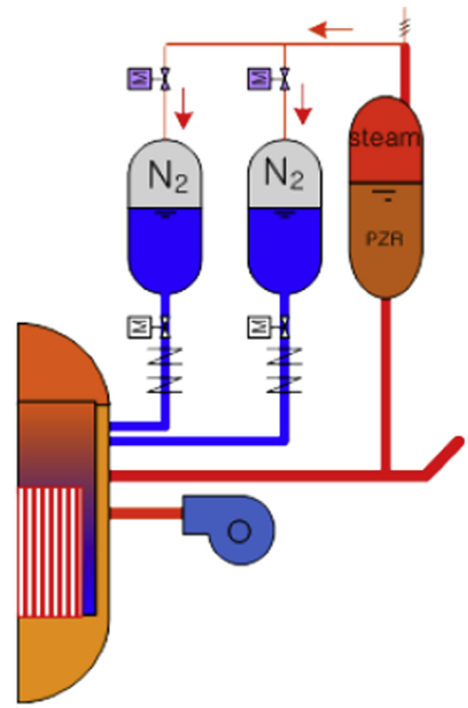

Fig. 1 – Outline of the hybrid safety injection tank system [7]. N2, nitrogen; PZR, pressurizer.

situation, the H-SIT can be also used with many active systems; therefore, parallel operation between an H-SIT and active systems should be considered for an operation strategy. Active systems can be used for accident mitigation instead of an H-SIT. This suggests that an H-SIT is not applicable to all accident scenarios. Therefore, applicable scenarios in which H-SIT needs to be used should first be developed. The complexity of making an operation strategy for accidents decreases if applicable scenarios are developed.

2.1. *Hybrid safety injection tank functions and parameters*

In this section, parameters are determined to develop applicable scenarios efficiently. Parameters are an important standard to use to reasonably select applicable scenarios from among all possible accident scenarios. They also help in analyzing the characteristics and phenomena of complicated accidents.

In this study, the parameters were determined by considering three key points: (1) the plant state, (2) the characteristics and functions of the H-SIT, and (3) the soundness of the safety systems that are associated with the H-SIT operation. In an accident situation, the functions of the H-SIT are duplicated by many active systems. Therefore, whether the active systems that are related with H-SIT functions are sound is a very critical point for constructing the operation strategy of an H-SIT.

The H-SIT was originally designed for the inventory makeup of the RCS. This function can be used for various purposes such as pressure control or heat removal. Before developing

Download English Version:

https://daneshyari.com/en/article/1740148

Download Persian Version:

https://daneshyari.com/article/1740148

Daneshyari.com