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Preliminary Evaluation of Interfacing System Loss of Coolant Accident for OPR1000

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1. Introduction

In accordance with the amendment of Nuclear Safety Act in 2015 and the amendment of regulation on technical standards for nuclear power facilities in 2016, accident management is legislated and the range of accident management is classified design basis accident (DBA), multiple failure accident, extreme hazards and severe accident.

An interfacing system loss of coolant accident (ISLOCA) was included in multiple failure accident and ISLOCA evaluation of domestic nuclear power plants in operation was required.

This paper describes the preliminary evaluation of ISLOCA for OPR1000 nuclear power plants.

2. Definition and Design Requirements of ISLOCA

2.1 Definition of ISLOCA

An ISLOCA is defined as a class of accidents in which a break occurs in a system connected to the reactor coolant system (RCS) due to failure of the equipment isolating the low pressure system and the reactor coolant system (RCS) pressure boundary, causing a loss of the primary system inventory [1, 2].

2.2 ISLOCA Design Requirements

Design Requirements for ISLOCA are described in SECY-93-087 [3] and regulatory standards and guides for light water reactors by KINS [2].

All systems and subsystems connected to the RCS which extended outside the primary boundary must be designed to the extent practicable to an ultimate rupture strength of at least equal to full RCS pressure [2, 3].

Interfacing systems or subsystems which do not meet above requirement must be designed as follows [2]:

(1) Valve position indication for open/close state of pressure isolation valves in the main control room (MCR).
(2) High pressure alarm to warn MCR operators when rising pressure approaches the design pressure of attached low pressure system and both isolation valves are not closed
(3) The pressure isolation valve installed between reactor coolant system (RCS) and interfacing systems(or subsystems) shall be capable of periodic leakage testing

3. ISLOCA Evaluation for OPR1000

3.1 Design experience review for ISLOCA prevention

The APR1400 (originally known as the Korean Next Generation Reactor, KNGR) is designed to prevent ISLOCA [4]. And the ISLOCA evaluation is included in APR1400 Standard Safety Analysis Report (SSAR) [5].

However, most OPR1000 nuclear power plants in Korea did not fully reflect design features for ISLOCA prevention because it was not design requirement at the time of construction.

3.2 Direct and indirect system connected to RCS pressure boundary

Since ISLOCA assumes that the pressure of the low pressure system is exposed to the reactor coolant system pressure, it is necessary to examine the pressure boundary of the system connected to the reactor coolant system.

Firstly, the direct/indirect system connected to RCS pressure boundary was identified by referring to OPR1000 piping and instrumentation diagram (P&ID).

The systems that is directly connected to RCS in OPR1000 are Shutdown Cooling System (SCS), Safety Injection System (SIS), Containment Spray System (CSS), and Chemical & Volume and Control System (CVCS). Pipes in the directly connected system to RCS are primary connection point where the ISLOCA can be initiated.

And for example, systems indirectly interfacing with RCS in SCS are CVCS, CSS, SIS, SS, and atmosphere.

To assess the structural integrity under ISLOCA, an evaluation of all direct and indirect systems connected to the reactor coolant system is necessary.

3.3 ISLOCA impact evaluation of major systems

ISLOCA preliminary evaluation of OPR1000 was performed with reference to the APR1400 SSAR ISLOCA evaluation process [5] and the results of the study on the system directly connected RCS pressure boundary are as follows.

3.3.1. Shutdown cooling system

Shutdown cooling system (SCS) was designed to be at least 40% of the normal operation pressure of RCS. Unlike other systems, SCS was designed and constructed considering ISLOCA. Therefore, safety cooling system meets the ISLOCA design requirements.

3.3.2. Safety injection system

Most piping in safety injection system has a high design pressure of 2,050 psig. But some pipe lines were designed with low pressure such as 100 psig or 150 psig.

LPSI and HPSI pump suction piping line of OPR1000 was designed to 100 psig and there is a possibility of pipe damage or break if high pressure is applied through pipe line. Therefore, design improvements such as high pressure alarm and pressure relief valve are required as measures to meet design requirements.

3.3.3. Containment Spray System

The containment spray system is not directly connected to the RCS in operation modes where ISLOCA can occur. But containment spray pump can replace the low pressure safety injection pump (LPSI) during shutdown cooling operation and can be indirectly overpressurized by the pressure of reactor coolant system. The containment spray pump inlet line connected to the LPSI pump was designed to 485 psig. Therefore, as design improvements to prevent ISLOCA, high pressure alarms and pressure relief valves may be installed at the front of containment spray pump.

3.3.4. Chemical & Volume Control System

Pipe line of chemical & volume control system can be divided into letdown line and charging line.

Shutdown cooling return line in letdown line is indirectly connected to RCS pressure boundary and design pressure of it is 200 psig. Because the design pressure does not exceed 40% of the reactor coolant system normal operation pressure, high pressure alarm and pressure relief valve may be installed in order to maintain the integrity of the system.

Charging line is directly connected to RCS pressure boundary and ISLOCA can occur through charging line. The design pressure of the charging pump suction is 200 psig and does not meet design requirements. But a pressure relief valve is installed in the each charging pump suction part to prevent overpressure. Therefore, as design improvements to prevent ISLOCA, high pressure alarm may be installed at the front of charging pump.

4. Conclusions

Preliminary evaluation of interfacing system LOCA for OPR1000 is accomplished. In the system connected to the reactor coolant system pressure boundary, it was examined whether it meets design requirements of interfacing system LOCA. We also reviewed design improvements against interfacing system LOCA vulnerabilities.

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