Wolsong Auxiliary Building Modeling for KHNP-SOARCA Project

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1. Introduction

After the Fukushima nuclear accident, domestic nuclear industry has been implementing and completing improvements to facilities and procedures in order to enhance the safety of nuclear power plants. In addition, additional safety improvements are required to be submitted for some targeting continued operation nuclear power plants as a result of stress test verification. As a result, the Nuclear Safety and Security Commission (NSSC) required the licensee to submit the results of the State-of-the-Art Reactor Consequence Analyzes (SOARCA) level for issues for safety improvement and that were raised during the stress tests, based on the latest Level 2 &3 PSA technology.

To address the foregoing issues, KHNP launched a three-year research project (called KHNP-SOARCA) in 2016, which aims at developing the technology elements of a Level 2&3 PSA and to perform both the optimum analysis of a severe accident progress with the latest codes, and an off-site consequence analysis reflecting the plant-specific conditions. Two NPPs, one for a PWR type (APR1400: SKN3&4) and one for a PHWR type (CANDU: Wolsong), have been designated as the reference plants for the foregoing project.

Among them, a main concern of this paper focuses on developing and optimizing a plant-specific auxiliary building model of the WS-1 MAAP-ISAAC[1] parameter file [1], which is available for the subsequent best-practice Level 2 PSA and severe accident analysis.

The aforementioned auxiliary building model is required for (1) an analysis of an interfacing systems loss-of-coolant accident (ISLOCA) or (2) a breakdown of the reactor building airlock seal during accident progression, in which coolant or other fluids (molten gas, dousing water, moderator, etc.) that may be discharged from the reactor building to the auxiliary building.

2. Modeling

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[1] MAAP is an Electric Power Research Institute(EPRI) software program that performs severe accident analysis for nuclear power plants including assessments of core damage and radiological transport. A valid license to MAAP4 and/or MAAP5 from EPRI is required.

2.1 MAAP-ISAAC 4.03 Computer Code

The MAAP-ISAAC (Modular Accident Analysis Program - Integrated Severe Accident Analysis code for CANDU plants) computer code has been developed to simulate accident scenarios that could lead to a damaged core and eventually to containment failure at the Wolsong NPPs. The MAAP4 computer code developed by EPRI for pressurized light water reactors was used as a reference code for development of MAAP-ISAAC [1]. As the Wolsong NPPs, which are CANDU 6 type reactors, differ from typical PWRs, the Wolsong-specific features are newly modelled and incorporated into the MAAP-ISAAC code. The code was used to assist in supporting PSA and estimating source terms by analyzing the accident progression beyond core damage resulting to the containment failure. The MAAP-ISAAC code is constructed in modules covering for individual regions in the plant: primary heat transport system, pressurizer, steam generators, calandria, calandria vault, end-shields, degasser condenser tank, and the containment. Every major engineered safety features are included in the code: shutdown cooling system, emergency core cooling system, moderator and shield cooling system, reactor building local air coolers, igniters, and containment dousing system.

2.2 Auxiliary Building Modeling

2.2.1 Assumptions

In modelling of the auxiliary building, the same assumptions are applied with the reactor building model. However, in the case of the MAAP-ISAAC 4.03 computer code used in the KHNP-SOARCA project, there is a limitation in that all auxiliary building compartments cannot be modeled in detail due to the limitation of the number of compartment usage. Therefore, after reviewing the flow path of the fluid discharged from the reactor building in case of ISLOCA and airlock seal failure through the Wolsong auxiliary building walkdown and review of drawings of auxiliary building [2], only the compartments in which the fluid was thought to pass through are reflected in the auxiliary building modeling.

The compartments in the auxiliary building are connected to each other by openings, dampers and doors. In the case of a damper, it can be closed during a

fire, but it is assumed that it is always open conservatively. There are two types of door, solid sliding doors and general doors. In this analysis, sliding doors are assumed closed under all conditions. And a general door is assumed to be opened at the differential pressure of 1.7 kPa(d), which is the same assumption used in the safety analysis of Wolsong NPP [3].

Since Wolsong auxiliary building compartment is selectively modeled, the wall of the selected compartment may exist between the compartment selected in modeling and the compartment excluded from modeling. The assumption that the heat is not transferred to the compartment excluded from the modeling is applied conservatively. And in this case these walls were treated as insulating walls.

2.2.2 Methodology

Following the assumptions mentioned above, Wolsong auxiliary building is modeled consistently with reactor building modeling. The auxiliary building modeling is divided into three parts. The first is a compartment parameter for entering information about the auxiliary building compartment, the second is a junction parameter connecting the compartments and finally a heat sink parameter corresponding to the compartment wall equipment existing in compartment. Details of the input variables used in Wolsong auxiliary building are described below.

2.2.2.1 Compartment parameter

Through the walkdown of the Wolsong auxiliary building, the compartments were selected which are expected to form a path in case of an accident. The selected compartments are shown in Table I and Figure 1 shows the nodalization reflecting this. A total of 29 compartments were selected for Wolsong auxiliary building modeling, and these compartments were restructured to 14 compartments. If the pressure and temperature in compartments are considered to remain the same in both normal and accident conditions, they are modeled as a single compartment.

There are two types of airlock doors in Wolsong auxiliary building through which containment can be accessed. The personnel airlock door is located in the basement, and the equipment airlock door is located on the ground (S-128). In order to reduce the deposition effect conservatively, only the equipment airlock door was considered in this analysis.

Wolsong auxiliary building has three parts connected to the atmosphere. The mechanical work shop room (S-149) was modeled open since it was always connected to the atmosphere during working hours. The third floor S-303 is connected to the turbine hall, which is always open. Therefore, this junction is also always open. Finally, there is a window and a rolling door installed in the crane hall (S-128), which breaks down to reach the atmosphere when it reaches a certain pressure.

Table I: The selected compartments

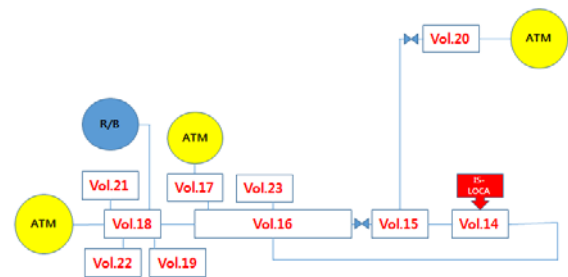| Node for A/B	Compartment	Note
VOLRB(14)	S-146, S-147	occurring the ISLOCA place
VOLRB(15)	S-145, S-304	
VOLRB(16)	S-105, S-106, S-144, S-148, S-169	
VOLRB(17)	S-149	Connected ATM
VOLRB(18)	S-120, S-221, S-128	Connected ATM & Airlock seal located
VOLRB(19)	S-201, S-211	
VOLRB(20)	S-302, S-317, S-322, S-303	Connected ATM (T/H)
VOLRB(21)	S-124	
VOLRB(22)	S-129, S-130, S-131, S-132, S-135, S-136, S-138	
VOLRB(23)	S-143, S-155	

Fig. 1. The nodalization for Wolsong auxiliary building

2.2.2.2 Junction parameter

A total of 20 paths were used to connect the compartments to the compartments. A damper or a path when it is always open is modeled as a junction, and the door that can be opened by pressure difference is modeled as a failure junction. A door is modeled to use the same assumption used in the safety analysis of Wolsong NPP. There are three types of doors inside the auxiliary building. The first type is shielding doors, which are assumed to be strong enough to withstand all pressure loads. The second type is doors which are designed to blow open when the latch holding the door closed breaks at a differential pressure of 1.7 kPa(d). The third type is a rolling door. This type of door is modeled to rupture the panel only when the differential pressure across the door reaches a threshold pressure of 8.9 kPa(d).

If there is only one flow path between the compartments and the fluid is not flowed smoothly, the area of the flow path is divided into half and which is modeled by two flow paths.

2.2.2.3 Heat Sink

The walls of the compartment, such as the outer wall, the inner wall, the floor, and the ceiling, serve to absorb heat when the temperature in the compartment increases. Many devices in the compartment also absorb heat. These heat absorbers are modeled as heat sinks. They are divided into Distributed Heat Sink for wall and Lumped Heat Sink for device.

2.2.2.3.1 Distributed Heat Sinks (DHS)

The DHS model is used when modeling the wall surface as a heat absorber. The walls are divided into outer wall, inner wall, ceiling and floor. In the case of the reactor building model, all the compartments of the reactor building are modeled, so the ceiling of the lower compartment is the bottom of the upper compartment and thus modeled as a 2 side model wall. However, in the case of the auxiliary building model, only the compartments considered to have fluid flow are modeled selectively, unlike the reactor building model, and floors and ceilings were modeled as 1 side models. If the outer wall does not come into contact with the atmosphere, and if it does not come into contact with the compartment used for modeling, it is modeled as an insulating wall.

2.2.2.3.2 Lumped Heat Sinks (LHS)

The devices in the compartment are modeled using the LHS model. We confirmed the equipment to be used for the modeling through the review of the drawing and the walkdwon. Table II provides information on the LHS used in Wolsong auxiliary building.

Table II: LHS information

Devices (no.)	Location	LHS parameter
ECC HX (1 ea)	S-144	AEQRB(13)
3831-FM020 (6 ea)	S-146	AEQRB(14)
3831-DH-16 Pipe (1 ea)	S-146	AEQRB(15)
3712-FR-1 (1 ea)	S-147	AEQRB(16)
37120-FAN (2 ea)	S-147	AEQRB(17)
Tank (1 ea)	S-147	AEQRB(18)
33610-Y01 MOD cabinet (2 ea)	S-147	AEQRB(19)
5542-MCC (6 ea)	S-304	AEQRB(20)

3. Conclusions

Basic input parameters of Wolsong auxiliary building were developed for the KHNP-SOARCA project with MAAP-ISAAC 4.03. The basic input parameters of Wolsong auxiliary building will be added to the parameter file [4] of Wolsong reactor building. Afterwards combined parameter files of Wolsong will be used for the analysis of ISLOCA and events causing failure of reactor building airlock seal during severe accident transients.

REFERENCES

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[3] J.Y. Lee, Containment Analysis Models, 59RF-03500-AR-006, Rev.2 2009.
[4] KAERI, Technology Transfer Contract between KAERI and ACT : Wolsong-1 ISAAC 4.0.3 parameter file for SOARCA project (2 years), 2017, 12.