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# Study of Scenarios Related to Design Extension Conditions of PHWR Using PSA Methodology

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## 1. Introduction

After Fukushima accident, International Atomic Energy Agency(IAEA) has introduced Design Extended Condition which includes Beyond Design Basis Accidents(BDBAs) and Severe Accidents(SAs) with SSR-2/1(2012) and demanded complementary measures, accident managements and off-site emergency countermeasures for preventing from aggravating accidents, mitigating accidents and influence by radioactive material [1]. Currently, studies to establish the event classification framework and acceptance criteria for an event that exceeds the existing DBAs in order to enhance the safety operation of nuclear power plants in accordance with the domestic nuclear safety laws amended recently have been doing briskly in the country. In this perspective, a study of DECs for domestic PWRs has already begun, and accordingly, studies to cope with BDBAs including DECs for domestic CANDU plants also are required. In this paper, a postulated event which might be included into DECs for domestic CANDU is analyzed by CATHENA code [2], and Probabilistic Safety Assessment(PSA) data needed for selecting events for DECs are drawn.

## 2. Methods and Results

### *2.1 Selection of DECs*

The concept of DEC was referred to first in European Utility Requirements (EUR) prepared as the guidance of developing reactor types in the middle of 1990s, and EUR defined DEC as including multi-failures and Low pressure core melting accidents.[3] Classification of DECs is based on the frequency of occurrence. In Canada, REGDOC-2.5.2, a regulatory document, contains the concept of DECs and they are planning ways to apply to existing nuclear power plants.[4]

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### *2.2 Analysis method*

To simulate the plant status practically, the PHT system, SGs and feedwater systems were modeled, and reactor power for all accident scenarios was assumed to be 100% FP and Loss of UHS, SBO, loss of EDG and the active components powered by EPS System are assumed as well.

### *2.3 Analysis results*

The result of cliff-edge situation simulation with a complete loss of all heat sink and electrical power shows that, once failed to secure an alternate heat sink (feedwater flow) and alternate power supply for SGs, the plant is unable to remove heat in the primary side due to depletion of SG inventory in 5000 seconds after reactor shutdown. As illustrated at Figure 1, liquid relief valves(LRVs) and degasser condenser relief valves(DCRVs) come to open as pressure in the PHT system subsequently goes up. Opening of DCRVs leads to temperature and pressure rising in the containment, necessitating activation of the dousing system. Subsequently, dousing tank inventory cannot be fully used for feedwater to the SGs. During the accident, the secondary side pressure is maintained within the range of MSSV's opening and closing setpoints.[5]

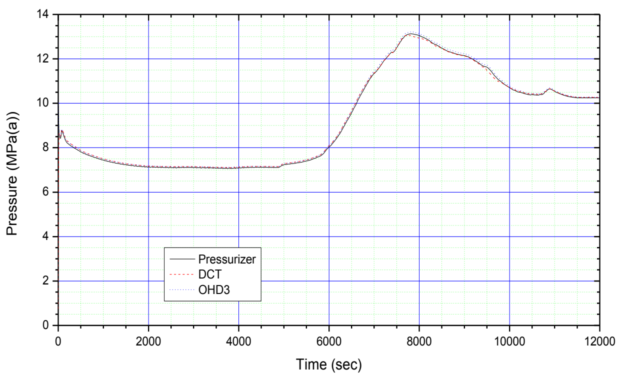


Fig.1 Reactor outlet header pressure

In the scenario that assumed loss of all heat sinks and powers, the mitigating action should be done before opening of DCRVs due to overpressure of the coolant system. And to do that, first of all, the operators should open MSSVs before depletion of S/G and also start up a mobile generator before depletion of dousing tank. If these two cliff-edge effects are clear, the integrity of reactor core and containment building would be secured.

In the scenario, EWS is not available due to loss of EPS, but Class I, II powers are available, so MSSVs can be opened, which enables to make up by gravity-fed of 500 tons from dousing tank to S/G for about 14 hours and cooling water from EWS to S/G by start-up of MG before depletion of dousing tank.

Therefore, power and water source are limited around 2.5 hours and 14 hours, respectively immediately after the accident, but with the start-up of MG, power and water source are extended for about 11 hours and 4.6 days, respectively. And then, fuel can be supplied from the side and when MG is connected to Class III power, core cooling can be achieved through feedwater and shutdown cooling system operation, not occurring cliff-edge effects in the scenario.

Table 1 summarizes the result of assessment on the plant coping capabilities and cliff-edge effects under the condition of SBO and loss of EPS System combined with loss of UHS.

Table.1 Power and Water sources available

| Before using in-site mobile facility | | | | | |
|---|---|---|---|---|---|
| Action | Required Time Assessment | | | | |
| | Situation recognition point | Response measure | | | Max. available hours (h) |
| | | Decision | Implementation | Hours available (h) | |
| Accident occurrence | 0 sec | | auto | 1.4 | power(2.5) water(1.4) |
| Reactor shutdown | 3.1 sec | | auto | 1.4 | |
| Accident diagnosis | 15min | | - | 1.1 | |
| Declaration of "White Emergency" | - | 20min (5min) | - | 1.1 | |
| Gravity-fed make-up water from the dousing tank to SGs (13.9 hrs available) | - | - | 33min (auto) | power(2.0) water(14.8) | power(2.5) water(15.3) |
| Technicolor Support Center(TSC) starts | - | - | 120min | power(0.5) water(13.3) | power(2.5) water(15.3) |
| **After using in-site mobile facility** | | | | | |
| MG Start-up (11 days available with refill of Emergency or SDG fuel) | | | 135min (15min) | power(264) water(13) | power(264) water(15.3) |
| Water from EWS reservoir to SGs (4 days available) | | | 8h (5.7h) | power (No time limit) water (101.7) | power (No time limit) water(109.7) |

Figure 2 shows Schematic diagram of PSA Model for SBO and Loss of EPS system combined with loss of UHS.

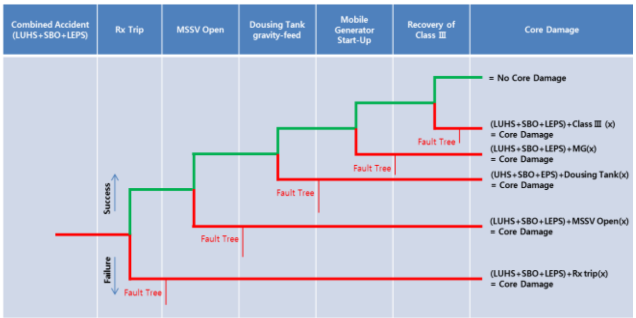


Fig.2 Schematic diagram of PSA Model

## 3. Conclusions

In this paper, based on the assumption that all the heat sinks and power are not available, countermeasure capability against loss of safety functions such as power supply system in domestic CANDU are assessed. The results and available power and heat sink source which are the required coping facilities for mitigating the accident are presented and the available limited time also are assessed. Provided that ways of long-term core cooling are secured later, it is expected that the safety functions of a plant can be secured even in the extremely severe natural disasters. The results from this paper can be used as preliminary data in developing DECs scenarios in future.

## REFERENCES

[1] IAEA, SAFETY STANDARDS SERIES No. SSR-2/1, International Atomic Energy Agency VIENNA, 2012

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[4] B.J. Jeong, J.H. Heo, A Study on the Design Extension Conditions of a Nuclear Power Plant, 2012

[5] Korea Hydro & Nuclear Power Corporation “Stress Test Report for Wolsong Unit One”, 2014 November