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Implementation of Control Logic for PHTS Pressure and Inventory to mSGTR analysis model of MARS-KS code in CANDU-6 Plants

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Contents

Introduction

Background

- SGTR (Steam Generator Tube Rupture)
  - one of the reactor building bypass events that lead to a release of fission products into the environment

- Especially, through mSGTR (Multiple SGTR),
  - The high temperature, high pressure primary coolant can be leaked or discharged to the secondary system and then directly reach the atmosphere and general public through the damaged SG or other possible release paths in the secondary system.

Introduction

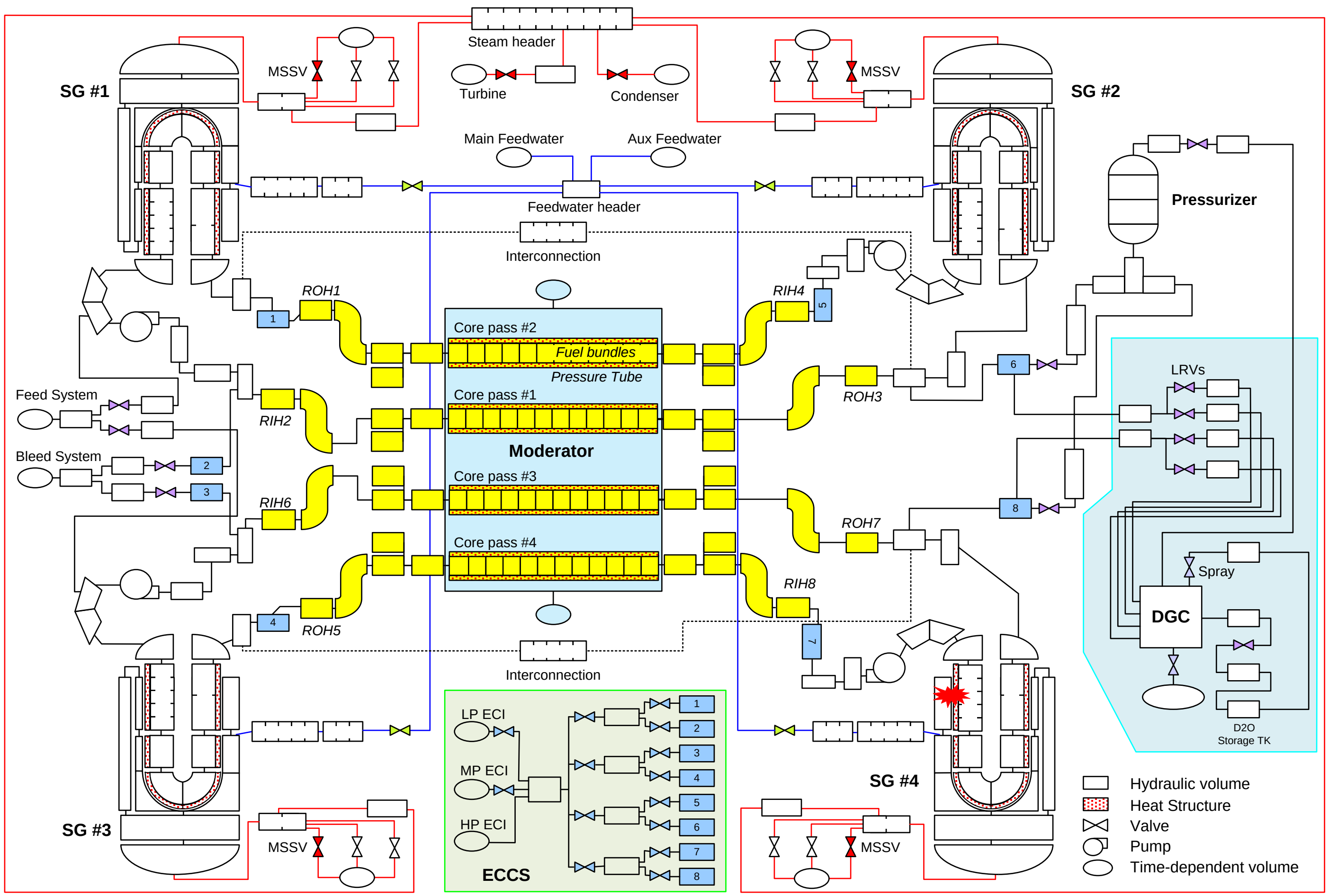
Objectives

- This study aims to develop an advanced evaluation technology for assessing CANDU-6 safety.

- For this purpose,
  - multiple SG u-tubes are assumed to be ruptured (mSGTR) during a normal operation as a target accident scenario and,
  - the operation logic models for the pressurizer heaters and feed system were implemented in the analysis model to evaluate the plant responses.

Code Modelling

Nodalization for Event Simulation



Code Modelling

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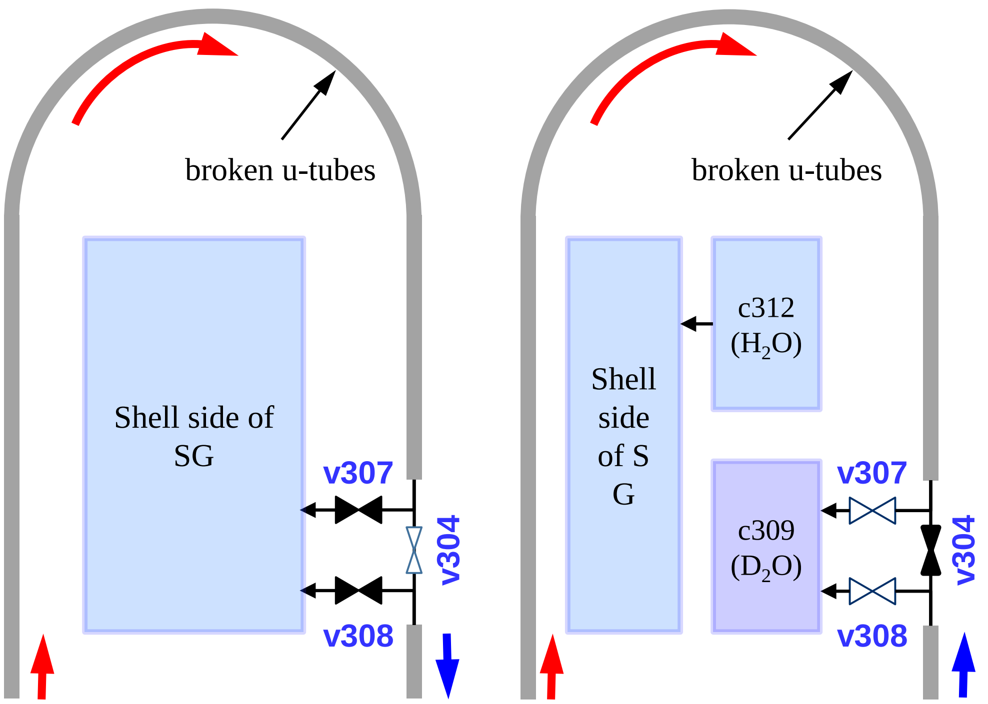
Faulted SG#4 Modelling

- When the u-tubes rupture, the primary coolant (D_2O) discharges to the SG shell and mixes with the secondary coolant (H_2O).
- Although their physical properties are similar, the code recognizes them as different fluids,
  - so there are limits to simulating mixing the two different liquids in the calculation.
- In order to simulate the discharge of the D_2O coolant to the SG shell through the ruptured u-tubes,
  - some imaginary components such as a valve (v304) between the broken u-tubes and the SG outlet plenum, two valves (v307, v308) for simulating the ruptures, and two time-dependent volumes (c309, c312) as imaginary boundary conditions were used.

Code Modelling

Faulted SG#4 Modelling

- Modelling for coolant discharge through ruptured u-tubes



(a) Normal operation (b) transient

Code Modelling

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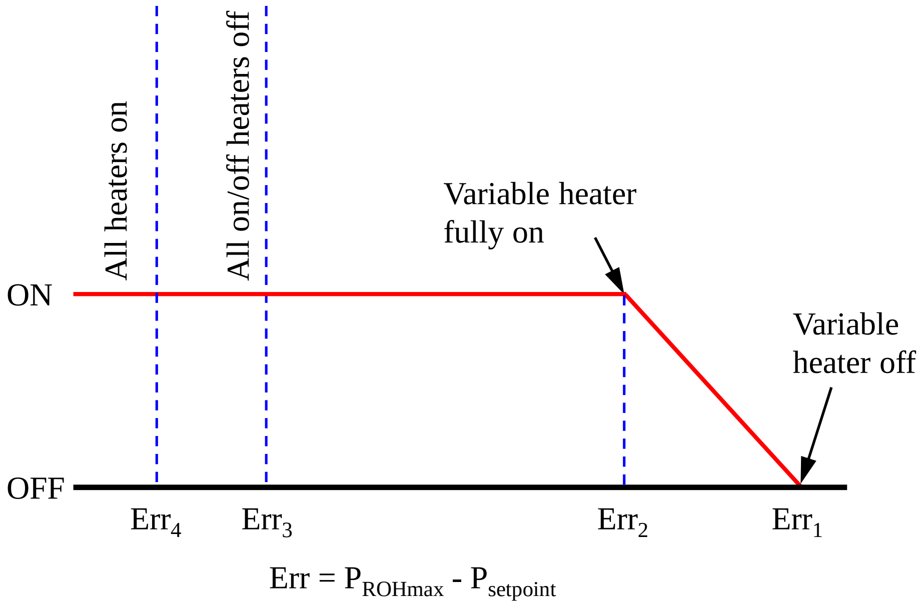
PHTS Pressure and Inventory Modelling

- In the case of mSGTR, the PHTS is not expected to be over-pressured,
  - so that the operating logic of the pressurizer heaters (1 variable heater and 4 on/off heaters) is modelled.
- When the maximum pressure of the reactor outlet header (ROH) becomes lower than an operational set value,
  - the variable heater actuates according to the increasing output demand.
  - However, if the pressure is not recovered, the four on/off heaters automatically operate.
  - In addition, all heaters become unavailable when the pressurizer's water level is below the set value to prevent exposure to steam.

Code Modelling

PHTS Pressure and Inventory Modelling

- Logic of the PZR heaters' operation



Code Modelling

PHTS Pressure and Inventory Modelling

- The coolant inventory in the PHTS decreases along with the pressure decrease during the mSGTR transient,
  - causing the water level of the pressurizer connected to the two loops via ROHs to drop.
- The control logic for the PHTS inventory was developed using the water level changes in the pressurizer to compensate for the coolant loss.
  - When the water level starts to decrease, the coolant feeds immediately from the D_2O storage tank modelled as a boundary condition.
  - The tank was assumed to be depleted if it became less than 10% of its initial amount and the feed stopped.

Results and Discussion

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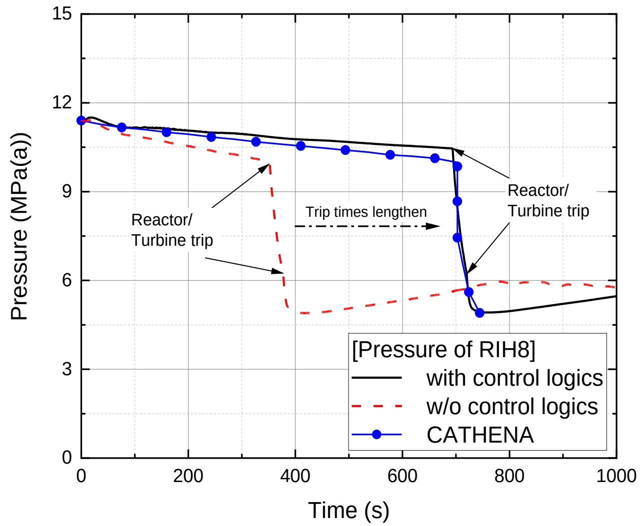
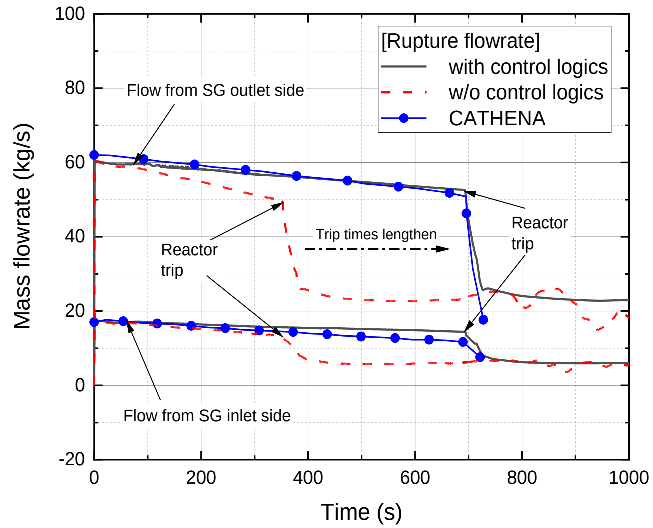
Effect of Control Logic implemented on Plant Responses

- Pressure and discharged flowrate
  - The control logic was modeled to realistically simulate the behavior of the PHTS pressure and inventory affected by the mSGTR.
  - The present control logic reasonably affected the transient behaviors, and the reactor shutdown was delayed about 342 s or about 97%, which was similar to the result of the CATHENA code.



Header pressure

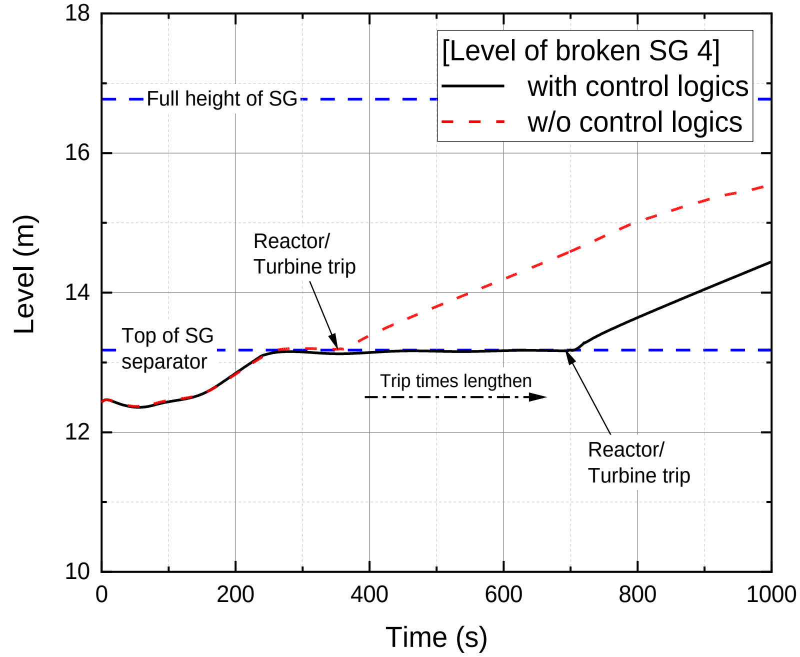


Discharging flowrate

Results and Discussion

◆ Effect of Control Logic implemented on Plant Responses

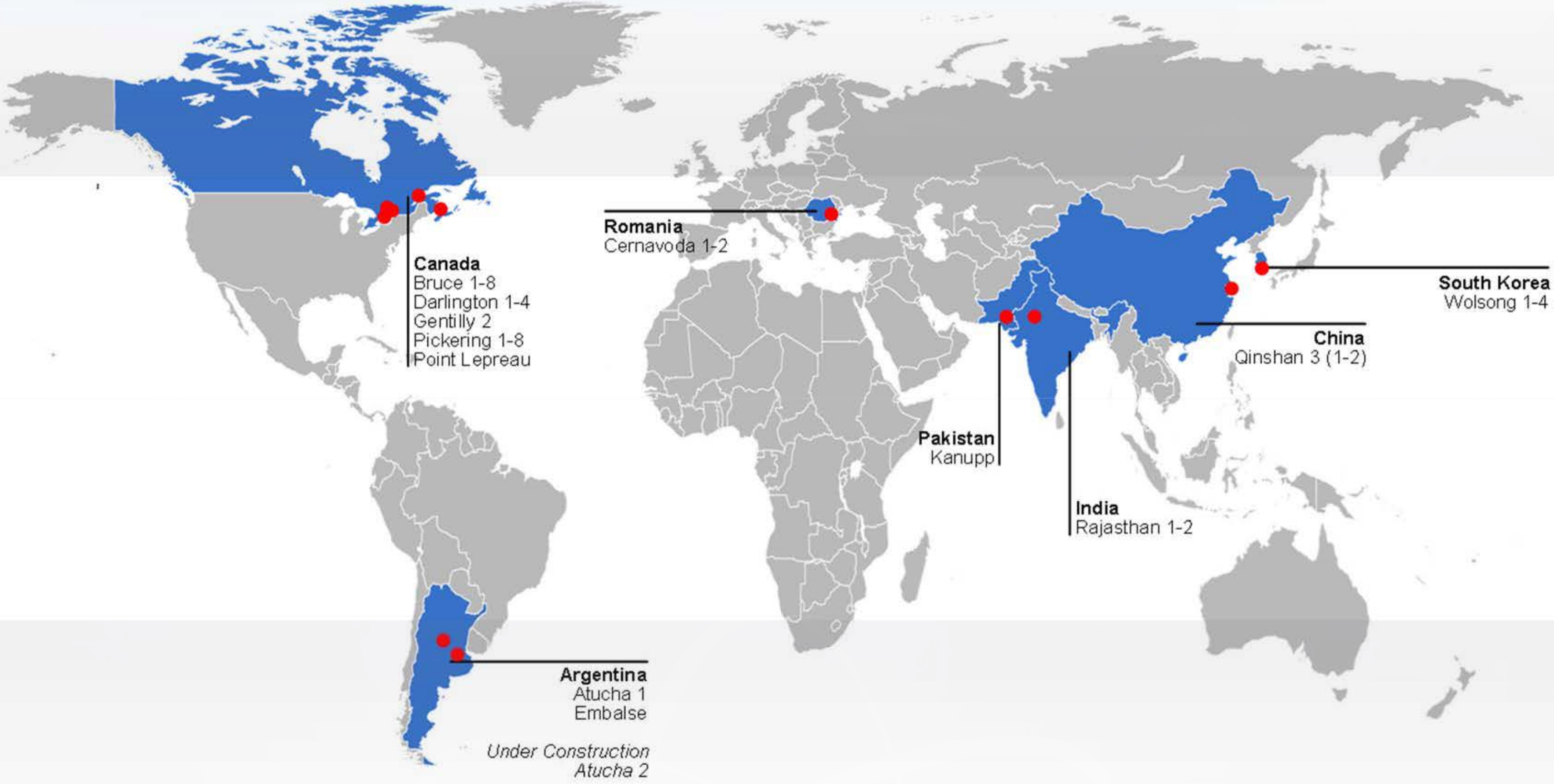
- Water level behaviors of the faulted SG
  - Due to the coolant inflow, the water level increased to the upper part of the SG separator, and
  - Even when the main FW pump was tripped due to the power loss assumed in this study, coolant continued to flow in and the SG became full.
  - These behaviors were similar regardless of whether the control logic was implemented or not, except the time of when the SG water level started to increase above the upper part of the separator.



Water level of SG#4

Conclusions

- For mSGTR simulation using the MARS-KS code,
  - the u-tubes of SG #4 were divided into intact and broken ones, and
  - the operation logic models for the pressurizer heaters and feed system were implemented in the analysis model to evaluate the plant responses.
- From the physically reasonable behaviors of the thermal hydraulic parameters and the comparison with other codes,
  - the operation of the PHTS pressure and inventory control logic implemented in the present analysis model is appropriate, and
  - it was evaluated that the system responses can be more realistically simulated in the accident analyses.
- Detailed accident analysis on the mSGTR is on progress.



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Thanks for your kind attention

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