Simulation of station blackout scenario in low-power and shutdown condition of Westinghouse two-loop plant with RELAP5 code

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1. Introduction

Station blackout is the complete loss of alternating current (AC) electrical power to the essential and nonessential switchgear buses in a nuclear power plant. Because many safety systems required for reactor core cooling and containment heat removal depend on AC power, the consequences of a station blackout could be severe. Especially, station blackout in low-power and shutdown condition is one of the current issues [1]. Therefore, the evaluation of plant safety with safety analysis code is opportune. A station blackout scenario in low power and shutdown condition of Westinghouse two-loop plant is simulated with RELAP5 code [2].

2. Analysis conditions and model

2.1 Analysis conditions

In low-power and shutdown condition, a station blackout scenario, where all off-site power is lost and the diesel generators fail, is simulated as an initiating event of an accident sequence. The refueling outage condition in Westinghouse two-loop plant of 610 MWe nominal electric power is considered.

2.2 Analysis model

The plant safety is evaluated with RELAP5 Mod3.2.2 code. In the RELAP5 input model, reactor vessel, cold leg, hot leg, pressurizer, reactor cavity, fuel transfer canal and spent fuel pool are modeled with control volume and junctions as depicted in Fig.1.

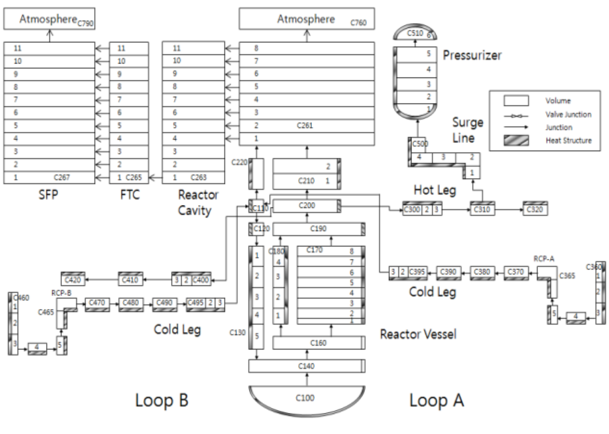

Fig. 1 RELAP5 model of WH 2-loop plant in refueling stage

The reactor power of 5.83MWth (0.338% to the nominal power) is applied. The shutoff valve of fuel transfer canal is in manual open condition. The power of spent fuel is 0.7787 MWth (358 spent fuel assembly). And initial temperature of primary coolant is 37°C (310.15K). Shutdown cooling is being provided by residual heat removal (RHR) pump before the station blackout. The reactor vessel head is removed and refueling cavity is flooded with borated water. The steam generators are separated with nozzle dams.

3. Analysis results

3.1 Transient analysis results

The transient calculation is carried out for 580,076 seconds (161.1 hours). The gradual decrease of primary system inventory due to the evaporation of coolant is shown in Fig. 2. After 155 hours, local coolant temperature is higher than the saturation temperature as

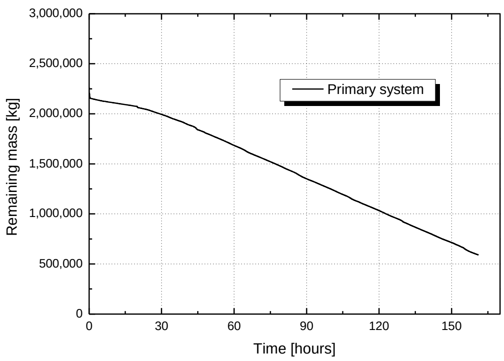

Fig. 2 Primary system inventory

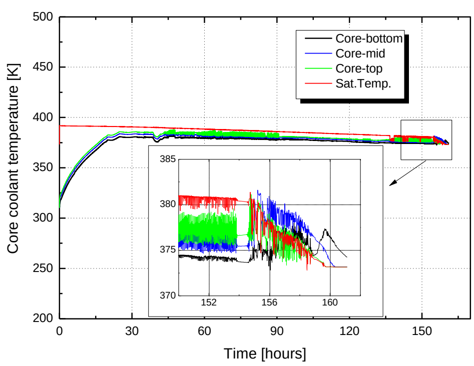

Fig. 3 Core coolant temperature

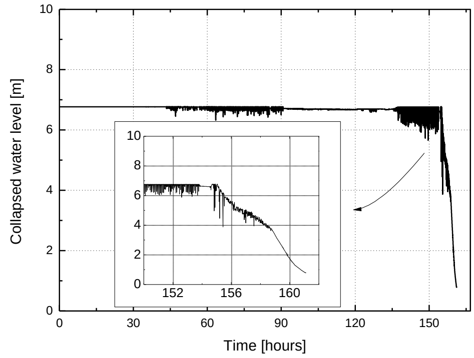

Fig. 4 Collapsed water level in core

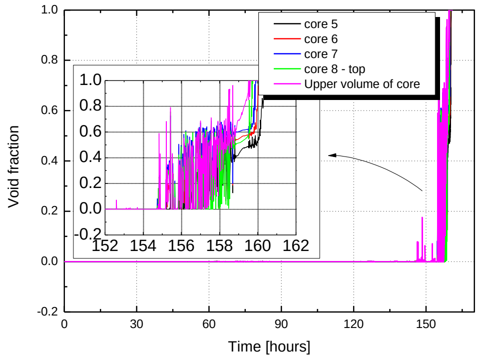

Fig. 5 Core void fraction

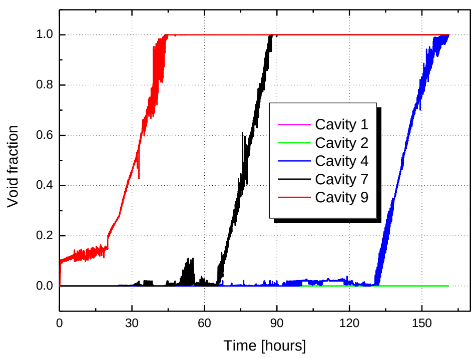

Fig. 6 Void fraction in rector cavity

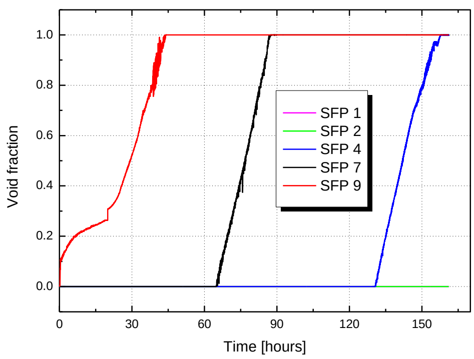

Fig. 7 Void fraction in spent fuel pool

presented in Fig. 3. At the same time, the collapsed water level declines sharply (Fig. 4) and void fraction in core is increased abruptly (Fig. 5). The spent fuel is uncovered at 128 hours. However, overall dryout does not occur in spent fuel pit (Fig. 9), while peak cladding temperature exceeds 1206K in core region as depicted in Fig. 8. The gradual decrease of liquid fraction in refueling cavity can be observed in Fig. 6 and 7.

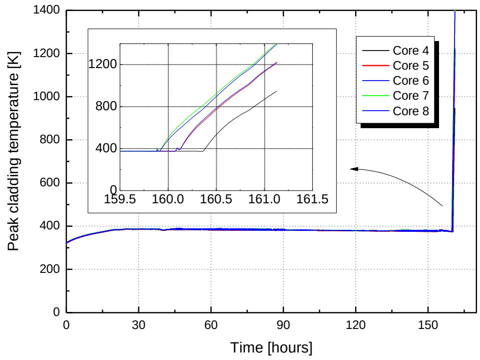

Fig. 8 Peak cladding temperature of core

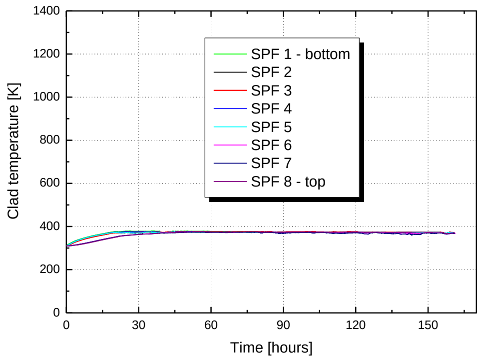

Fig. 9 Peak cladding temperature of spent fuel

4. Conclusions

To evaluate plant safety in station blackout scenario for low-power and shutdown condition, the transient calculation with RELAP5 code has been carried out for a Westinghouse two-loop plant. Without core cooling, the boiling in core and spent fuel pit occurs. The core uncovery is observed about 160 hours and the peak cladding temperature exceeds 1206K at 161.1 hours.

REFERENCES

[1] Park, S.Y. and Ahn, K.I., Comparative analysis of station blackout accident progression in typical PWR, BWR, and PHWR, NET, Vol. 44, No. 3, (2012)
[2] Thermal Hydraulics Group, RELAP5/MOD3 Code Manual, NRC, NUREC/CR-5535 (1998)