Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2026

Modelling of Component Cooling Water System Using GOTHIC

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Keywords : **Component Cooling Water System, Heat removal, Closed loop, Flow network**

1. Introduction

Component Cooling Water (CCW) system is an essential support system in nuclear power plants, providing cooling to various safety-related and nonsafety-related components to ensure continuous operation. The performance of CCW system is therefore directly related to the safe and reliable operation of the plant.

In recent years, concerns regarding the increase in seawater temperature have been raised, as seawater is commonly used as the ultimate heat sink. This may degrade the heat removal capability of cooling systems, potentially affecting the performance of the CCW system. To evaluate the impact, it is necessary to establish a reliable thermal-hydraulic model of the CCW system that can accurately simulate its behavior under various operating conditions.

In this study, The CCW system and major heat loads of the OPR-1000 nuclear power plant were analyzed based on their design specifications and implemented in the GOTHIC model. Based on this analysis, model of CCW system was established using GOTHIC. GOTHIC has been extensively applied to simulate thermal-hydraulic phenomena in nuclear power plant applications due to its capability to model complex geometries with flow networks.

2. GOTHIC Modelling of CCW System

2.1 Review of CCW system

One train of CCW system was analyzed in normal operation mode. Schematic diagram was developed for a typical CCW system of a domestic OPR-1000 nuclear power plant to identify the overall configuration, major components, and flow paths. It includes pumps, heat exchangers, and associated piping and valves, which provide cooling.

During normal operation, CCW pump circulates cooling water through the connected equipment and transfers the absorbed heat to the Essential Service Water system using CCW heat exchanger. Cooled water is then returned to the heat sources by CCW pump suction, forming a closed-loop circulation. One of the two pumps and two of the three heat exchangers are in operation. Also, essential water chiller condenser, spent fuel pool cooling heat exchanger, containment building water chiller and four reactor coolant pumps (RCP) operate as heat sources.

A simplified schematic diagram was developed, as shown in Fig. 1. The schematic diagram illustrates the major components, flow paths, and connections within CCW system.

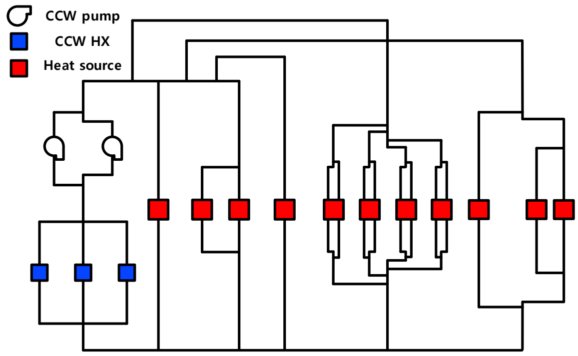

Fig. 1. Schematic Diagram of CCW system

2.2 Modelling of CCW

To model CCW system, flow network was used. Flow network can be modeled with standard volumes and junctions but that approach is cumbersome and can result in small time steps for the simulation because of the large flows through the small duct volumes[1]. As shown in Fig. 2, Flow network consists of nodes and links. Pipe junctions or heat sources can be modeled as nodes, and pipes can be modeled as links connecting two nodes or node to control volume.

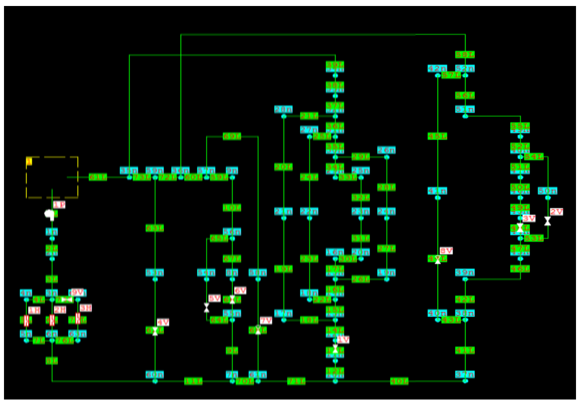

Fig. 2. GOTHIC flow network model of CCW

To evaluate the cooling performance of the nuclear power plant, conservatively determined flow rates should be supplied to each heat source. Valves were installed at the links connected to heat source, and openings were adjusted so that flow rates closely match the target flow rates.

The CCW heat exchanger in plant is a plate type heat exchanger, for which a detailed model has not been developed. Therefore, shell and tube heat exchanger with the equivalent heat transfer coefficient was used.

3. GOTHIC Simulation Result

Fig. 3. shows target and calculated mass flow of each component. The discrepancy between the calculated and target flow rates was less than 0.6%, demonstrating that the developed model closely calculates OPR-1000 flow conditions through valve opening adjustments.

Fig. 4. shows the fluid temperature at the outlet of the CCW heat exchanger. It is observed that the fluid temperature stabilizes at approximately 93.37°C after about 250 seconds.

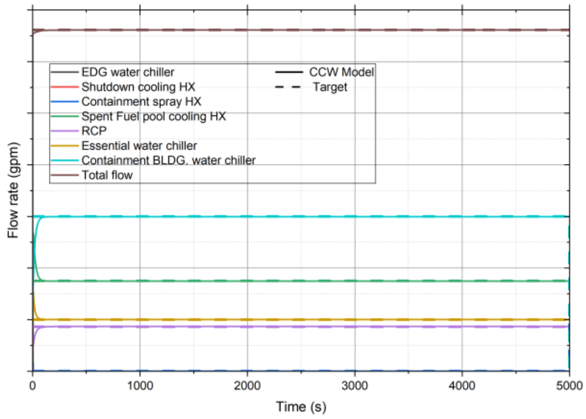

Fig. 3. CCW system mass flow

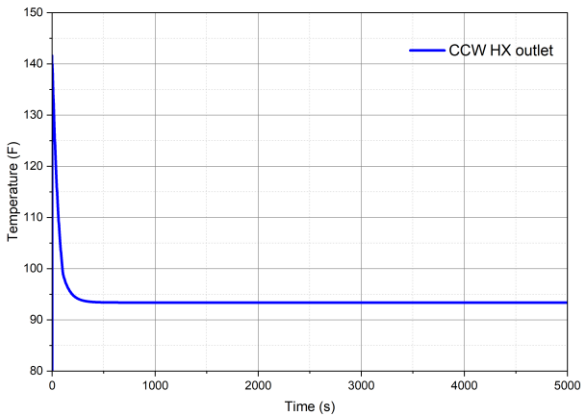

Fig. 4. CCW heat exchanger inlet & outlet temperature

4. Conclusions

In this study, a GOTHIC model of CCW system was developed based on the system configuration described in the FSAR and plant operating conditions. To achieve the target flow rates specified for each cooling load, valves were installed at the corresponding links, and their openings were adjusted. As a result, it was confirmed that the calculated flow rates in the model closely matched the target flow rates, demonstrating the adequacy of the developed model in representing the actual system behavior. In addition, it was confirmed that the heat exchanger in the CCW closed loop continuously removed heat maintaining the cooling function of the system.

With further development of detailed heat exchanger models and the implementation of various operating modes, the proposed model can be extended to simulate the CCW system under a wide range of plant operating conditions. Ultimately, the validated model can be utilized to evaluate the cooling performance of the CCW system under varying seawater temperature conditions.

Acknowledgement

This paper was supported by the 'Development of technology for evaluating cooling system margin of a nuclear power plant related to the ultimate heat sink'.

REFERENCES

[1] EPRI project manager Matthew Nudi, GOTHIC thermal hydraulic analysis package technical manual, May 2022.