Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 9-10, 2024

Development of MCR HVAC Simulator for Digital Twin

Seunghoon Kang[a], Sungman Son[a], Daekyung Lee[a], Choengryul Choi[a*]
[a]*ELSOLTEC, 1401-2 U-Tower BD., 184, Jungbu-daero, Giheung-gu, Yongin-si, Gyeonggi-do, 17095, Korea.*
**Corresponding author: crchoi@elsoltec.com*

***Keywords : Simulator, Digital Twin, MCR, HVAC**

1. Introduction

Recently, digital twins are expanding beyond fields such as smart cities and factory automation monitoring to the entire industry. In power plants, there are various attempts aimed at integrated management based on digital twins that go beyond the level of power plant monitoring using digital twins and introduce simulation technology. In this study, we develop a simulator that controls the HVAC ROM (Reduced Order Model) of the main control room (MCR) of a nuclear power plant based on CFD analysis results.

2. ROM based on AI

ROM is a technology that reduces the computational complexity of mathematical models in CFD simulations. It is being applied to the development of a digital twin that supports real-time simulation, replacing time-consuming CFD analysis.

ROM maintain the performance of ordinary CFD analysis results, predict the behavior of physical systems, and help users derive governing equations that allow them to obtain the desired results. ROM created through learning allows the operation of the system to be predicted using minimal computational resources according to changes in analysis variables specified by the engineer.

Figure 1 below shows the procedure for creating ROM using artificial intelligence.

Fig. 1 ROM generation process

In this study, HVAC conditions similar to actual power plants were applied to the previously developed virtual nuclear power plant MCR, and ROM was used to predict state changes within the MCR according to key variables (temperature, flow rate) [1].

3. HVAC Simulator for ROM

3.1. MCR HVAC

Nuclear power plant MCR HVAC is responsible for maintaining comfortable environmental conditions and appropriate working conditions for workers and equipment in all areas of the main control room area, namely MCR, TSC, Computer Room, HVAC Equipment Room, and Toilet & Kitchen.[2]

MCR HVAC consists of a total of four subsystems, and each subsystem is as follows.

- Air supply and recirculation system
- Emergency makeup & air purification system
- Exhaust system
- Computer room air conditioning system

In the conducted research, an HVAC control simulator was developed according to changes in outdoor temperature for normal operation in the area.

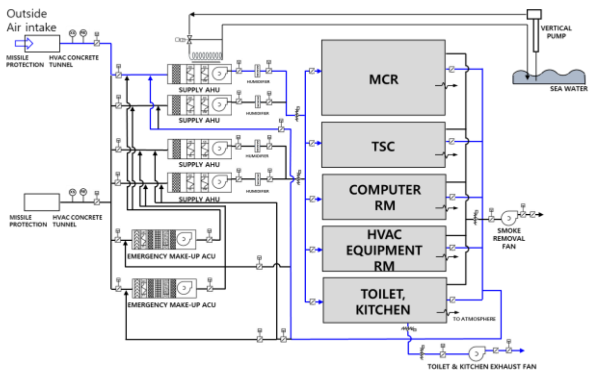

Fig. 2 MCR area HVAC Normal Operation Diagram

3.2. HVAC Simulator

3.2.1. Considerations

In this study, operating conditions (temperature, flow) for MCR and other rooms were set by referring to the MCR area HVAC data provided to NRC.ORG by KEPCO-ENC and KHNP[3]. Before developing the simulator, we manually calculated the temperature and flow rate change tables to be used in the simulator with the following prerequisites.

- When the temperature of the outside air and the calorific value of each room are changed, the total heat transfer coefficient of the AHU heat exchanger changes to the set air temperature of 20℃ at the AHU outlet.
- Changing the total heat transfer coefficient means that the flow rate of circulating coolant (sea water) changes.
- The flow rate of the coolant is variable so that the temperature within the MCR can be maintained within an appropriate temperature.

The flow distribution ratio delivered to each room was calculated based on the MCR operating conditions and other ROOM operating conditions. The amount of heat generated was calculated as a virtual value by selecting representative facilities and devices for each room.

3.2.2. Process of HVAC Simulator

The developed simulator follows the flow in Figure 3. As shown in the figure, 2022 weather database (hourly temperature, SKN, Ulsan) obtained using the Korea Meteorological Administration OpenAPI[4] is used as input data. Depending on the outside temperature, the AHU operation mode heats or cools the circulating air and calculates it until the operating conditions are satisfied (stable).

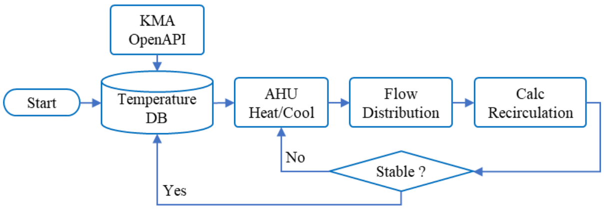

Fig. 3 Process of HVAC Simulator

The simulator was developed considering the leakage flow rate in each room and temperature management by its own air conditioner.

4. Results

4.1. Simulator UI

The simulator was developed as an input module for the digital twin for HVAC control of the MCR area, which changes according to the outside temperature in the actual digital twin. Since the digital twin system to be developed in the future does not have a specialized UI and operates as an internal module, the user interface was designed simply so that only the operation and operating status of the simulator can be identified.

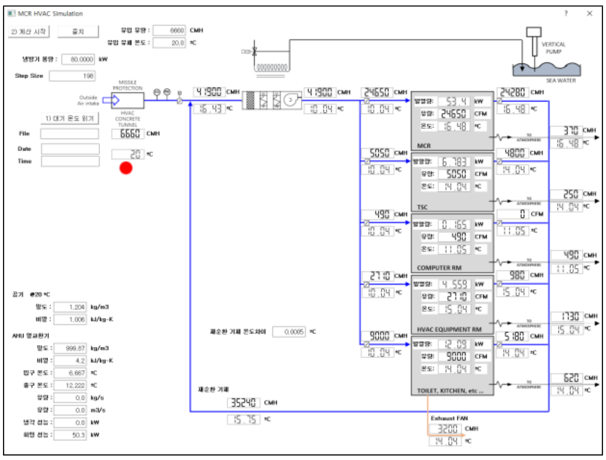

Fig. 4 Simulator UI

4.2. Air temperature vs AHU Powers

As described above, the simulator used 2022 hourly weather (temperature) data in the Ulsan area as input and simulated temperature changes in MCR, TSC, Computer Room, HVAC Equipment Room, and Toilet & Kitchen according to the operation of the AHU.

Figure 5 shows the AHU heat capacity changing with changes in outside temperature. To simplify the simulation, the AHU capacity change was set to increase by 10 in the range of -20.0 (Heating) to 130.0 (Cooling).

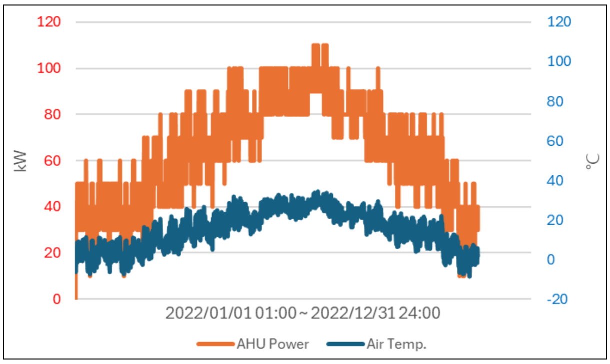

Fig. 5 Air temperature vs AHU power

5. Conclusion

The simulator described in this study was developed for HVAC control according to external air temperature in a virtual nuclear power plant digital twin. AHU operation was simulated to satisfy the operating conditions of an actual nuclear power plant, and the HVAC status of each room could be confirmed according to the changing AHU capacity. The results of this study are expected to play a significant role in digital twin simulation of virtual nuclear power plants in the future.

ACKNOWLEDGEMENT

This work was supported by the Technology development Program(S3323979) funded by the Ministry of SMEs and Startups(MSS, Korea)

REFERENCES

[1] Seunghoon Kang, et al, Development of MCR HVAC ROM model for simulation-based digital twin system, Trans. of the KNS Autumn Meeting, 2023.
[2] JinWoo Hyun, FEG Development of MCR HVAC System for NPP, Trans. KPVP, 2012, 09, pp.21-25
[3] KEPCO-ENC, KHNP, APR1400 Design Control Document Tier 2, NRC.ORG
[4] https://data.kma.go.kr/api/selectApiList.do?pgmNo=42