Proceedings of the 2021 Winter Simulation Conference
S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, eds.

MODEL PREDICTIVE CONTROL OF COOLING SYSTEM FOR AN EXISTING BUILDING

Young-Sub Kim
Cheol-Soo Park

Department of Architecture and Architectural Engineering, Seoul National University
1 Gwanak-ro
Gwanak-gu
Seoul, 08826, SOUTH KOREA

ABSTRACT

This commercial case study presents the development of a data-driven simulation model and its use for control optimization of HVAC cooling system for a building. Time series data is collected from building energy monitoring and automatic control system. Inputs and outputs are selected considering a causality to predict indoor air temperatures for next 20 minutes and to find optimal control variables of HVAC system. For three days' validation, electric energy was saved by 31% compared to the existing rule-based control.

1 INTRODUCTION

The target building is a food factory building located in Nonsan, Korea (Figure 1). Three chillers (CH1, CH2, CH3) and two air handling units (AHU1, AHU2) provide cold for the air-conditioning zone (red box in Figure 1). The chillers and AHUs can be controlled individually with the following three control variables: chiller's operation (on/off), outdoor air intake ratio (0, 30, 70, 100%), and supply air fan's frequency (0, 20, 40, 60Hz). Four indoor air temperature and humidity sensors are measured as shown in Figure 1.

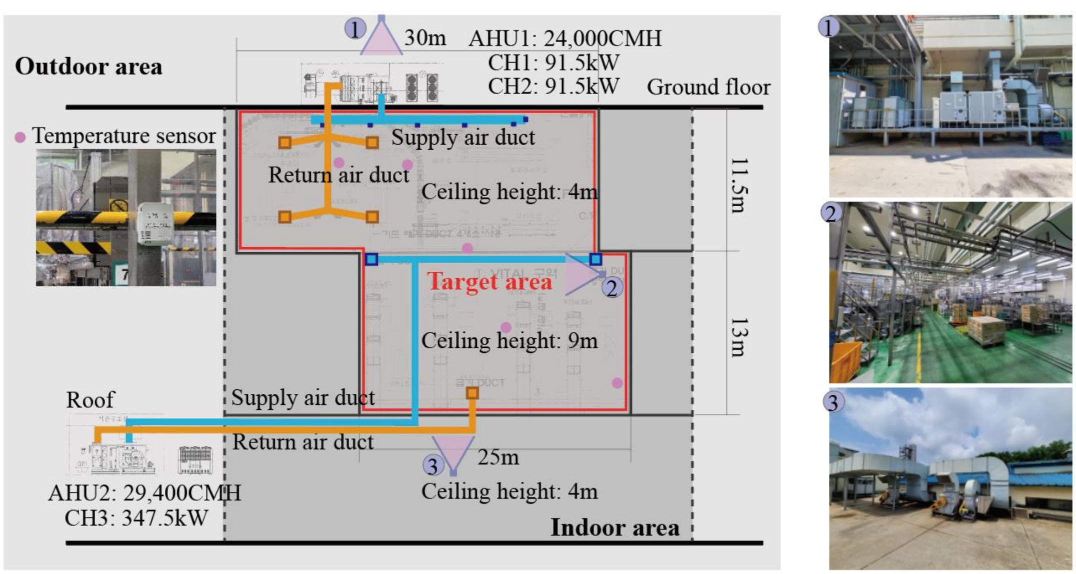

Figure 1: Target building's floor plan

2 MACHINE LEARNING SIMULATION MODEL

Two simulation models were developed for each AHU. One simulation model is to predict supply air (SA) temperature and humidity with the inputs of outdoor air (OA) and return air (RA) temperature and humidity, and the aforementioned three control variables. The time horizon is set to 20 minutes. The other simulation model is to predict indoor air (IA) temperature with the inputs of the predicted SA temperature and the control variables. The models were developed using ANN with the collected data from 1st to 20th, June 2021. The model's MBE and CVRMSE are 3.63% and 6.99%, respectively. The data-driven model can accurately predict multiple points of indoor air temperatures in a large open space.

3 RESULTS AND CONCLUSION

Model Predictive Control (MPC) was applied to the target building from 25th to 29th June, 2021. The optimal control variables that minimize total energy consumption of the chillers and AHUs were found while keeping the difference between predicted IA temperature and the setpoint temperature less than 2℃. During the test period, electric energy was saved by 31% (MPC: 1,779 kWh) compared to the existing rule based control (2,575 kWh) (Figure 2). MPC could provide appropriate amount of cold for the target zone, while minimizing total energy consumption by the chillers and AHUs (Figure 2). In addition, it could regulate OA intake ratio depending on the difference in an enthalpy between OA and RA, which enables AHUs to provide SA temperature more energy-efficiently than the existing rule-based control. This approach can be applied to other existing buildings with several environment sensors and a simple data logging system.

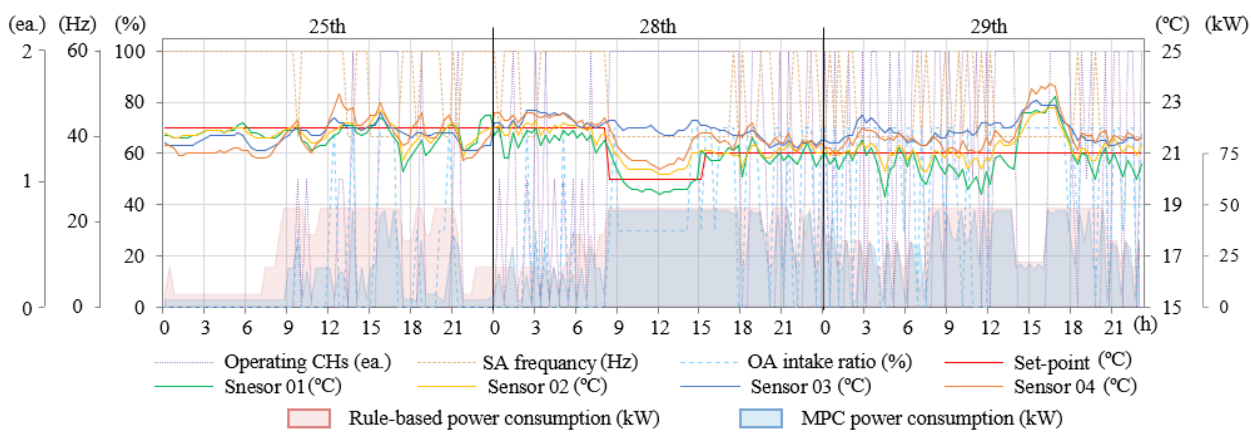

Figure 2: Indoor air temperature and three control variables (25th, 28th and 29th June, 2021)

ACKNOWLEDGEMENTS

This work was supported by Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (20202020800030, Development of Smart Hybrid Envelope Systems for Zero Energy Buildings through Holistic Performance Test and Evaluation Methods and Fields Verifications)

REFERENCES

Afram, A., and Janabi, F. 2014. "Theory and Applications of HVAC Control Systems – A Review of Model Predictive Control (MPC)". *Building and Environment* 72:343-355.

Kusiak, A., and Xu, G. 2012. "Modeling and Optimization of HVAC Systems Using a Dynamic Neural Network". *Energies* 42(1):241-250.