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

REAL-TIME MODEL PREDICTIVE HEATING CONTROL FOR A FACTORY BUILDING USING LUMPED APPROACH

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ABSTRACT

This case study focuses on a Model-Predictive Control (MPC) result using predicted indoor air temperatures at multiple points in a factory building. Rather than resorting to a full-blown dynamic simulation model, the authors developed a lumped simulation model only using temperature sensor & HVAC system operation status because of the building with lack of information. It is found that the model can accurately predict the temperatures and then is beneficially used for optimal on/off control of 61 unit heaters installed in a factory building. Owing to the simulation model's prediction, energy savings by 56.3% was realized, while the indoor air temperatures were maintained within comfortable ranges close to heating setpoint temperature.

1 INTRODUCTION

Approximately 30% of factory buildings do not have targets and improvement schemes for energy efficiency (Manufacturer, 2018). In addition, the staff prefer simple on/off-based controls and are reluctant to disclose or modify how HVAC system operate. This often leads to thermal discomfort for workers due to excessive heating and cooling. Therefore, it is necessary to promote a comfortable indoor environment and energy saving through an appropriate HVAC system control. MPC is the control technique to save energy by maintaining a comfortable indoor environment and operating efficiently in response to future loads. Many methods exist to predict indoor thermal behavior, e.g. Computational Fluid Dynamics, a full-blown dynamic thermal simulation, etc. The aforementioned methods are not suitable for a large factory building due to uncertainty of complex environment, computation time. Therefore, the authors present a lumped approach that can predict temperatures aggregated over multiple points and its application to MPC focusing on occupant's area. The study was successfully conducted, leading to significant energy savings (56.3%) over three weeks and less temperature deviation in the large factory building.

2 METHODOLOGY

The target building is a factory building (floor area: 6,867m^2, a single-story), located in Incheon, South Korea (Figure 1). The heating of the building is provided by 61 unit heaters (capacity per unit: 58.1 kW). The unit heaters are operated based on a facility manager's experience and subjective judgment. In winter, all unit heaters are simultaneously switched on or off at designated times. Such operation scheme often causes overheating and significant deviation of indoor air temperatures from heating setpoint temperature (13℃ in winter time). To overcome this problem, the authors divided the entire indoor space into ten thermal zones denoted by A1-A10 (Figure 1). At each zone, one to four temperature sensors are installed. For MPC, ten machine learning models were developed to predict indoor temperatures of A1-A10. The model's input variables are measured indoor temperature (T), outdoor air temperature (OAT), and unit heater's status (U, on/off) at the sampling time of 10 minutes. The model's output variable is future indoor temperature over 10 minutes. The optimal control variables (U, on/off) were found as an exhaustive search method. The MPC process consist of 5 phases (Figure 2). The data measured from the equipment (phase 1) was transmitted to the data storage server (phase 2). And then, Using indoor air temperature predicted by ANN (phase3), the operation state of the unit heater was determined with the optimization logic (phase 4), and the operation signal was transmitted to the system through the command & control server (phase 5).

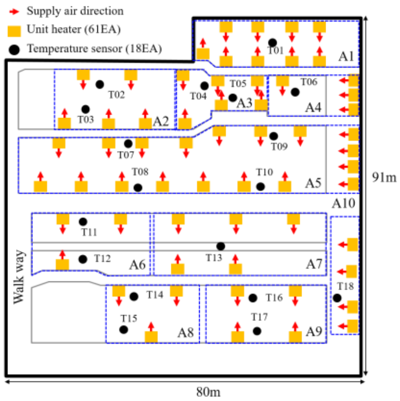

Figure 1: Target building

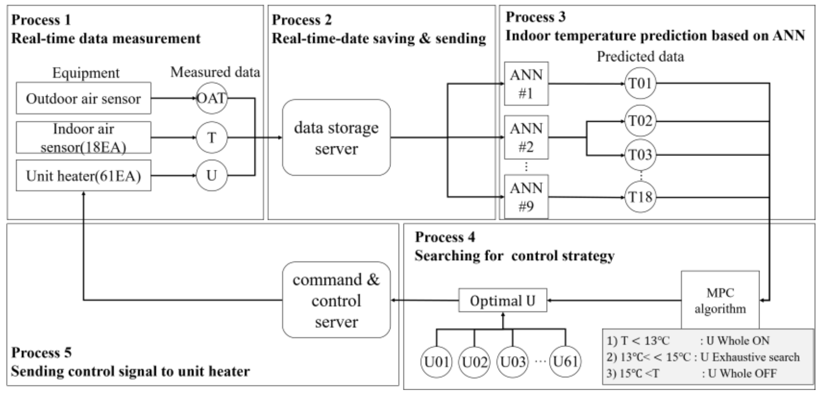

Figure 2: MPC process

3 RESULTS AND DISCUSSION

As a result, from Feb. 22, 2021 to March 12, 2021(the number of days: 14, data points: 924), the unit heaters' operating hours as well as heat supply were significantly reduced (baseline heating hours: 1,846 hours → MPC: 806 hours; baseline heat supply: 107.3 MWh → MPC: 46.9 MWh), leading to energy savings by 56.3 %. In addition, the overheating and indoor temperature deviation were also decreased (Figures 3, 4). In summary, it can be concluded: (1) the lumped model is good enough and can be beneficially used for predicting indoor temperatures for a large factory building, (2) For large spaces and complex building, subdivided air conditioning zone control with focus on occupants can contribute to energy savings and thermal comfort, (3) the data-driven machine learning model can be a good alternative to the 1st principles based model.

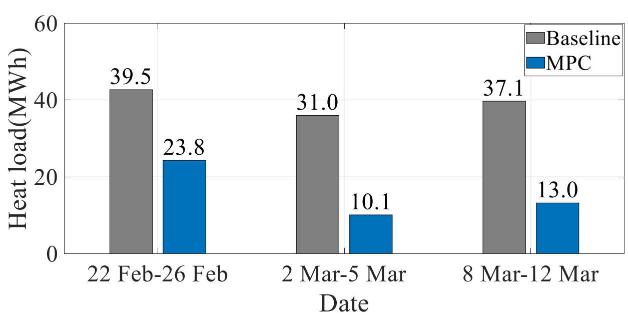

Figure 3: Comparison of heat supply (baseline vs. MPC)

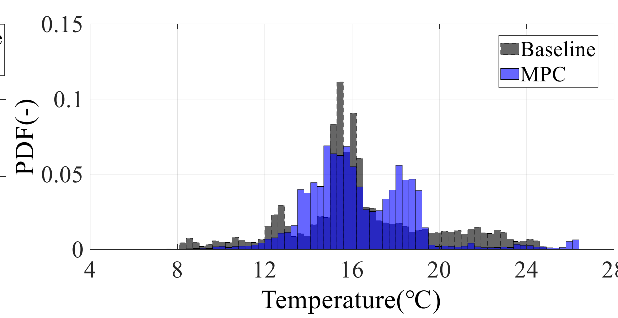

Figure 4: T01 (baseline vs. MPC)

ACKNOWLEDGEMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20202020800360).

REFERENCES

Manufacturer, T. (2018). Failure to prioritise resource efficiency.