A Study on Optimization of Multi-Energy Smart Apartment Operation Considering COP of Heat Pump

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Introduction

In response to worsening global warming, households integrate Renewable Energy Sources (RES), raising the importance of energy management. Many residential models adopt Air Source Heat Pump (ASHP) for cooling/heating and hot water because of their high Coefficient of Performance (COP). However, previous studies often assume a rated COP, overlooking the strong dependence of heat-pump efficiency on heat-source temperature, especially for ASHPs whose COP varies with outdoor air temperature. Furthermore, compared to ASHP, ground- and water-source heat pumps offer more stable inlet temperatures and can achieve higher COP. Moreover, Heat Pump for Simultaneous heating and cooling (HPS) can recover condenser heat to meet hot-water demand, improving efficiency when cooling and heating loads coexist [1]. In summer apartments, cooling and hot water loads frequently overlap, suggesting an opportunity to reduce energy use and emissions.

Therefore, in this study, we consider the COP of HP and compare and examine the impact of HP technology selection on the operation of Smart Apartment (SA). Specifically, we consider the SA using ASHP as the conventional model and the SA using water-source HPS as the proposed model and evaluate the economic and environmental performance of both models by implementing optimal scheduling of controllable loads. We then compare the proposed model with the conventional model to verify its effectiveness.

Simulation

The SA model proposed in this study is shown in Figure 1. The SA is equipped with Photovoltaic (PV) system and Battery Energy Storage System (BESS), and Heat is stored in the hot water tank and cold water tank by the water source HPS, and hot water demand is met by the hot water tank, and cooling demand is met by using heat exchanger from the cold water tank. In the conventional model, PV and BESS are installed, and hot water and cooling demands are met using ASHP (Air conditioner and HP water heater). The HP unit and BESS are controllable loads, and their operation methods are determined by an optimization problem that minimizes the SA's operation costs.

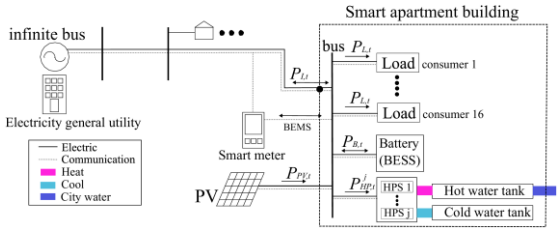

Figure 1 Smart apartment model (Proposed).

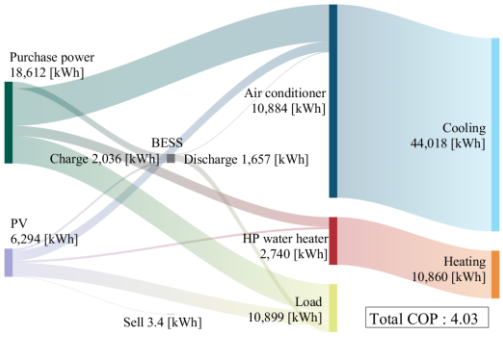

Figure 2 Energy flow (conventional model).

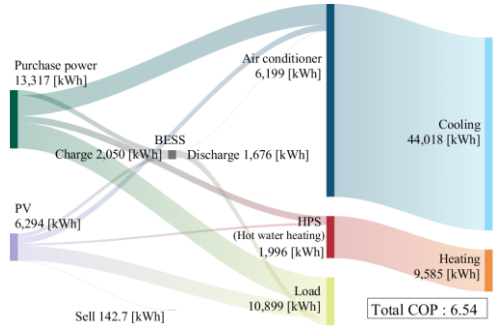

Figure 3 Energy flow (proposed model).

Results and Discussion

Figures 2 and 3 show the energy flow calculated from the simulation results of each model. From Figures 2 and 3, the proposed model achieves a high COP using the water-source HPS and is able to meet heating and cooling demands with small input power. Compared to the conventional model, the proposed model improved the total COP by 2.51, reduced operating costs by 29.9%, and reduced CO_2 emissions by 28.4%, demonstrating the effectiveness of the proposed model.

References

[1] E. Osterman and U. Stritih,"Review on compression heat pump systems with thermal energy storage for heating and cooling of buildings, "Journal of Energy Storage, vol. 39, p. 102569, Jul. 2021.