Energy Performance Investigation of PVT assisted Heat Pump System for a Net Zero Office Building

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Abstract

This paper investigated the energy saving potential of the photovoltaic and solar thermal panel (PVT) assisted multi-source heat pump system for net zero office buildings. We proposed the schematic of the PVT assisted multi-source heat pump system to serve heating and domestic hot water load. The energy saving potential of the proposed system was also analyzed by simulation research compared with the conventional system. The conventional system composed of the air-source heat pump integrated with PV system. It was found that the proposed system can save 33% of operating energy consumption compared with conventional system. The renewable energy penetration rate of the proposed system showed 14.8% higher than the conventional system.

Keywords: PVT assisted heat pump system, multisource heat pump, BIPVT

1. Introduction

Over the last decades, the interests in terms of the renewable energy system has been raised to improve the renewable energy penetration rate and energy efficiency of the building service system. Recently, photovoltaic and solar thermal panel (PVT) system has been interested caused by the energy generation density per unit area is much higher than the conventional photovoltaic (PV) and solar thermal collector. The temperature raises of PV panel surface is critical causes of the degradation of power generation. PVT is one of the solutions to cool the PV panel and also produce thermal energy sources for heat pump system to serve heating and domestic hot water. Also, recently researches have been conducted to reduce the installation cost of PVT, the PVT panel is integrated with the building surfaces and wall, so it calls building integrated PVT (BIPVT). Thermal demand of heating season is much higher than the cooling season. The south-facing vertical wall is good place to install the solar thermal panel. It caused that the solar radiation of the south-facing wall in cooling season is much lower than that in heating season. The stagnation problem of solar collector can be solved by installing the PVT into the south-facing wall. This paper presents the energy saving potential of the PVT assisted multi-source heat pump compared with the conventional air-source heat pump system.

2. PVT assisted multi-source heat pump system

Figure 1 shows the schematic of PVT assisted multi-source heat pump system and conventional heat pump system. In this proposed system, the PVT system simultaneously produced electric and thermal energy. When the solar irradiation reached panel, about 20% of electricity and 25% of thermal energy were produced. The electricity is directly used building or operation of heat pumps, the thermal energy is stored into the buffer thermal energy storage (TES). The temperature above 50 °C can supply directly to the heating demand or hot water demand, but the high temperature leads the degradation of power generation in PV panel. In this research, the target temperature of PVT outlet water is set at 35 °C. Then, the stored thermal energy is used as a heat source of heat pump. The heat pump produces over 50 °C hot water and stored into another TES. The size of this TES should be covered by the daily thermal load. During the heating season, the daytime stored thermal energy is used as a heat source of heat pump during the daytime. Caused by the weather condition, the PVT cannot produce thermal energy, the air-source heat pump is operated. In cooling season, the thermal energy produced by the PVT is stored into the buffer TES during the daytime, and cooling water is produced by the heat pump with air-source. Then, during the nighttime, the hot water is produced by the heat pump with buffer TES heat source.

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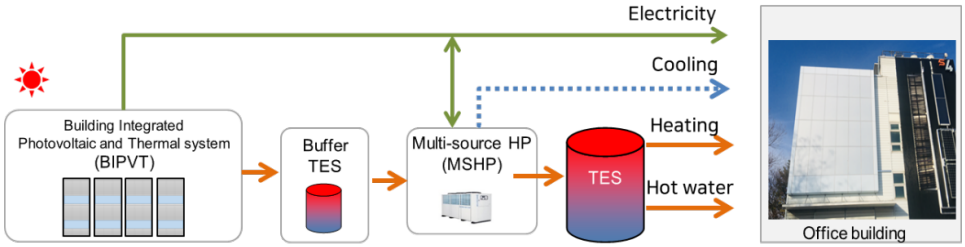
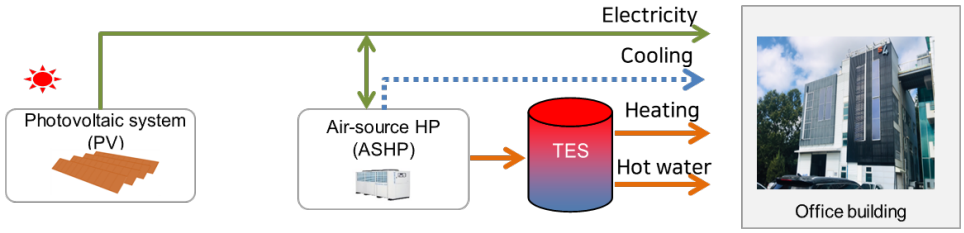


(a) PVT assisted heat pump system

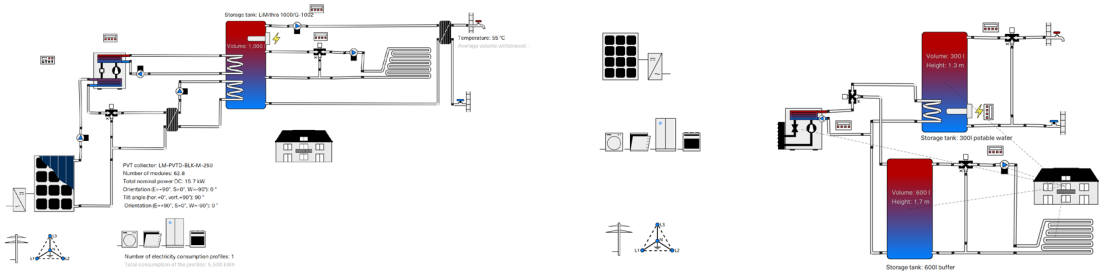


(b) Conventional system

Fig. 1: Overview of system schematics

3. Simulation study

The energy saving potential of the proposed system was analyzed by the simulation work. In order to simulate the PVT panel, the manufactured data was used in Polysun software. The power generation and thermal energy output was simulated using Polysun software (Fig.2). The selected office building is four-story and total floor are of 400 m^2, it is assumed that the PVT panel is installed into the south-facing wall. The electric load and thermal load (i.e., heating, hot water and cooling demand) have been monitored, and we used measured data. We found that the annual heating and hot water load of the building in each floor is 10,291 kWh_{th}. For the heat pump simulation, experimental data for multi-source heat pump was used. This multi-source heat pump is installed in the greenhouse, and 30 RT capacity of heating and cooling. This heat pump uses air source and water source, and the heat source can be selected manually or automatically. The heat pump operation schematic is that the water source is primary used as a heat source, but when the temperature of heat source is lower or higher than the target temperature, the heat pump is automatically changed by the air-source operation mode. The heat pump simulation model is generated by the measured data, and it serves the coefficient of performance (COP) depends on the inlet source side water temperature, flow rate, outlet load side water temperature, and flow rate. In order to serve heating and domestic hot water, about 1000 Liter of storage tank was used for the PVT source heat pump system. The air-source heat pump system used 300 Liter and 600 Liter of water storage tank for serving domestic hot water and heating, respectively.



(a) **PVT source heat pump system configuration** **(b) PV and air-source heat pump system configuration**

Fig. 2: Overview of system schematics

4. Results

In Table 1 below, hourly simulation based annual energy performance on the proposed system was investigated compared with the conventional system. The installation capacity of PVT is 15.4 kWp and 88 m^2 in each floor. The total annual power generation of PV is 6.1 MWh. The heat pump operating energy consumption of the proposed

system can save 33% for serving heating and hot water demand via conventional system. It mainly caused that the proposed heat pump enhanced over 30% of COP compared with air-source heat pump. It was found that the renewable energy penetration rate is predicted to be 82.0% and 96.8 % of conventional system and proposed system, respectively. The proposed system can improve 14.8% point of renewable penetration rate.

Tab. 1: Impact of system configurations

	PV-ASHP	PVT-MSHP
Heating and hot water demand	10,291 kWh_{th}/a	10,291 kWh_{th}/a
Cooling demand	12,134 kWh_{th}/a	12,134 kWh_{th}/a
Heat pump power consumption	7,475 kWh_{el}/a	6,332 kWh_{el}/a
PV generation	6,132 kWh_{el}/a	6,132 kWh_{el}/a
Net-zero	82.0%	96.8%

5. Conclusions

In this paper, the energy saving potential of the PVT assisted multi-source heat pump has been investigated via compared with the conventional air-source heat pump system. It was found that heat pump operating energy consumption of the proposed system can save 33% for serving heating and hot water demand via conventional system. It was also found that the renewable energy penetration rate of the proposed system can improve 14.8% point of compared with that of the conventional system.

6. Acknowledgments

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7. References

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