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Study on the Annual Energy Performance of Parallel Solar-Assisted Air Source Heat Pump Integrated with PCM TES for DHW

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Extended Abstract

Domestic hot water (DHW) and space heating (SH) are occupying more than 65% of carbon dioxide emissions in the residential sector. As global warming is critical issue, reducing carbon dioxide emissions is essential by decreasing fossil fuel energy use and improving energy efficiency. Air source heat pumps (ASHPs) are promising technologies that can provide DHW and SH with higher energy efficiency with less carbon dioxide emissions than conventional gas boiler systems [1]. Recently, heat pumps (HPs) integrated with photovoltaic thermal modules (PVT), referred to as PVT-HP or solar-assisted heat pump (SAHP), have gained attention. PVT system can reduce HP operation time and power consumption, resulting in increased overall efficiency. However, owing to the imbalance between energy demand and the supply of renewable energy in these systems, thermal energy storage (TES) is required. Additionally, TES acts as a buffer tank, contributing to a reduction in the heating capacity required from the HP [2].

Various studies have been conducted on SAHP and TES. Bae et al. [3] experimentally investigated the effect of the PVT-ASHP integrated with two water storages for DHW and space heating. The coefficient of performance (COP) of the system improved by approximately 52% compared to the ASHP system. Huan et al. [4] found that the parallel SAHP achieved 34.4% higher COP than the serial SAHP during the annual operation of a hot water supply system at a university in Xi'an, China. For TES, phase change materials (PCMs) have been gaining attention owing to their significant latent heat during phase transition. Cunha et al. [5] denoted that a SAHP with PCM TES system could store more energy within narrower temperature range than water storage, resulting in 56% reduction of annual CO_2 emissions, and energy savings of 76% compared to the conventional gas boiler system. However, research on PVT-ASHP system integrated with PCM TES is limited.

In this study, the annual energy performances of DHW systems are analysed using the dynamic simulation program TRNSYS. Parallel solar-assisted air source heat pump (SAASHP) integrated with two different TESs, PCM TES and water storage, are selected as the analysed system. DHW load profile is set according to the 210 L water tank load profile in the European standard EN 16147[6]. For the solar source, a PVT module with 1.58 m^2 absorber area is selected. System COP, electrical power, and thermal energy are primarily used as energy performance parameters. As a result, the SAASHP with PCM TES shows 9.2% higher system COP than the SAASHP with water storage through a year. The annual electricity generations of the PVT module for both cases are 931 MJ. The thermal energy generation of the PVT module of the PCM TES case is 8.1% higher than that of the water storage case owing to PCM TES's superior thermal characteristics. PCM TES demonstrates an isothermal characteristic during charging and discharging, which contributes to a lower temperature of the circulating water through the condenser of ASHP and PVT module compared to that of water storage. The lower circulating water temperature results in higher ASHP COP and larger thermal energy generation from PVT, leading to better overall system COP compared to the water storage case. However, the total amount of thermal energy from PVT is only 0.5% of the energy demand for DHW owing to the limited PVT area. Further optimization of the PVT module area can lead to more effective system configuration.

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