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Economic and Performance Analysis of Hybrid Water Source Heat Pumps at Low Water Temperatures

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Extended Abstract

The building sector is responsible for approximately 36% of the overall global energy consumption, with 50% allocated to space heating, cooling, and water heating [1,2]. Predictions indicate that the energy utilized for heating and cooling buildings will surge to about 65% of the total energy consumption in the building sector by 2050. This escalation is attributed to factors such as population growth, accelerated urbanization, and an expansion in building floor area [3]. In response to this trend, there is a growing demand for water-source heat pumps (WSHPs) in both residential and industrial facilities owing to their cost-effectiveness in terms of investment and operation [4]. WSHPs leverage water with high energy density as a heat source, leading to enhanced energy efficiency in building heating and cooling processes. Despite their advantages, WSHPs are subject to regional constraints and necessitate significant pumping power. Raw-water source heat pumps (RWSHPs) have emerged as an alternative solution, drawing attention for their utilization of a relatively clean raw water source (RWS), which poses a lower risk of fouling compared with other water sources. Moreover, RWSHPs exhibit high performance levels with minimal power consumption for water pumping. However, it is essential to note that RWSHPs may encounter a reduction in water source temperature during winter, leading to a decline in overall performance. This study investigates the economic and performance analysis of a solar-assisted RWSHP (SA-RWSHP) using the TRNSYS software tool to provide an effective solution for the performance degradation of WSHPs at low water source temperatures. The SA-RWSHP can improve performance during the heating period by elevating the entering water temperature (EWT) using solar collectors. During the cooling period, a solar heat source can be used to produce domestic hot water. Optimal design parameters are determined by analyzing the performance of the SA-RWSHP. Additionally, the performance of the SA-RWSHP is compared with that of RWSHP. The optimal flow rates of the pumps on the SBT-, water-source-, and heat-pump-source-sides were determined to be 70, 20, and 40 LPM, respectively, considering the rate of increase in the EWT and heat pump COP (COP_{hp}). Furthermore, the solar collector area was determined to be 14 m^2 considering the point at which the rate of increase in the EWT decreased. Additionally, the performance of the SA-RWSHP was compared with that of the RWSHP based on the optimized system design parameters. During the heating period, the COP_{hp} of the SA-RWSHP was, on average, 12.7% higher than that of the RWSHP owing to the increase in the EWT. During the cooling period, both the RWSHP and SA-RWSHP showed the same COP_{hp} owing to the same EWT and load, without using a solar heat source. Accordingly, during the heating period, the COP_{hp} of the SA-RWSHP increased by approximately 4.3% for every 1 °C increase in the EWT difference between the SA-RWSHP and RWSHP. Furthermore, the annual total system COP (COP_{sys}) of the SA-RWSHP was approximately 18% higher than that of the RWSHP. The LCC of the SA-RWSHP was 7% lower than that of the RWSHP. The payback period of the SA-RWSHP was 13.81 years based on the conventional RWSHP.

References

[1] International Energy Agency (IEA). "2019 global status report for buildings and construction: Towards a zero-emissions, efficient and resilient buildings and construction sector", 2019.

[2] Y. Xu, F. Li, A. Asgari, "Prediction and optimization of heating and cooling loads in a residential building based on multi-layer Perceptron neural network and different optimization algorithms," Energy, vol. 240, 122692, 2022.

[3] J. Conti, P. Holtberg, J. Diefenderfer, A. LaRose, JT. Turnure, L. Westfall, "International energy outlook 2016 with projections to 2040," Washington, District of Columbia: USDOE Energy Information Administration (EIA), 2016.

[4] H. Chen, D. Li, X. Dai, "Economic analysis of a waste water resource heat pump air-conditioning system in north China," *In: Proceedings of the sixth international conference for the enhanced building operations*, Shenzen, China, 2006.