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Performance analysis of a novel solar assisted air source heat pump

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Abstract –Solar assisted heat pumps (SAHPs) are energy-efficient and environmentally friendly heating systems that utilize solar energy in different configurations. In this study, the potential benefits of heating the evaporator inlet air using solar energy as a new method were investigated using a developed correlation. The study focused on a 4 kW air conditioner that achieved a COP value of 4.17 for heating with an indoor temperature of 20°C and an outdoor temperature of 7°C. The aim was to determine how the COP value, evaporator inlet air temperature, and total power consumption changed based on the amount of solar energy transferred when the system was supported using the mentioned method. It was observed that a solar support of 5000 W increased the COP value of the SAHP from 4.17 to 4.99.

Keywords – Solar Assisted Heat Pump, Performance, Evaporator Inlet Air, Solar Heating, Novel System

I. Introduction

The interest in solar assisted heat pump (SAHP) systems has been increasing in recent years due to their more environmentally friendly, sustainable, and efficient heating solutions achieved through the integration of solar energy into the system [1]. Currently, buildings account for approximately 40% of total energy consumption, with heating applications representing the largest share of this consumption, reaching 55% in the United States, 70% in China, and 80% in Europe [2]. Solar energy is a renewable, clean, and easily accessible energy source that can contribute to environmentally friendly and sustainable energy management in buildings when used for heating purposes [3]. Heat pumps, on the other hand, are energy-efficient heating systems that can transfer heat from a cold environment to a warmer one with less input work than the heat transferred [4]. Therefore, the development of suitable solar energy support methods for heat pumps is of great importance for achieving more environmentally friendly and efficient heating solutions.

In this study, the performance improvement resulting from increasing the solar-induced air temperature at the evaporator inlet in a solar assisted air source heat pump (SA-ASHP) was investigated using a correlation based on model results. The change in power consumption and COP of the solar assisted heat pump was determined in response to the solar energy transferred to the evaporator inlet air, thus demonstrating the benefit derived from solar energy utilization.

II. Materials and Method

The refrigerant, circulating through the components of the air source heat pump (ASHP), absorbs heat from the outdoor environment through the evaporator and transfers it to the indoor environment at a higher temperature via the condenser, facilitated by the compressor. This thermodynamic process primarily involves heat transfer between the refrigerant and the air at the evaporator and condenser, as well as the transfer of input power to the refrigerant in the compressor. In addition, in the SA-ASHP system examined, the evaporator inlet air is heated by solar energy.

Figure 1 presents the energy equations for the air and refrigerant in the thermodynamic cycle of the proposed SA-ASHP.

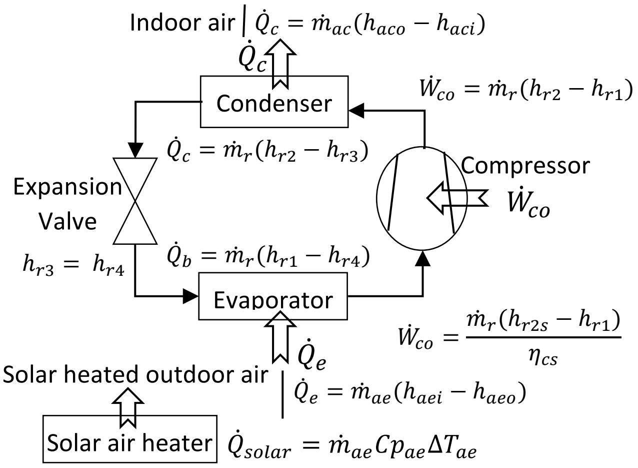

Fig. 1 Energy equations for the air and refrigerant in the thermodynamic cycle of the proposed SA-ASHP

The developed model, based on the provided energy equations and the logarithmic mean temperature differences in the evaporator and condenser, has allowed for the generation of correlations that provide the variation of COP value with respect to the evaporator inlet air temperature. In the previous study, a detailed methodology related to the model and correlations was presented [5]. For the case of heating the indoor environment at a nominal heating load with a temperature of 20°C, the following correlation, based on evaporator air inlet temperature T_{ae}, has been used;

$$COP_{ratio} = 0.3772(10^{-3})T_{\text{ae}}^{\;2} + 0.016T_{\text{ae}} + 0.8676 \quad (1)$$

The heating load of the evaporator $\dot{Q}_e$ and the total input power $\dot{W}_{in}$ can be calculated using the COP value and the condenser heating load $\dot{Q}_c$ with the following equations:

$$COP = COP_{ratio} \cdot COP_{nominal} = \frac{\dot{Q}_c}{\dot{W}_{in}} \quad (2)$$

$$\dot{Q}_c = \dot{Q}_e + \dot{W}_{in} \quad (3)$$

III. Results and Discussion

The 4 kW capacity air conditioner, operating at a nominal heating power of 4 kW with a COP value of 4.17, was studied under the conditions of indoor and outdoor temperatures of 20°C and 7°C, respectively. The changes in evaporator inlet air temperature, COP value, and total power consumption due to the solar heat transferred to the evaporator are shown in Figure 2.

The transfer of 2000W, 5000W, and 8000W of solar heat to the evaporator inlet air results in an increase in COP values from 4.17 to 4.47, 4.99, and 5.58, respectively. The power consumption of the SA-ASHP decreases accordingly to 896W, 802W, and 717W, from an initial value of 959W.

Unfortunately, in this system, the proportion of the decrease in SA-ASHP power consumption to the transferred solar energy remains at the level of 3%.

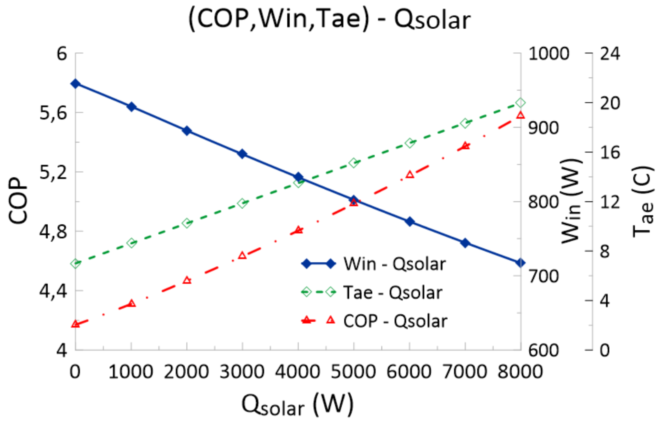

Fig. 2 The changes in T_{ae}, COP, $\dot{W}_{in}$, depending on $\dot{Q}_{solar}$

IV. CONCLUSION

The utilization of solar energy by heating the outdoor air entering the evaporator allows for its direct use in the system without the need for a heat transfer fluid or additional equipment such as a liquid-type condenser.

The increase in evaporator inlet air temperature due to the transferred solar energy leads to an increase in COP and, consequently, a decrease in compressor power consumption. However, the fact that only 3% of the solar energy transferred to the air can effectively be utilized in the indoor environment raises questions about the efficiency of the system.

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