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Suitable Ambient Condition Ranges for Solar Assisted Heat Pump Types

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Abstract **–** Solar assisted heat pump (SAHP) systems meet the heating need by using different heating modes according to their structure. Each heating mode has a range of ambient operating conditions in which it is more advantageous than the others. In this study, the heating modes used by the SAHP system classes are introduced and the ambient condition ranges where these modes are advantageous are discussed and explained.

Keywords – Solar Assisted Heat Pump, Ambient Condition, Solar Radiation, Outdoor Temperature, Frosting

I. INTRODUCTION

The energy need of buildings constitutes 40% of the world's energy consumption and more than half of this need is used for heating purposes [1]. The world's energy need, which has increased dramatically with industrialization, is unfortunately still provided by fossil fuels at a rate of 80% today [2]. Fossil fuel-based CO2 emission is the biggest obstacle to an environmentally friendly and sustainable energy management by causing global warming. According to the International Energy Agency, the increase in CO2 emissions increased by 37% from 1990 to 2021, and this is projected to increase by another 42% by 2040 [3]. Solar assisted heat pumps (SAHP) can reverse this bad trend by meeting the heating need in buildings, thanks to the energy efficient and environmentally friendly heating they provide [4].

In the most basic sense, heat pumps are systems that can transport heat from a low temperature environment to a high temperature environment by consuming less energy than it transfers. The sun can support these systems as a heat source or with direct heating. There are ambient condition ranges where the heating modes of SAHP system types are more advantageous than each other. In this study, the classes of SAHP systems and the heating modes used by these classes are introduced, the boundary conditions for the heating modes are determined and evaluated. In this way, the importance of environmental conditions in the selection of SAHP type has been revealed.

II. SOLAR ASSISTED HEAT PUMP (SAHP) SYSTEMS

Solar assisted heat pumps (SAHPs), as their name suggests, are systems in which heat pumps are supported by solar energy. This support can take place in the thermal sense by using solar energy as a heat source in the evaporator or by directly bypassing the heat pump and meeting the heating demand. Basically SAHPs are divided into two classes as DX-SAHP and IDX-SAHP, according to the direct or indirect transfer of the heat gained from the collectors to the evaporator of the heat pump. IDX-SAHP systems may operate in solar source heat pump (SSHP) mode, which can use the solar energy as heat source, direct solar heating (DSH) mode where solar system bypasses the heat pump and directly heats, and air source heat pump (ASHP) mode, where air is used as the heat source for conditions where solar radiation is insufficient. Series IDX-SAHP has SSHP and DSH modes, parallel IDX-SAHP has DSH and ASHP mode and dual source IDX-SAHP has SSHP and ASHP mode. DX-SAHP, on the other hand, can operate in SSHP, ASHP modes as well as in solar-air source heat pump (S/ASHP) mode, where heat is gained from

both air and solar at the same time, by switching depending on the ambient conditions.

III. Ambient Condition Ranges For Solar Assisted Heat Pump Types

The suitable ambient operating ranges of SAHP systems are related to the heating modes they have. Sezen, K., et al. [4], in the review article, determined the appropriate ambient conditions for these operating modes in the light of reviewed studies, as shown in Figure 1.

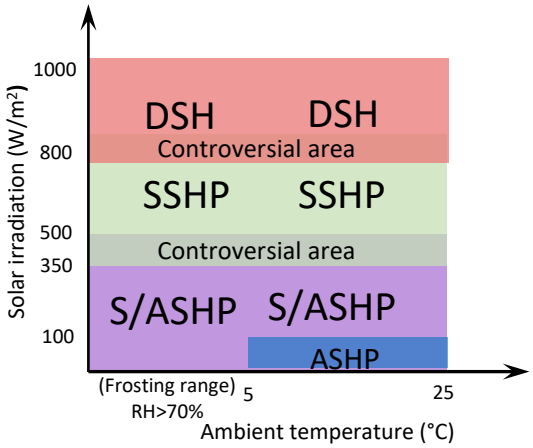

Fig. 1 Proper ambient condition ranges for SAHP heating modes

In DSH mode, the heat gained from solar in the collector must be 10-15°C above the indoor temperature in order to provide effective space heating. Since the high temperature the collector needs to reach will also cause high heat loss, therefore a reasonable heating can be provided by conventional flat collectors in DSH mode only above about 800W/m^2 solar irradiation values.

In the SSHP mode of IDX-SAHP systems, if the solar irradiation is insufficient, the temperature of the insulated heat storage tank will drop below the outdoor temperature, resulting in a performance degradation compared to the ASHP mode. Li, M. Y., et al. [5] observed this decrease in radiation values below about 350W/m^2 in their experimental studies.

SSHP mode is observed in DX-SAHP systems at solar irradiation values above 500W/m^2, where the collector-evaporator temperature rises above the outdoor air temperature. Below this radiation value, there is also heat gain from the air and S/ASHP mode is active.

The ASHP mode is suitable for use in conventional finned air type evaporators at temperatures above 5°C and below 70% relative humidity, which is non-frosting conditions. Since there are no air ducts to be closed in the flat collector structures of DX-SAHP systems, frosting develops more difficult and even solar radiation as low as 100W/m^2 is anti-frosting [6].

IV. CONCLUSION

SAHP systems work with the highest performance by switching between their operating modes optionally or automatically depending on their structure. In this study, the suitable ambient condition ranges for the operating modes of SAHP system types is specified and discussed. While DSH mode requires high solar irradiation, SSHP mode provides lower heat gain than air can provide at irradiation values lower than about 350W/m^2. DX-SAHP systems can benefit from S/ASHP mode at irradiation values below about 500W/m^2, where the collector temperature does not exceed the air temperature. For this reason, the SAHP selection should be made according to the compatibility of its heating modes with the outdoor conditions of the selected region.

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