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Proceeding Paper

Model Based Transient Analysis of a Solar Assisted Absorption System for Multi-Climate Zones with Dynamic Building Load †

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Abstract: The current study investigates the impact of solar collector array, employing flat plate solar collectors (FPC) and evacuated tube solar collectors (ETC) on the transient performance of a solar-driven single-effect absorption cooling system. The investigation was executed for provision of a peak cooling demand of 102 kW for an office building with 147 m^2 of floor. Building geometry has been developed in Sketch Up and modeled in TRNBuild. The system has been simulated in TRNSYS during the summer season through weather data of Cairo (30.0444° N 31.2357° E), Lahore (31.5204° N 74.3587° E) and Abu Dhabi (24° N 54° E). An auxiliary heater (i.e., gas-fired boiler) was installed in the hot storage tank of an absorption chiller loop to maintain the desired generator temperature of 116 °C. The complete system configuration was modeled in TRNSYS. Transient analysis was carried out by the criterion of maximized primary energy saving (f_{sav}) and solar fraction (SF). The main results of the study indicate that to achieve f_{sav} of at least 50%, the required evacuated tube solar collector areas are 600 m^2, 650 m^2 and 700 m^2 for Lahore, Abu Dhabi and Cairo, respectively. Similarly, 50% primary energy is saved for flat plate collector areas of 1000 m^2 for Lahore and Abu Dhabi and 1500 m^2 for Cairo. Furthermore, for both FPC and ETC, Abu Dhabi and Lahore yields maximum primary energy savings of 0.6–0.7 at a storage volume of 10–30 L/m^2. The present model was compared and validated with a published work that showed a deviation of 7.34%.

Keywords: absorption cooling; transient simulations; auxiliary boiler; solar fraction; primary energy savings

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1. Introduction

The global primary energy demand has grown much in past two decades, naturally resulting in an increase/rise in energy consumption. A large number of energy sources are needed to meet this growing demand [1]. The performance of a solar lithium-bromide-H_2O absorption air conditioning system has been assessed for a conference hall located in Sharjah, under hot climate conditions. The cooling load was computed using modeling and simulation analysis, showing the maximum to be in the month of July [2]. A solar thermal absorption air conditioning system was designed that operated under UAE climate conditions. Results suggested that the proposed design matched well to meet the cooling load demand, which was about 300 watts [3]. A hybrid solar assisted system, along with a concentrator, was studied by Rafał Figa et al. A single-floor small-scale residential building was considered for this purpose. A total of 50% primary energy savings was achieved. A single, double and triple effect LiBr-H_2O absorption system powered directly and indirectly, was studied by Md. Azhar et al. With a temperature difference of 6–37 °C between the heat source and generator, the double effect system showed better performance in regard to exergy analysis [4]. A solar driven single effect absorption cooling system was studied by Muhammad Shoaib Ahmed Khan et al. The simulation results reveal that high primary energy savings can be obtained by employing FPC in combination with C-2. Minimum collector area and higher solar collector efficiency can be achieved by using ETC, along with C-2. C-2 with an ETC area of 400 m^2 was required to have a monthly averaged collector efficiency of 0.54 and solar fraction of 0.59 to achieve primary energy savings of at least 0.5. To obtain the same primary energy savings of 0.5, C-1 requires a substantially larger ETC area of 560 m^2 [5].

An exclusively detailed multi-climate analysis regarding the design of a solar field, absorption system and auxiliary integrations was carried out in the current study. Multi-climate regions are taken into account for carrying out analysis to meet peak cooling demand of 102 kW.

2. Description of System's Configuration and Modeling in TRNSYS

In configuration, flat plate and evacuated tube solar collectors have been employed for supplying hot water to the single-effect absorption chiller, as depicted in Figure 1. Water is then fed to the backup auxiliary boiler which starts working and boosting the temperature to the level required, if the water temperature flowing out of thermal storage is less than 116 °C. Water flows back to the thermal storage tank after transferring its heat in the absorption chiller. The pump starts working only if the temperature of water flowing out of solar collector is more than the inlet temperature. Table 1 shows the weather details of the three cities (Cairo, Lahore, and Abu Dhabi) used in this study.

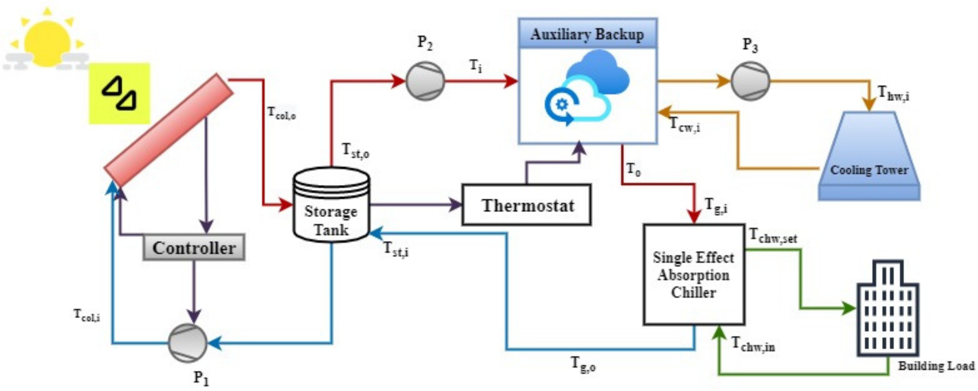


Figure 1. Schematic of Single-Effect Absorption Chiller.

Table 1. Weather details of Cairo, Lahore and Abu Dhabi.

Sr. No	Name of City	Köppen Classification Group	Climate Description
1	Cairo (Egypt)	Bwh	Arid Hot desert
2	Lahore (Pakistan)	Bsh	Semi-Arid–Steppe
3	Abu Dhabi	Bwh	Arid Hot desert

3. Results and Discussion

The proposed system configuration scheme was transiently simulated and analyzed in TRNSYS 18.0 to ascertain the influence of various operating and design parameters on the overall performance of the proposed system configuration. The influence of collector tilt on the overall energetic performance of system configuration for all three locations is evaluated as delineated in Figure 2. For Lahore, solar fraction slightly increased when the tilt varied from 5° to 15° for FPC, while this range is 5° to 10° in case of ETC. For Cairo, a slight increase in solar fraction was observed for varying collector tilt, ranging from 5° to 10° for both FPC and ETC.

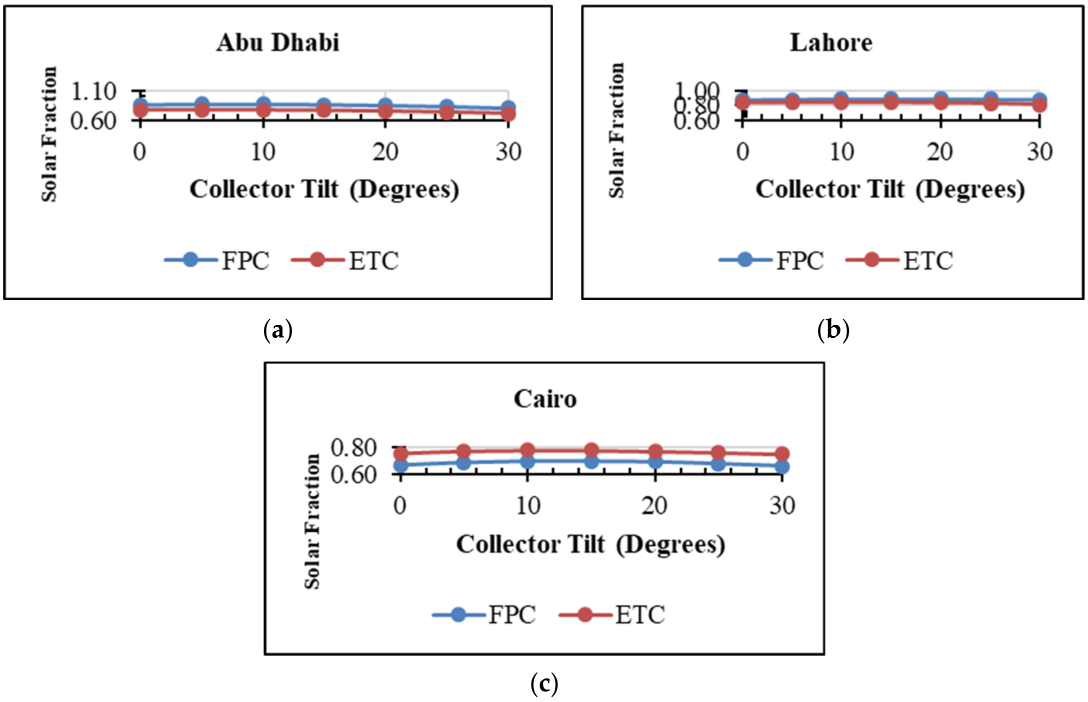


Figure 2. Variation of Solar Fraction versus Collector Slope for (**a**) Abu Dhabi (**b**) Lahore (**c**) Cairo. (FPC A_c = 1600 m^2, ETC A_c = 600 m^2), Storage Capacity = 30 L/m^2, T_g = 116.11 °C.

Figure 3 shows the variation of primary energy savings with storage volumes computed for a evacuated tube collector area of 600 m^2 and flat plate collector area of 1600 m^2. It is quite obvious from the results that primary energy savings increase with smaller values of storage volumes and the trend follows a decline afterwards.. Abu Dhabi and Lahore indicate maximum primary energy savings of 0.7 at lower values of storage volume of 30 L/m^2.

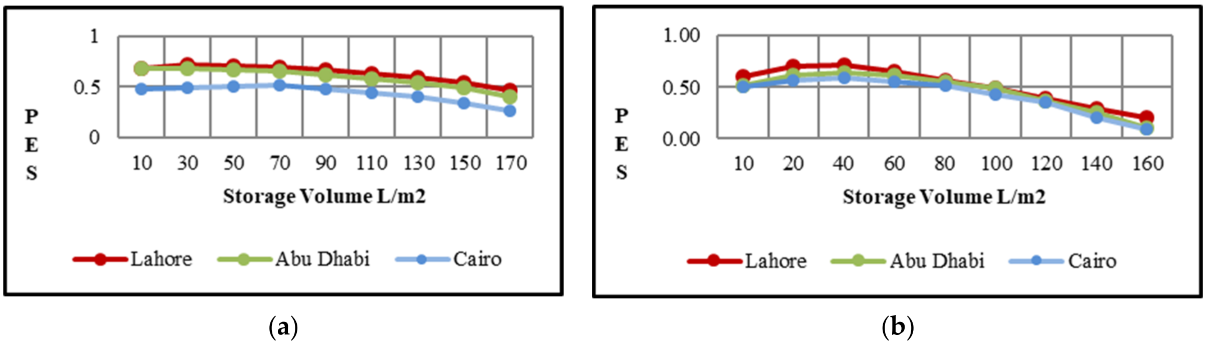
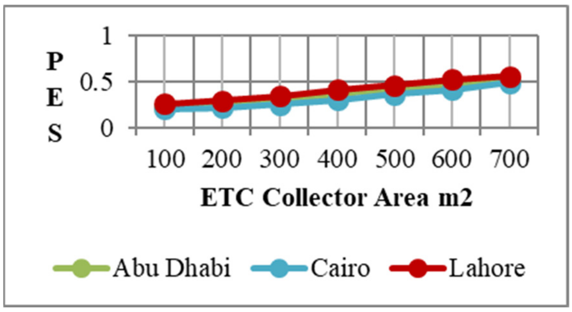
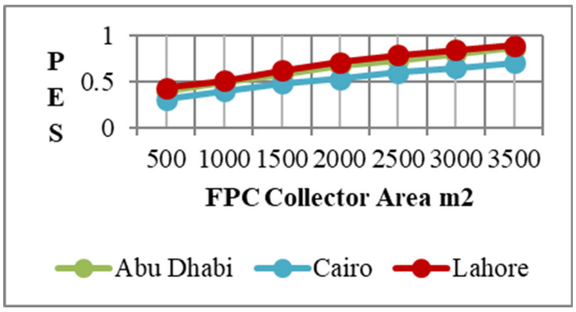


Figure 3. Primary energy savings vs storage capacity per A_c of tank with for Cairo, Lahore and Abu. Dhabi (**a**) ETC (**b**) FPC, A_c = 600 m^2, T_g = 116.11 °C, β = 10°, U = 0.83 W/m^2·K.

The variation of primary energy savings with respect to varying FPC and ETC areas is plotted and presented in Figure 4. It is quite obvious from the results that for both FPC and ETC, increasing the collector area causes an increase in primary energy. A total 50% energy savings are achieved for an ETC area of 600 m^2 for Lahore and 650 m^2 Abu Dhabi. For Cairo, the optimum collector area is around 700 m^2. A total of 50% primary energy is saved at FPC area of 1000 m^2 for Lahore and Abu Dhabi and 1500 m^2 for Cairo.



(**a**)



(**b**)

Figure 4. Variation of seasonal primary energy saving with (**a**) ETC and (**b**) FPC areas for Cairo, Abu Dhabi and Lahore storage capacity per A_c = 30 L/m^2, T_g = 116.11 °C, β = 10°.

4. Conclusions

The key outcomes of the above research are summarized as follows:

1. It was found that to achieve f_{sav} of at least 50%, the required evacuated tube solar collector areas are 600 m^2 for Cairo, Lahore and Abu Dhabi. Similarly, 50% primary energy is saved for flat plate collector areas of 1600 m^2 for Cairo, Lahore and Abu Dhabi.
2. The collector efficiency increases by increasing storage volume, but this increase is less sensitive for higher values of storage volume. At a higher volume, the exposed surface area of the storage tank is greater, causing thermal losses.

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