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A Solar System for Heating and Cooling a House in Misurata

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Abstract
The aim of this work is to design a cooling and heating system that works with solar energy for a 175 m^2 house located in Misurata. At the beginning of this study, the weather data was collected in order to choose the proper two days for designing the system. Then the cooling and heating loads for the house were calculated. The amount of solar incident radiation on the flat plate solar collector at the two design days was determined mathematically. Also in this study, the area of the flat plate collector that required to cover the heating and cooling loads was found in cases of using single and double-glazed flat plat collectors. The proper size of hot and chilled water tanks for this system was also determined. If the solar system cannot provide adequate space heating and cooling, an auxiliary or back-up system provides the additional heat. Finally, the collector efficiency curve for a single and double-glazed was found. After writing the proper code for the calculations. Microsoft excel was used to analyze the data and to produce the curves.

Keywords: Flat plate collector; Solar cooling and heating system; Collector efficiency curve; Vapor absorption system; Lithium bromide-water.

I. Introduction

The solar energy can be used for heating during winter and for cooling (air-conditioning) during summer. Heating can be either passive or active, in passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter.

This called passive solar design or climatic design because it does not involve the use of mechanical and electrical devices [1]. Active solar heating systems use solar energy to heat a fluid, either liquid or air and then transfer the solar heat directly to the interior space or to a storage system for later use.

Using solar energy for cooling buildings is an indirect method, as it needs to transfer the Sun heat energy to cooling energy in order to cool the space. It is known that the energy that required to cool the space in summer is more than that needed in winter for heating purposes in winter, fortunately the solar radiation reaches its maximum in summer were the cooling energy is required.

There are two main systems for solar air condition, the vapor compressor system and the absorption cooling system. The refrigerant side of the absorption cycle essentially works under the same principle as the vapor-compression cycle. However, the mechanical compressor used in the vapor-compression cycle is replaced by the thermal compressor in the absorption cycle. Water/lithium bromide Absorption system was chosen for this study as it can operate at low pressures and, therefore, at lower generator temperature [2].

II. Building Location and Specification

The building is located in Misrata city at latitude 32.19 degrees north and Longitude 15.03 degrees east. The total area of the building is 175 m^2 and consists of 2 bedrooms, 2 corridors, living room, sitting room, 2 toilets, kitchen, guests room. The building outer walls consists of 100 mm bricks and 150 mm concrete blocks.

III. Cooling and Heating Load Calculating

The day of 17^{th} of July was chosen as a design day for the cooling system, because it has highest temperature records according to data that obtained from Misurata Meteorology center, to ensure the cooling system will work at highest cooling load. The indoor design temperature was chosen to be 26 ^{o}C and relative humidity was 45 %.

The cooling load for the house was calculated using cooling load temperature difference method (CLTD) [3-6]. The cooling loads for walls, roof, doors, windows, infiltration, ventilation, lighting and the house occupier were determined using CLTD method. The total cooling load of the house for the design day is depicted in Figure (1).

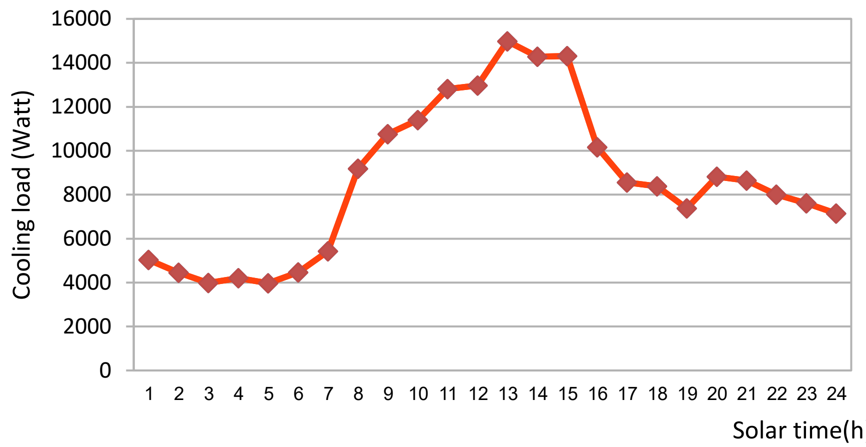

Figure (1) Total cooling load

For heating load calculation, the month of January was chosen as it had the lowest temperature after checking the weather data for several years, and the 2nd of this month was chosen to be the design day in order to ensure the heating system will work on the highest expected heating load. The indoor design temperature and the relative humidity were chosen to be 21 degree and 45% respectively. The total heating load for the house during the design day is illustrated in Figure (2).

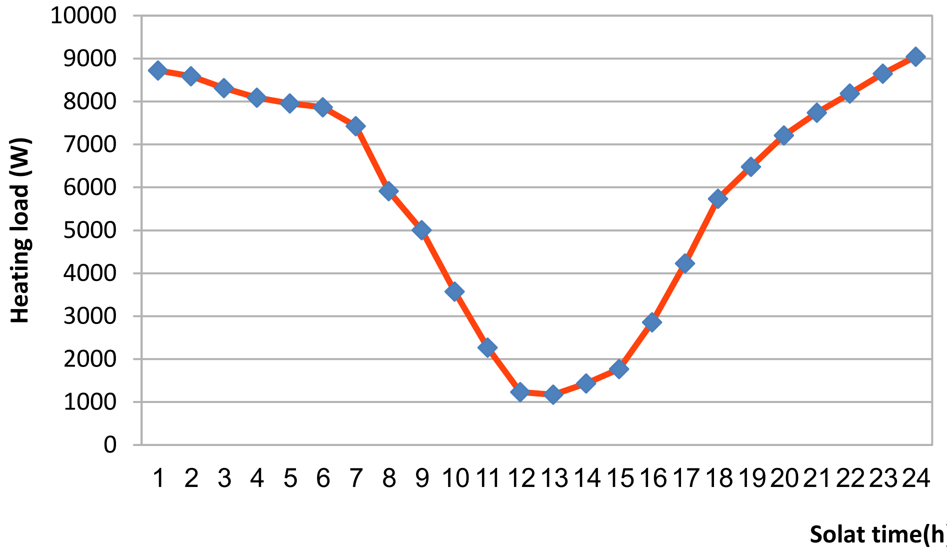

Figure (2) Heating load during design day

Figure (3) shows a sketch of the heating and the cooling system used in this study. The solar collector gathers the heat from solar radiation from a flat plate collector and transfers the heat to a hot water tank through a heating fluid (water). When the system is used for cooling purposes, the storage tank linked to the absorption system (lithium bromide-water) in order to provide the generator with the energy that required to operate the absorption unit. The absorption unit is connected to a chilled water tank, which is used to cool the house throughout the day. In winter, the heat storage tank is connected to the house directly to heat it. This system contains an auxiliary heating unit, which can be used to provide the system with the required energy in case of shortage of solar energy.

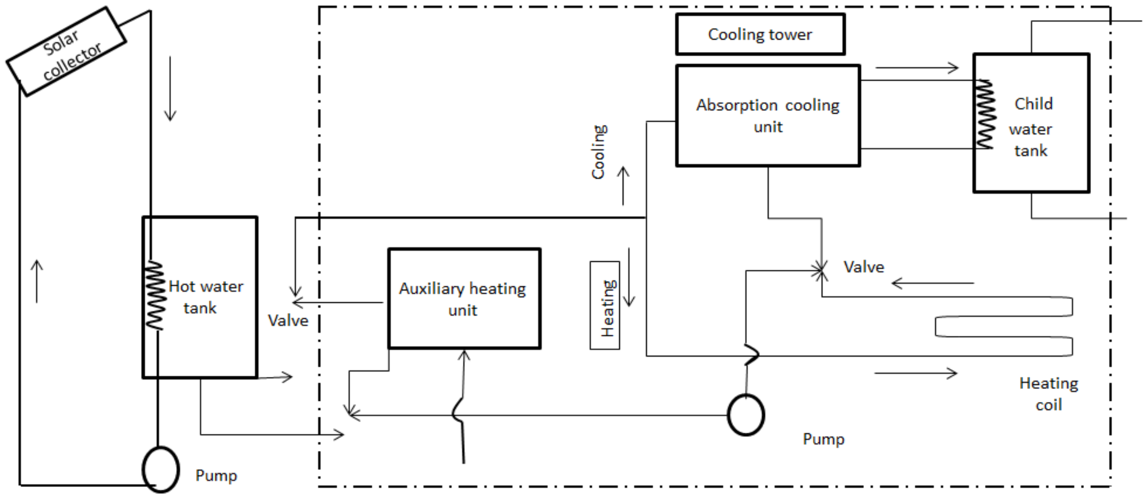

Figure (3) Solar powered heating and cooling system

IV. Choosing The Direction and Tilt Angle of The Flat Plat Collector

The amount of solar radiation that incident on any surface and in any time depends on the direction and tilt angle of that surface [7]. For maximum efficiency the orientation of the collector should follow the Sun as it passes overhead from East to West [8], this means that the sun must strike the surface of flat plate collectors at right angles and not be subjected to any shade. However because of this process is costly, the solar collector should be placed facing the sun (towards the equator), i.e. it should face true south in the Northern Hemisphere, North in the Southern Hemisphere [9, 10].

For the collector tilt angle, it should be pointed almost at an angle perpendicular to the sun when its radiation reaches maximum value (at noon). If the solar collector is used for heating (winter), then it should be placed at an angle 10 to 15 degrees greater than the angle of latitude of the location, and if it used for cooling purposes, then it should be placed at an angle 10 to 15 degrees less than the angle of latitude of the location. However, in case of using the collector for both heating and cooling then it is better that the collector is tilted at an angle equal to the angle of latitude. Figure (4) illustrates the relation between latitude angle and the optimum collector tilt angle [11].

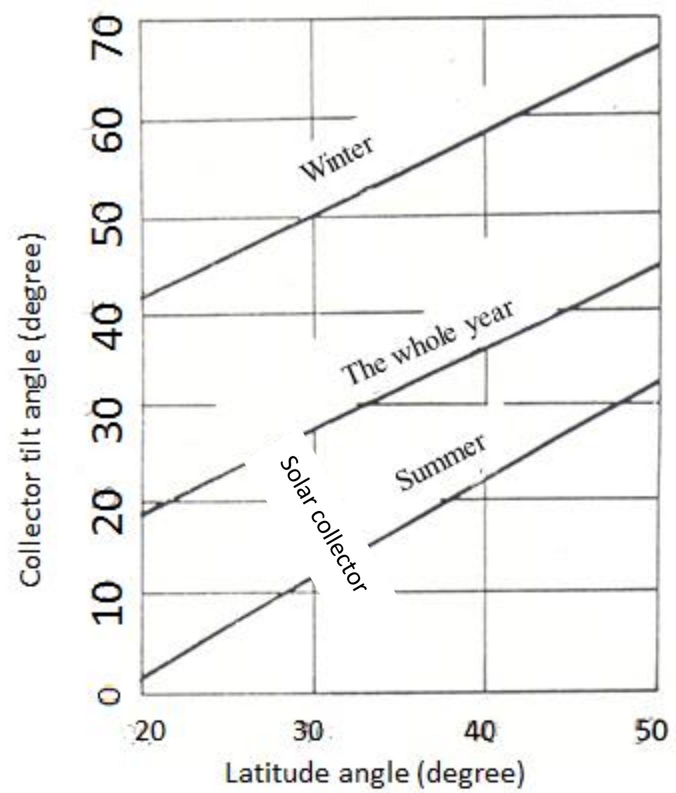

Figure (4) relation between the collector tilt angle and the latitude angle

V. Solar Collector Design Calculation

The irradiation incident on the collector surface was determined mathematically (12, 13), and the radiation intensity during the design day (17 July) was found to be as shown in Figure (5). From this figure, the maximum value of the radiation was 935.66 W/m^2 at 12 noon.

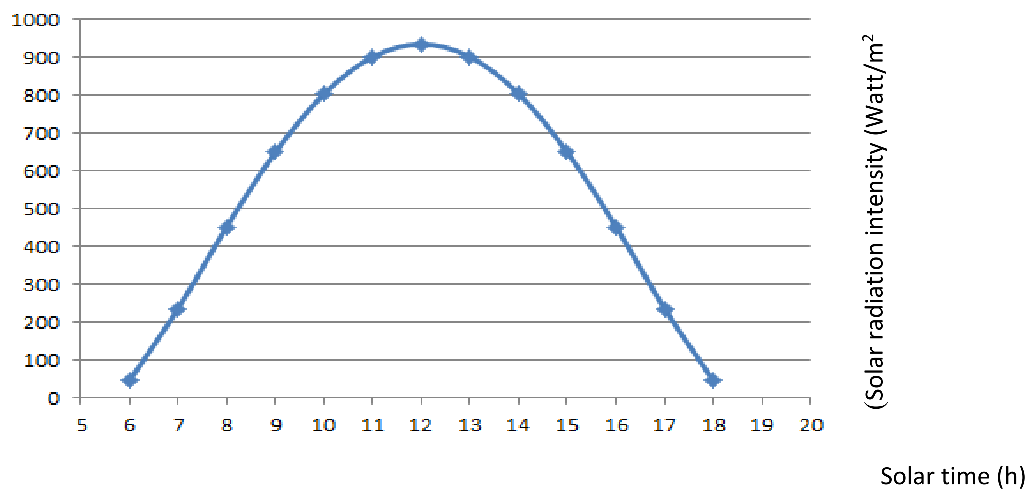

Figure (5): Incident radiation on the collector at the design day for the cooling system

In order to evaluate the collector performance, the collector efficiency curve was obtained for a single and a double glazed cover and the curve is shown in Figure (6). This Figure shows that at small values for (T_{in}-T_a/H_t), the efficiency of single glazed collector is higher than double glazed one, and as the value (T_{in}-T_a/H_t) increased (above 0.035 °C m^2/W) the double glazed collector efficiency is higher than the single glazed one. (Notice: T_{in}, T_a are water inlet and ambient temperature respectively, and H_t is solar intensity).

To determine the total collector area that covers the total cooling load during design day, the inlet water temperature was fixed at 77 ºC and various collector areas were assumed having that the temperature of outlet water into the collector must be at least one degree centigrade higher than its inlet temperature. The proper collectors area were found to be as shown in Table (1).

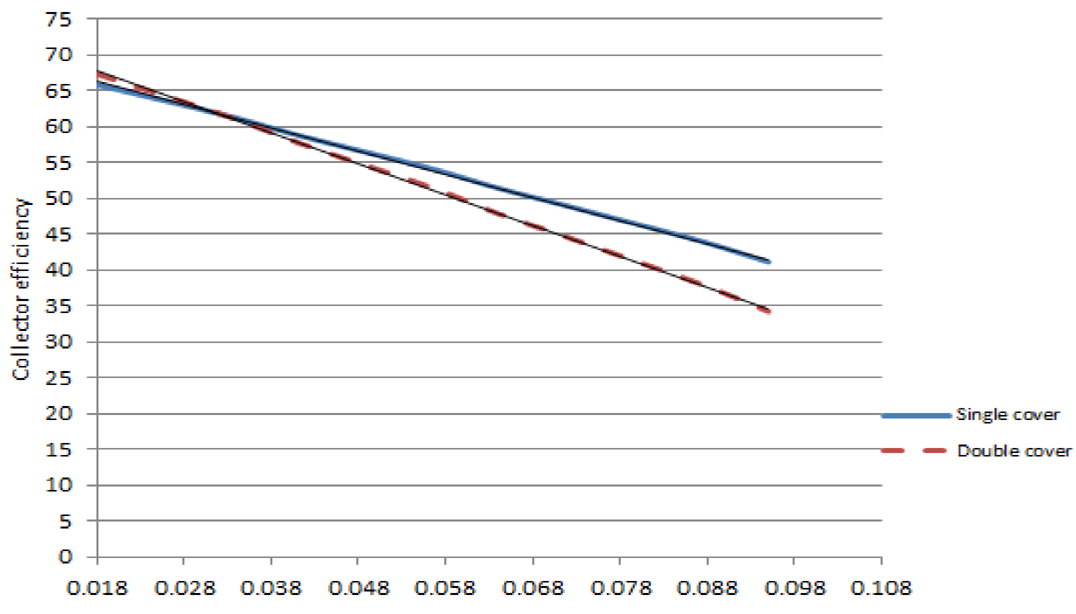

Figure (6) Collector efficiency curve

Where: T_{in} water inlet temperature, T_a water ambient temperature, and H_t Solar intensity

From Table (1) above, each 1m^2 produces around 3376.5 W/day for a single glazed collector, and gives 3548.5 Watt/day for double glazed collector. The system worked from 8 to 18 O'clock.

Table 1. Collector area required for the system.

Collector area (m^2)	No of glass covers	Collector energy (kW/day)
92	1	310.67
88	2	312.28

After determining the area of the flat plate collector that required to cover the cooling load and the number of working hours of the solar system, then the sizes of the chilled and hot water tanks were found. At first the sizes of hot water tanks were assumed 4,5,6,7 m^3, and the cold water tanks assumed 2,3,4 m^3, then the results were analyzed and was found that when a single glazed collector was used the proper tanks sizes were 5 and 2 m^3 for hot and chilled water tanks respectively. Moreover, for double glazed collector the right sizes of hot water tank was 4 m^3, and 2 m^3 for the chilled one. See Figures (7) .

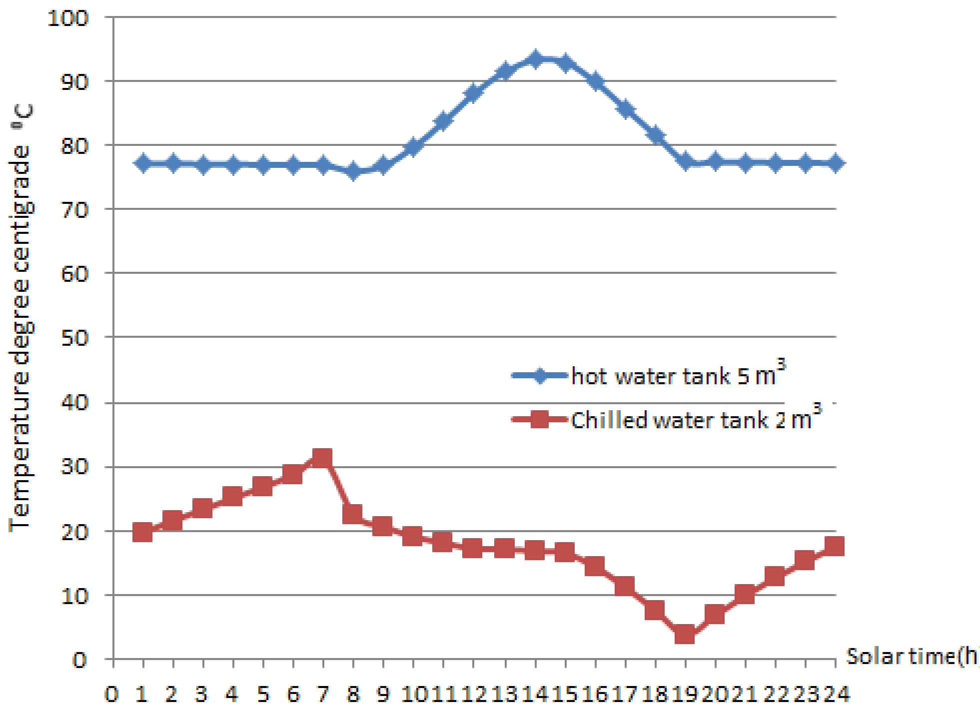

Figure 7. Temperature of hot and chilled water tanks for a single-glazes collector

For the area of the flat plat collector that required to cover the heating load (during winter), it was found to be 36 m^3, and total power from this collector was 139 kW/day.

VI. Conclusion

In this study two solar operating systems were designed, one for cooling and the other for heating, for this work it found that the cooling load for the building under investigation was higher than the heating load, which leads to increase the cost of the cooling system comparing to the heating system. In addition, the collector efficiency curve for single and double glazed collector was found, from this curve and it concluded that at small values for (T_{in}-T_a/H_t), the efficiency of single glazed collector is higher than double glazed one, and vice versa. To cover the heating and cooling loads, the required flat plate collector area was determined, and it was 92 m^2 if a single glazed collector was used, and the area of the collector was 88 m^2 if a double glazed collector was used. The area of the collector required to cover the heating load was 36 m^2 and this is for a single glazed collector. The lithium bromide absorption unit was chosen as it works properly at temperatures, which can be obtained from the flat plat solar collectors. Also in this work, the proper sizes of the hot and chilled tanks that the system needs were determined.

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