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TRNSYS simulation of a solar cooling system for the hot climate of Pakistan

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Abstract

Cooling is a basic need for buildings in hot and sunny climates. In most countries the major source of cooling is electrical power based. During summer in hot climates there is an increase in electricity consumption due to cooling load. Pakistan is facing an electricity shortage crisis, which becomes worse in summer due to the high demand for cooling. The annual average insolation for Pakistan is 5-6 kWh/m^2/day, reaching 6-8 kWh/m^2/day in summer with sunshine of 10-13 hours a day, which gives suitable conditions for solar powered cooling system operation. TRNSYS software provides the possibility to simulate a complete solar air conditioning system integrated with a building. In this study, TRNSYS is used to model an absorption chiller operated by hot water from an evacuated tube collector. It is found that, with a hot water storage tank, a collector area of 12 m^2 is sufficient to maintain the temperature in a room in a typical house at or below 26°C during the cooling season.

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Keywords: Solar Cooling Pakistan; TRNSYS Simulation; Solar Thermal Cooling

1. Introduction

Pakistan has a generally hot and sunny climate, and many buildings use electrically powered air conditioning for much of the year. Most of the electricity system is dependent on fossil fuels (Fig.1(a)), which are expensive and damage the environment by their emissions (including greenhouse gases) [1]. Pakistan is an energy deficient country, where the majority of the population has inadequate provision of basic energy facilities like electricity and

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gas [2]. The current electricity shortage crisis started in 2007 and has affected the operation of cooling systems, causing discomfort in buildings, particularly in summer [3].

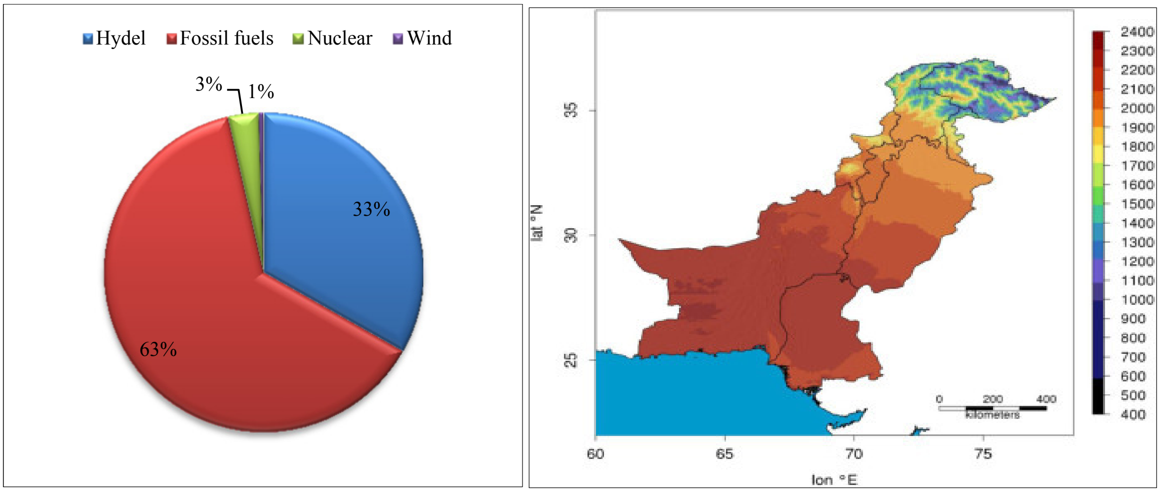

Fig. 1: Pakistan's (a) electricity generation by fuel type; (b) solar energy potential

The annual mean global insolation in Pakistan is 5-6 kWh/m^2/day, with 10 - 13 sunshine hours per day, which gives suitable conditions for solar powered cooling system operation[4]. The multi-year (2000-2012) mean of annual global horizontal irradiance for Pakistan is shown in Fig.1 (b)[5]. A clean and sustainable cooling system, such as solar energy cooling, can provide an alternative green source for comfort in buildings.

TRNSYS is a widely used, thermal process simulation program. It was originally developed by the members of the solar energy laboratory at the University of Wisconsin for solar energy applications, and can now be used for a wider variety of thermal processes. The first version was released in 1977 [6]. TRNSYS has the capability of interconnecting system components in any desired manner, solving the system differential equations, and producing information output. Component models may be selected from the libraries, or written by the user and linked to the main TRNSYS model [7].

The aim of this research is to use a TRNSYS simulation to determine whether it is feasible to use a system comprising an evacuated tube solar collector driving an absorption chiller, to maintain a comfortable temperature in a typical single family house in Pakistan during the cooling season.

Nomenclature

COP	Co-efficient of Performance
kW	Kilo Watt
kWh	Kilo Watt hour
TRNSYS	TRaNsient SYstem Simulation
TESS	Thermal Energy System Specialists
TR	Ton of Refrigeration

2. System description and modelling

The building comprises one room of a typical single-storey house in Pakistan, with one single-glazed window and one timber door. The room is of brick and concrete construction, uninsulated. The cooling system comprises an evacuated tube solar collector which supplies hot water to an absorption chiller, which in turn supplies chilled water to an air cooling coil. A fan circulates room air through the cooling coil. The chiller rejects heat to ambient air through a cooling water circuit using a dry cooling tower. A stratified tank stores hot water from the collector to allow the chiller to operate when there is insufficient solar energy available (which is mainly at night).

Pumps circulate water through the system. The solar collector circuit is controlled so that it operates when heat is available and required by the chiller or storage tank; the rest of the system operates continuously during the cooling season to maintain the room temperature at the set point.

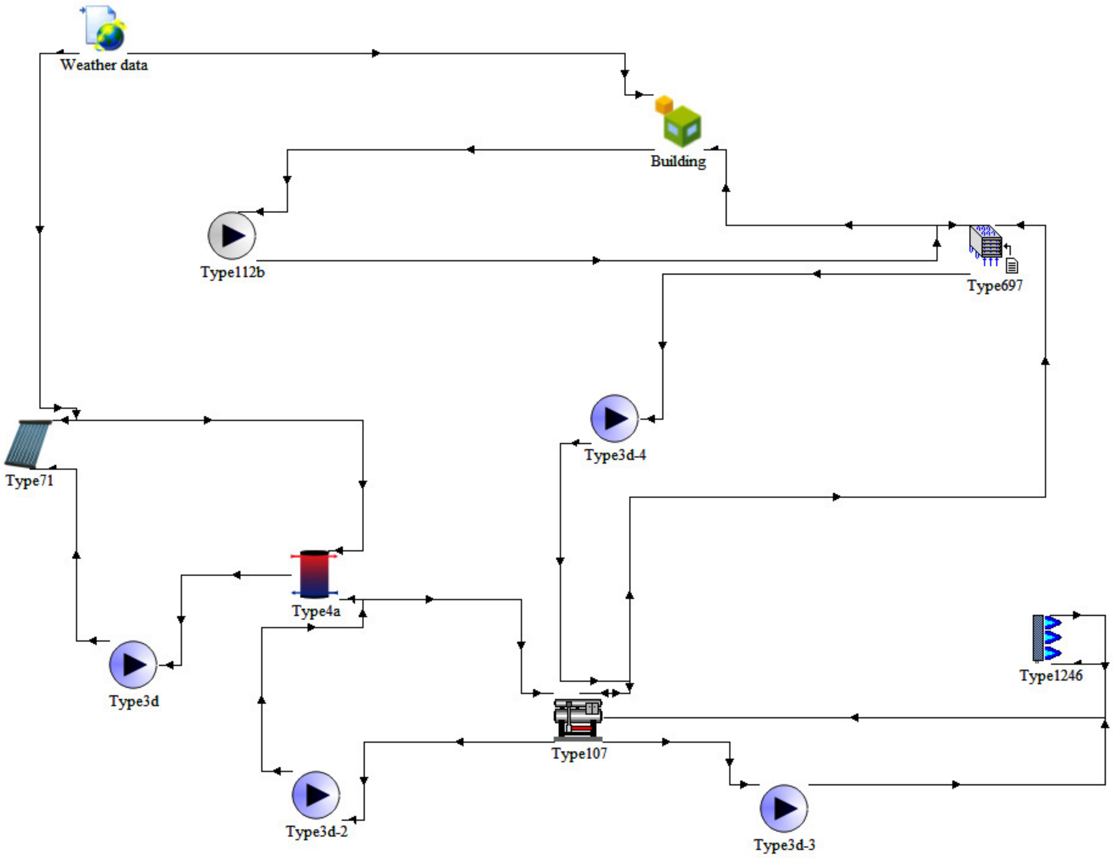

Fig.2: TRNSYS model of building integrated solar thermal cooling system

Sketchup was used to model the room geometry. The model was imported to TRNSYS; building constructions and the components of the solar thermal energy and cooling systems were selected from the libraries. The components were integrated in operational order and the cooling system connected with the building (Fig.2). (Note that the lines in Fig.2 represent logical connections in the simulation model, not necessarily physical connections.)

An absorption chiller capacity of 3.52 kW (1 TR) is chosen to match the cooling load of the space (a single room); other component sizes were optimized to maintain the room temperature set point throughout the summer season. The chiller model is a scaled-down version of a realistic, larger, absorption chiller. In practice, a single larger chiller would probably be used to cool several rooms. TRNSYS Type 107 can simulate any cooling capacity chiller and this small size chiller (3.52kW) was used by references [8, 9]. Simulation was performed for one year starting on 1st January. Key parameters are given in Table 1.

Table 1. System key parameters

Description	Specification
Room floor area	14 m^2
Cooling set point	26°C
Operation hours	Continuous
Solar fraction	100%
Design cooling load	2 kW
Chiller type	Hot water fired absorption
Chiller capacity	3.52 kW (1TR)
Collector type	Evacuated tube
Collector area	12 m^2
Collector slope	0
Hot water storage tank volume	2 m^3
Weather data	TMY2, Lahore, Pakistan

The storage tank size is chosen to ensure that the system can meet the cooling load at all times without an auxiliary heat input. Topics for further research could include reducing the tank size by, for example, changing the system temperatures or using an auxiliary heat input.

3. Results

The TRNSYS simulation was run with 15 minute time step and results were obtained. The selected system successfully maintained the room temperature below set point 26°C, even when the ambient temperature was more than 40°C, during peak summer season (Fig. 3). The other key results during the summer (April –September) for the cooling season are presented in Table 2. All the energies are stated per m^2 of collector area.

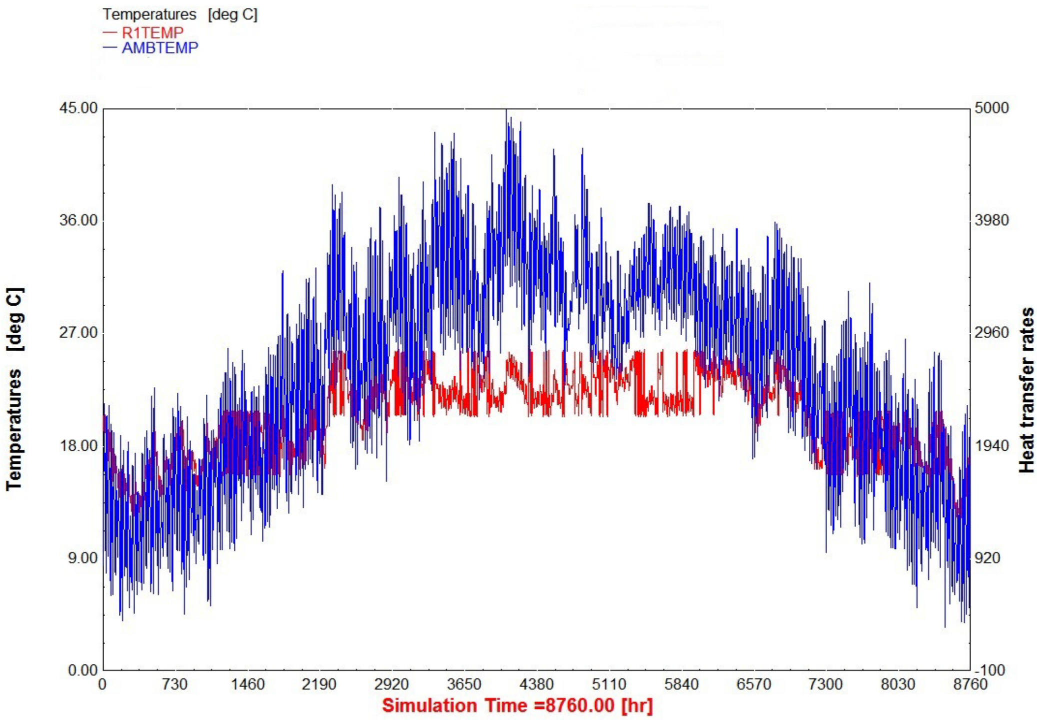

Fig.3. Simulated room temperature and ambient temperature for one year

Table 2. Simulation Results

Period	Specification
Collector efficiency (%)	75
Chiller COP	0.60
Total Chiller yield (kWh/m^2)	790
Total room cooling load(kWh/m^2)	479
Total electrical energy consumption (kWh/m^2)	67
Total pipes and tank heat loss (kWh/m^2)	6.5

The results are presented in term of collector area so easy to compare with any other result (similar or different capacity) as collector area is key parameter for solar thermal cooling system design. The comparison of these results with the similar capacity references [8, 9] showed a better energies per collector area.

4. Conclusions

According to TRNSYS simulation of solar powered absorption cooling system, using TMY2 data of Lahore, following conclusions are established.

- The evacuated tube solar collector yield is sufficient to meet the system required thermal energy input during the cooling season.
- The stratified hot water tank stores heat efficiently, with losses of less than 1% of total input energy.
- The electrical energy supply to the system is about 14% of the cooling load.
- The equipment sizes could reasonably be accommodated in the building, and could be reduced by measures to reduce the cooling load.
- Pakistan's climate has the potential for use of solar powered thermal cooling systems in summer.

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