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Research Article

Dynamic Simulation of Solar-Powered Heating and Cooling System for an Office Building Using TRNSYS: A Case Study in Kerman

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A B S T R A C T

Recently, novel techniques have been developed in building industries to use solar heating and cooling systems. The current study develops a Solar-powered Heating and Cooling (SHC) system for an office building in Kerman and assesses the transient dynamics of this system and office indoor temperature. To this end, TRNSYS simulation software is utilized to simulate system dynamics. The developed system comprises Evacuated-Tube solar Collectors (ETCs), heat storage tank, heat exchanger, circulating pumps, axillary furnace, cooling tower, single-effect absorption chiller, and air handling unit. The office indoor temperature is assessed in two scenarios, including commonly-insulated and well-insulated envelopes, while window awnings are used to prevent the sun from shining directly through the windows. The results illustrate that the SHC system can meet the thermal loads and provide thermal comfort in line with ASHRAE standards. The indoor temperature reaches 21 °C and 24 °C on cold winter and hot summer days by using the SHC system; however, without the SHC system, the indoor temperature experiences 15 °C and 34 °C on cold and hot days, respectively. The SHC system provides 45 °C and 15 °C supply air on cold and hot days to keep the indoor temperature in the desired range. A thermostat monitors the indoor temperature and saves energy by turning off the system when no heating or cooling is required. Furthermore, the ETCs can run the SHC system for a long time during daytime hours, but the axillary heater is still essential to work at the beginning of the morning.

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1. INTRODUCTION

Buildings consume nearly 40 % of global energy, and this demand has grown dramatically in recent years. Since fossil fuels have been mainly used to meet this huge energy demand, policymakers have been encouraged to utilize green energy sources to improve sustainability and reduce greenhouse gas (GHG) emissions. Buildings consume approximately 35 % of total energy for Heating, Ventilation, and Air Conditioning (HVAC) systems; hence, renewable energy-driven HVAC systems can significantly affect and reduce required energy demands and improve building energy performance.

In 2008, the building sector in Iran accounted for 41.9 % of total energy demands, and this energy demand was mainly provided by utilizing fossil fuels, including natural gas 66 %, petroleum 20 %, electricity 2.5 %, and other sources 1.5 % [1]. Unfortunately, renewable energy sources do not effectively participate in meeting energy demands in this sector. However, Iran has great potential in renewable resources, especially solar energy, as the most affordable renewable energy source.

Using renewable resources to run heating, cooling, and air condition systems is a sustainable approach that easily improves building efficiency [2]. However, building efficiency is enhanced by considering a complex system designed to provide a comfortable, safe, and attractive living and work environment and increase its performance. This crucial issue requires superior engineering designs such as using sustainable and easily accessible energy resources. The major area of energy consumption in buildings is HVAC systems, i.e., nearly 35 % of total building energy demand [3]. In this case, there are opportunities for improving energy performance by using solar-powered HVAC systems. Numerous literature studies have evaluated solar-powered HVAC systems in different technical, environmental, and economic terms [4]. Hobbi and Siddiqui [5] designed and evaluated a solar water heating system for a residential building in Montreal, Canada using TRNSYS. They optimized and sized the designed system components including collector array area, fluid type, and heat storage tank, while employing this approach helped them achieve a 54 % solar contribution to meeting demands. Monne et al. [6] evaluated the efficiency of a solar-powered cooling system consisting of a 37.5 m^2 flat plate collector and a 4.5 kW absorption chiller to obtain the impacts of cooling water temperature and generator driving temperature on the COP of used solar-powered chiller.

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Tashtoush et al. [7] performed a dynamics simulation of a solar ejector cooling system in Jordan by using TRNSYS. This study also optimized the cooling system components such as collector type and area; they concluded that 60-70 m^2 ETCs could meet the energy required for the 7.0 kW ejector cooling system. A review study [8, 9] represented a comprehensive review of various solar-powered systems with focus on Building-Integrated Solar Thermal systems (BISTs) and compared these systems with Building-Added (BA) installations. Safa et al. [10] simulated the performance of a Ground Source Heat Pump (GSHP) to obtain GSHPs performance curve versus building loads and evaluate the heat pump's efficiency at different source temperatures. Asim et al. [11] utilized TRNSYS software to simulate a solar-powered cooling system consisting of ETCs, a hot water storage tank, and an absorption chiller in Pakistan to maintain a typical room temperature at 26 °C. A research study conducted by Guillen-Lambea et al. [12] reviewed various strategies to meet cooling & heating demands in residential buildings in European countries and compared them with strategies used in the USA. This study used a model developed in TRNSYS for a dwelling and performed a simulation with different ventilation strategies and envelope transmittance in numerous countries in Europe and the USA.

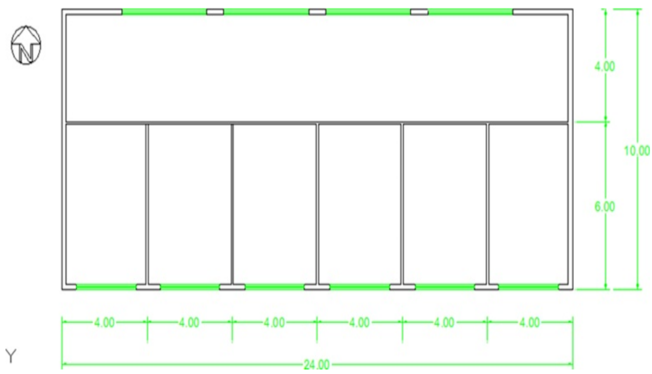
Alibabaei et al. [13] developed a MATLAB-TRNSYS co-simulator to investigate the effectiveness of predictive strategy planning in energy cost saving in an HVAC system. These controlling strategies include load shifting and dual fuel switching systems. The simulation indicated that these strategies effectively optimized energy cost saving; however, they depended on the outdoor temperature. Ghaith [14] used a parabolic trough solar collector and an absorption chiller to meet the cooling load of a residential building in the UAE, and a bio-mass heater was used as an auxiliary heater. The obtained results showed that this hybrid system made a 30 % solar contribution in to its optimal configuration. Angrisani et al. [15] carried out a thermo-economic analysis of an SHC system for an office building in Italy. They developed a TRNSYS model to assess different solar panel technologies and collector areas. The obtained results demonstrated that the solar-powered system could reduce CO_2 emissions by up to 23 %. Antoniadis and Martinopoulos [16] used TRNSYS simulation software to calculate space heating load and annual domestic hot water need in a residential building in Greece. Furthermore, they optimized the designed heating system, and the optimal system obtained a seasonal solar fraction of 39 %. Jani et al. [17] investigated a drawback of traditional HVAC systems in humid climate conditions with high latent cooling loads. They proposed and analyzed a solid desiccant-assisted space cooling system using TRNSYS modeling to handle this problem and reduce energy consumption. The obtained results proved that the proposed system could provide a desirable thermal comfort. Wu and Skye [18] and Irfan et al. [19] investigated numerous scenarios used in the USA and subzero temperature areas for photovoltaic and HVAC systems and evaluated these strategies in different technical and economic aspects.

Several studies have analyzed solar-powered heating & cooling systems from an economic point of view in different climate conditions [20, 21]. Pirmohamadi et al. [22] developed an optimization algorithm to transform an existing office building into a zero-energy building using an efficient solar thermal system to reduce CO_2 emissions. They used TRNSYS and DesignBuilder simulation software to evaluate the feasibility of this conversion. Ahmed et al. [23] and Rosato et al. [24] carried out transient building energy simulations for a residential building in Canada and Italy. In these studies, they designed, optimized, and assessed these solar-powered systems from different technical viewpoints.

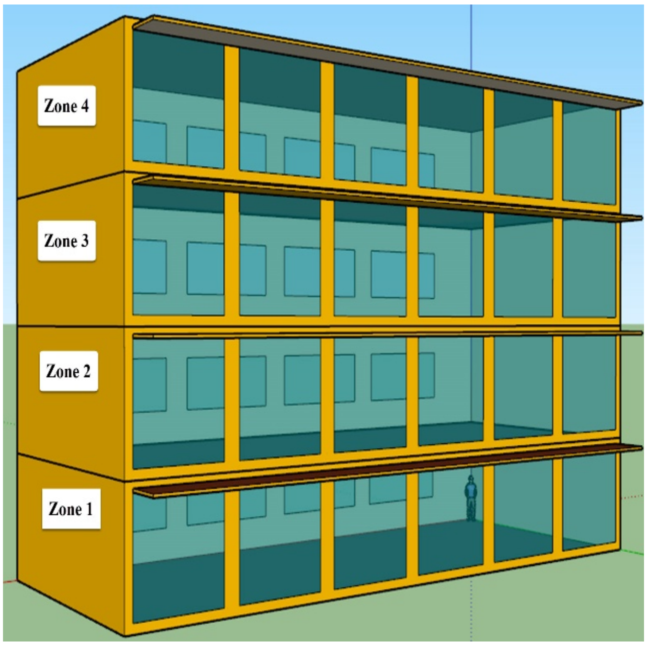
The current investigation utilizes TRNSYS simulation software to develop a numerical model and study the dynamics of an SHC system to meet heating & cooling loads for an office building in Kerman, Iran. Furthermore, this model investigates and analyzes the indoor office temperature in the presence or absence of the SHC system.

2. EXPERIMENTAL

The user in the current study is an office building whose schematic and floor plan are shown in Figure 1. The building modeling process was carried out in Sketch up software. This office is a four-story building with a 960 m^2 surface area and 48 working people. Window awnings are attached to the exterior walls of the building to prevent the sun from shining directly through the windows while still allowing natural light to pour through the windows. An air handling unit is utilized to meet heating & cooling loads in the building. Each floor is considered as a thermal zone to monitor indoor air temperature more precisely. The working hour is 8:00 to 16:00, and the office is closed on the weekends. The building envelope is thermally well insulated by polystyrene boards. The building envelope characteristics are shown in Table 1.



(a)



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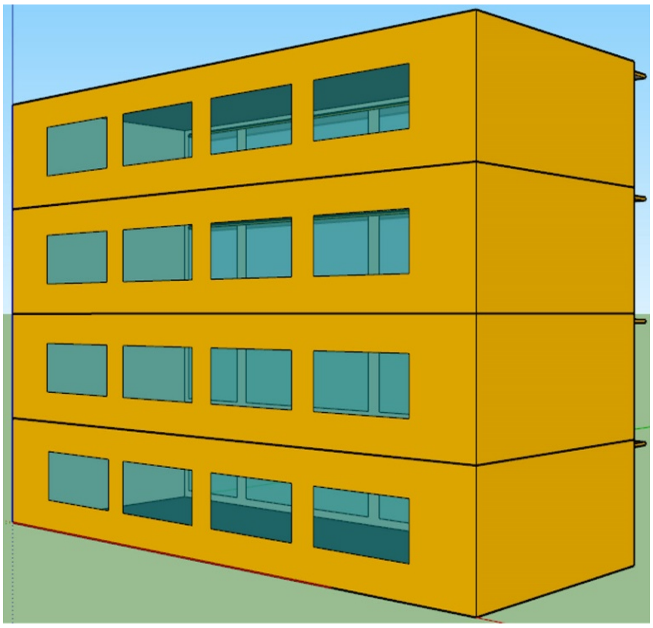


(c)

Figure 1. Building (a) floor plan and (b) south view (c) north view

Table 1. Main characteristics of building envelope

Insulation type	Envelope	U-value (W/m^2K)
Thermally well-Insulated envelope	External walls	0.501
	Internal walls	1.386
	Roof	0.497
	Floor	0.452
	Window	2.58

The people inside the office need fresh air. This air can be provided by infiltration or a designed HVAC system. The required air change rate for the people inside the building is assumed to be equal to 15 CFM per person, according to [27]. For this application, the required air change to satisfy ASHRAE standards is obtained nearly 720 CFM. The air infiltration depends on the wind velocity and is given as [25]:

$$ACH = 0.07v_w + 0.4 \quad (1)$$

where v_w is the wind velocity, and ACH defines the air change due to the infiltration.

The people working inside the office are seated and have a light activity. By assuming this scenario, the heat gain for a seated person is 400 Btu/hr and a total of 19200 Btu/hr [25]. Furthermore, each person has a personal PC, and the heat released to the space for each PC is equal to 100 W. ASHRAE handbook suggests a lighting power density of 1.11 W/ft^2 for office spaces [25].

The modeled office building is located in Kerman, Iran (30.2839° N, 57.0834° E). Kerman has hot arid climate conditions with an average elevation of 1755 m from the sea level. On average, July is the sunniest month with 329 hours of sunshine, and February has the lowest sunshine duration with 192 hours. The warmest month is July, with an average maximum temperature of 35 °C and the coldest month is January, with an average maximum temperature of 11 °C. Kerman has great potential in solar energy with the monthly average global solar radiation of 4.0 to 4.2 kW/m^2.day in winter and 7.0 to 7.3 kW/m^2.day in summer [26].

The heating and cooling loads were calculated using TRNSYS software considering internal gains (PCs, people, lightings), infiltration heat load, and solar radiation. The peak of heating and cooling loads is 455607 Btu/hr and 468702 Btu/hr, respectively.

3. SHC SYSTEM CONFIGURATION

Figures 2 and 3 show the schematic of the designed SHC system in the current study to satisfy heating & cooling demands and provide thermal comfort in the office building. It is worth noting that the TESS library was used in TRNSYS modeling. The developed SHC system is described as:

3.1. Solar heating system: The solar cooling system consists of the key components given as:

Evacuated tube solar collectors (Type 71): Type 71 simulates the transient thermal dynamics and efficiency of various ETCs. This type can consider ETCs in different parallel or series arrangements to obtain their performance and heat dynamics.

Storage tank (Type 4): This component models a stratified fluid-filled storage tank while the cold liquid enters the tank from the bottom side. The tank is divided into N sections with an equal volume to carry out the simulation. The N value determines the stratification degree. The current study assumes that the storage tank is well insulated to reduce heat loss to ambient environments.

Auxiliary heater (Type 700): The type simulates a fluid boiler and uses a user-defined set point temperature limited by the boiler capacity. The capacity defines heat amount delivered to fluid.

Shell & tube heat exchanger (Type 5): This component defines a shell & tube device. The performance of this type is achieved by determining inlet hot and cold fluid streams temperatures, their flow rates, and heat exchanger overall heat transfer coefficient.

Air handling unit (Type 752): Type 752 simulates a cooling or heating coil which cools or heats passing air stream. This component considers a bypass fraction required to obtain the outlet air temperature.

Mixing and diverting valves (Type 648): This component simulates an air plenum to determine the properties of leaving airflows mixed in the plenum.

Occupancy (Type 14): This type is a forcing function that defines a user-defined pattern that occurs several times throughout one cycle.

Building (Type 56): Type 56 models the thermal behavior of a building with several thermal zones.

3.2. Solar cooling system: The modeled cooling system has some auxiliary components compared to the heating system. These components are given as:

Single-effect absorption chiller (Type 909): Type 909 models a single-effect absorption chiller; based on data files containing the chiller performance in different operating scenarios.

Cooling tower (Type 126): This component estimates the dynamics of a cooling tower and uses weather data, inlet conditions, and overall heat transfer coefficient to calculate performance.

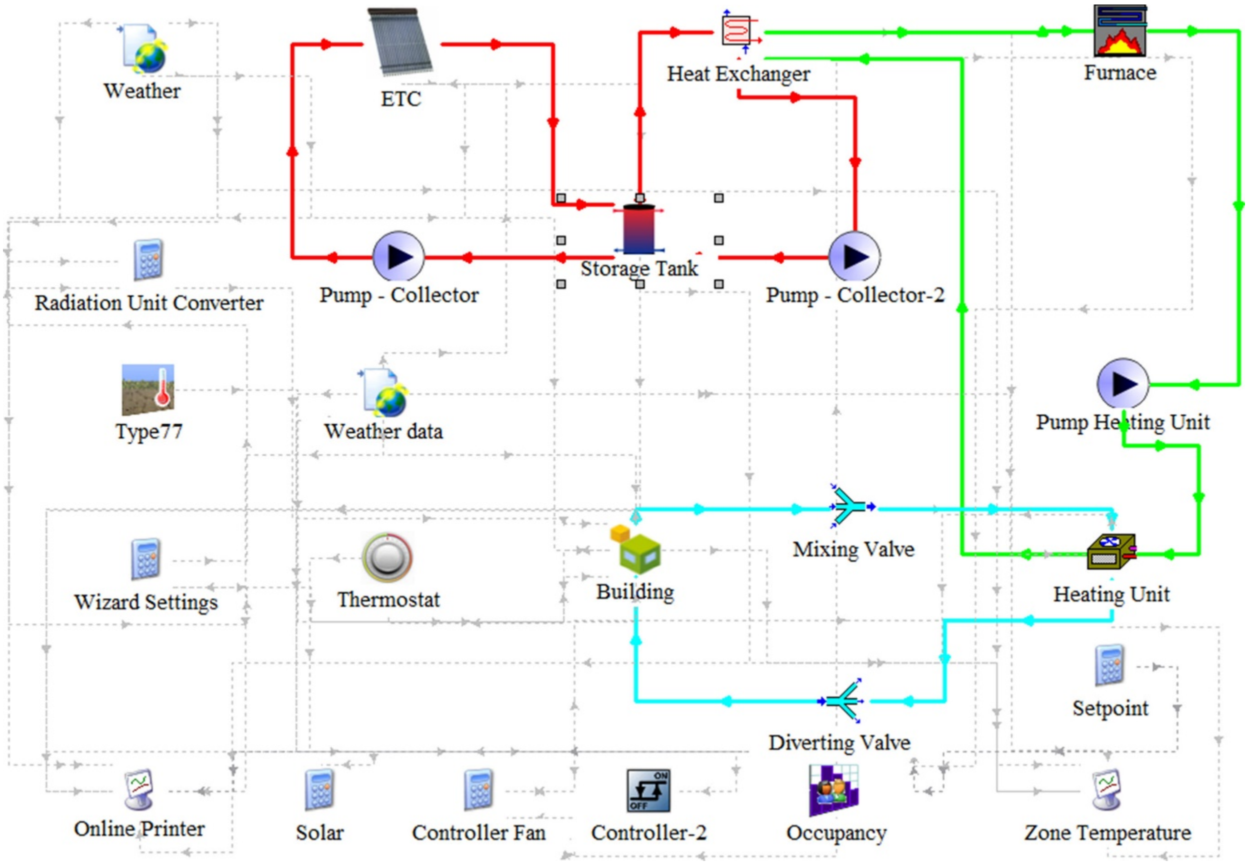


Figure 2. Schematic of the heating system in TRNSYS

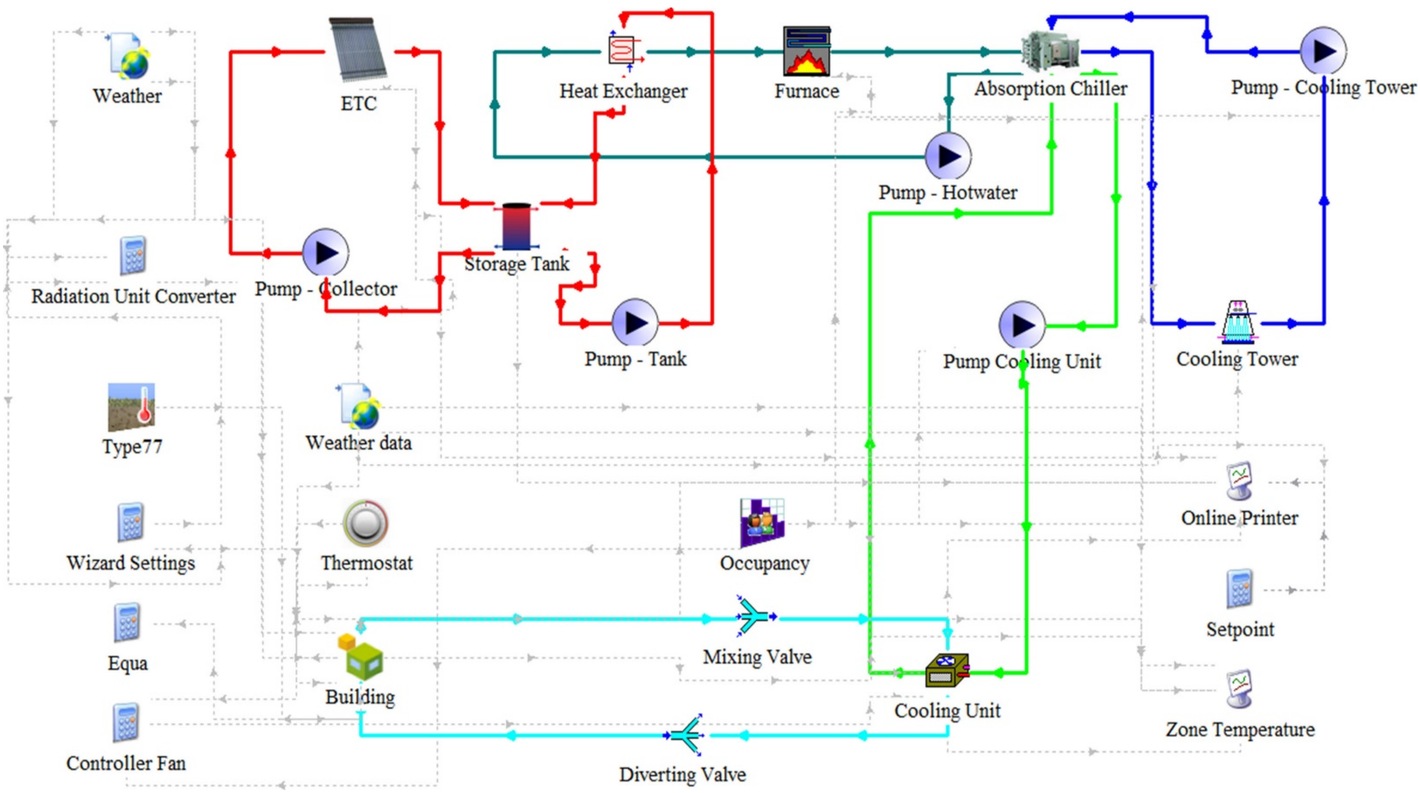


Figure 3. Schematic of the cooling system in TRNSYS

Table 2 shows the technical specifications of the used components in the SHC system. The installed thermostat monitors the indoor office temperature and controls the fan of the air handling unit during working hours. Using this strategy helps keep the indoor temperature in the thermal comfort temperature range and improve the system's energy efficiency. According to ASHRAE standards, the installed thermostat is set to 21 °C in winter and 24 °C in summer [25] with a 3 °C dead band.

Table 2. Main components of SHC system

System	Component	Technical specification	Value
Heating	Evacuated solar collector	Collector area array	200 m^2
	Storage tank	Volume	5 m^3
	Auxiliary furnace	Rated capacity	100 kW
		Setpoint temperature	90 °C
	Shell & tube heat exchanger	Overall heat transfer coefficient	500 W/K
Cooling	Evacuated solar collector	Collector area array	200 m^2
	Storage tank	Volume	5 m^3
	Auxiliary furnace	Rated capacity	100 kW
		Setpoint temperature	90 °C
	Shell & tube heat exchanger	Overall heat transfer coefficient	500 W/K
	Single effect absorption chiller	Rated capacity	50 TR
		COP	0.83
	Cooling tower	Rated capacity	90 tons

4. SHC SYSTEM DEESCRIPTION

In the heating system, the ETCs heat the circulating water-glycol mixture in the solar loop. The heat exchanger helps the heated water-glycol mixture transfers its heat content to the circulating water used in the air heating system. The used water-glycol mixture has a specific heat of 3.709 kJ/kg K and returns to the solar heating loop after heat exchange with the recirculating water in the air heating loop. The installed fan in the air handling unit has a design capacity of 45000 CFM. Furthermore, the outside air damper position is 10 % open to supply outside fresh air to the office. This heated air is carried and distributed equally in each thermal zone.

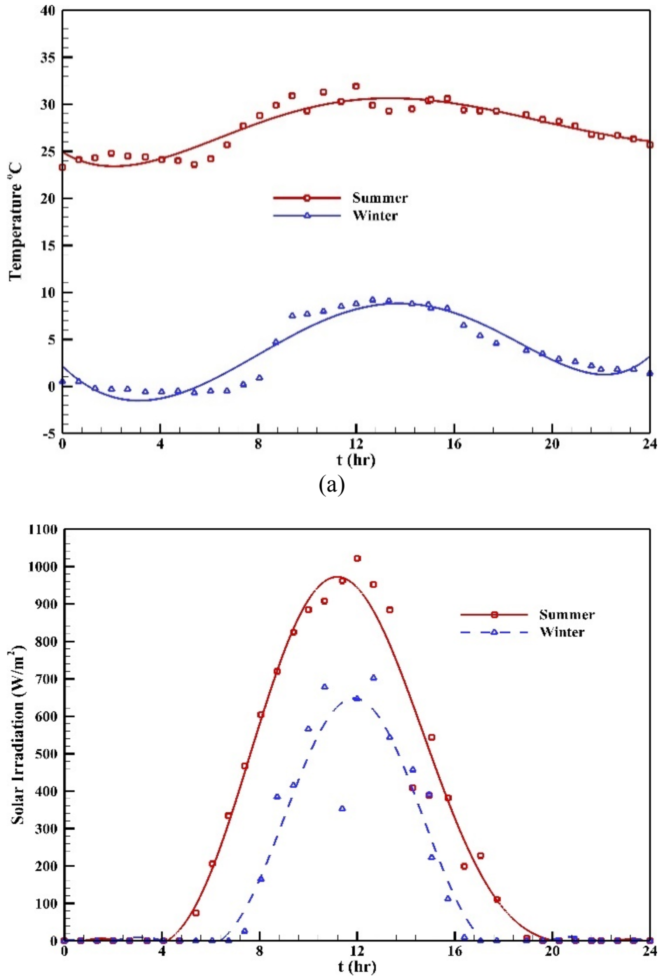
Same as the heating system, the ETCs produce a hot water flow stream used in the generator of the single effect absorption chiller to provide refrigeration. The chilled water is recirculating in the coils installed in the air handling unit and cools the supply air. As for the heating system, the outside damper position is 10 % open, and the cooled supply air is carried to the office space.

The thermostat monitors the indoor office temperature, and a forcing function named occupancy defines the working hours or people's presence inside the building. These two factors, including thermal comfort temperature range and people presence, serve as inputs to a control system that turns on/off the fan of the air handling unit. This strategy helps improve energy-saving costs by turning off the SHC system when the indoor temperature is in the desired range and no heating or cooling is required.

Since the building is exposed to cold ambient temperature on winter days, the indoor temperature may be so cold and intolerable for people starting to work in the morning. A strategy used on cold winter days is that the system is turned on one hour sooner. This strategy helps the indoor temperature reach thermal comfort temperature as soon as possible.

5. SIMULATION RESULTS AND DISCUSSION

The current study simulates the transient dynamics of the developed SHC system and indoor temperature for an office building located in arid hot climate conditions in Kerman, Iran. The weather conditions play a key role in the dynamics of an SHC system; hence, Figure 4 shows outdoor temperature and solar radiation intensity variations in February 1st and July 1st. The data shown in Figure 4 were obtained using a synoptic weather station in Kerman; however, the simulations were carried out utilizing Meteonorm software. The measured weather data have good agreement with the simulated one. Furthermore, February 1st and July 1st are assumed as the sample cold and hot days to perform simulation and investigate the transient dynamics of the SHC system and indoor office temperature.



(a)

(b)

Figure 4. (a) outdoor air temperature and (b) solar intensity in February 1st and July 1st in Kerman

Figure 5 shows the transient dynamics of the indoor office temperature on the considered cold winter day when no heating system is used. As seen in Figure 5, the indoor temperature decreases during the cold night, while the building interacts with a cold ambient and the heating system is off. These two factors are the reaons why the indoor temperature reaches nearly 7 °C at 7 A.M. During daytime hours, the building is exposed to incoming solar radiation and internal gains. Hence, the indoor temperature starts to grow to nearly 15 °C at 4 P.M. The indoor temperature is still so far from the desired thermal comfort temperature without using the heating system.

It is interesting to note that the fourth floor (fourth thermal zone) has the worst condition, and its indoor temperature is the lowest on cold winter days. However, the building is well-insulated, but the fourth floor is adjacent to the roof that is exposed to the cold outside air. This issue results in increase in heat losses from the fourth floor to the outside, and its indoor temperature drastically decreases compared to the other thermal zones.

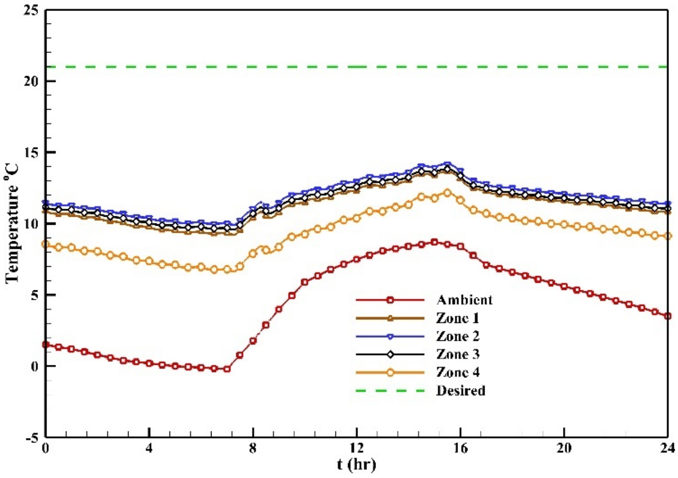


Figure 5. Transient dynamics of the indoor office temperature without using heating system

Figure 6 shows the transient dynamics of the indoor office temperature using the heating system. Figure 6 illustrates that the heating system can meet the required heating demands on cold winter days and maintain the indoor temperature in the desired range during long working hours. It is clear that the thermostat turns on and off the fan during the daytime hours. This factor causes the heating system to turn off when heating is not required and to save energy. On the other hand, the considered occupancy forcing function turns the heating system off when the people are not present in the office after 4 P.M.

The indoor office temperature is a function of the energy saved in the envelope mass and ambient temperature when the heating system is off. After 4 P.M., the indoor temperature is reduced due to interaction with cold environments. However, the indoor temperature is still higher than the outside air. Indeed, the energy is saved in the envelope mass during the period that the heating system is on. This saved energy releases and heats the indoor temperature when the heating system is off.

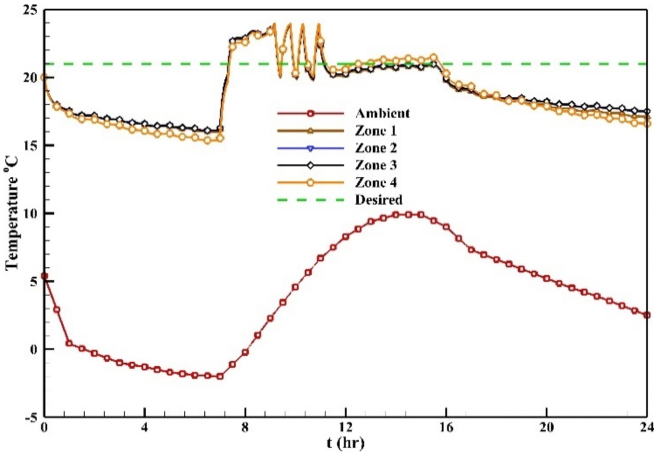


Figure 6. Transient dynamics of the indoor office temperature using heating system

Figure 7 represents the transient dynamics of the heating system. As seen in Figure 7, the collector outlet temperature increases in the beginning of the morning and reaches nearly 70 °C at noon. The collector outlet temperature remains maximum until 15:30 and, then, reduces when the solar intensity approaches zero. Furthermore, since the collector outlet is at its maximum temperature for approximately 8 hours, it provides this opportunity to use maximum solar energy during daytime hours.

In addition, Figure 7 shows the tank outlet temperature profile toward the heat source (ETCs). It shows that hot water-glycol inside the tank exchanges its heat content in the heat exchange with the recirculating water in the air heating system and its temperature reduces. Hence, it returns toward ETCs with a lower temperature. Since the solar intensity is too insufficient to heat water-glycol in the beginning of the morning at 7:00 A.M., the tank loses its heat content faster and its outlet temperature reduces in a steeper gradient. However, this trend is changed by increasing the solar intensity and the tank outlet temperature starts to increase after nearly 9:00 A.M.

The supply air temperature leaving the air handling unit is also shown in Figure 7. It is implied that the fan runs continuously to supply hot air to the office until noon due to the cold outside weather conditions. The thermostat turns off the fan sometimes in the afternoon since the indoor air temperature is in the desired thermal comfort range. The supply air temperature leaving the air handling unit reaches nearly 50 °C during the periods that the fan is working. During the times that the office is closed, the supply air temperature is near outside air temperature.

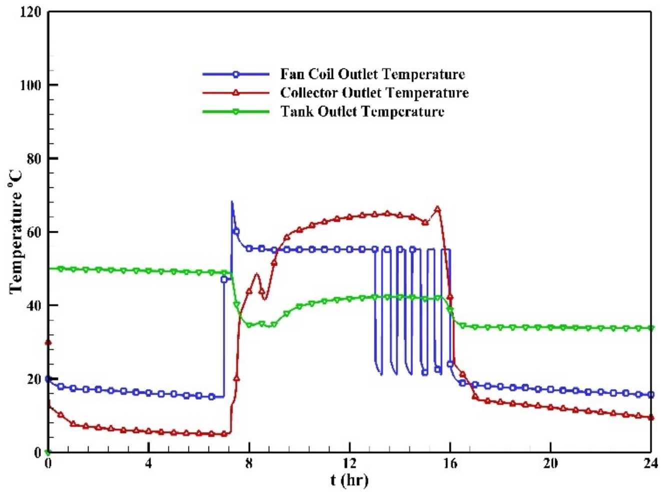


Figure 7. Transient dynamics of the heating system

Figure 8 shows the transient dynamics of the indoor temperature on the considered hot summer day without using the cooling system. During the daytime hours, the building is exposed to high solar intensity, and the internal heat gains release heat to the space. Therefore, the indoor office temperature increases during daytime hours. However, the indoor temperature reduces in the evening when the solar intensity is negligible or absent, and the people are not present in the office. Like on the considered cold winter day, the fourth floor has the hottest indoor temperature due to the interaction with the hot outside temperature through the roof exposure.

Since the building envelope is exposed to the solar intensity, the thermal energy is saved in the envelope. This energy releases in the evening and keeps the indoor temperature higher than the outside air temperature.

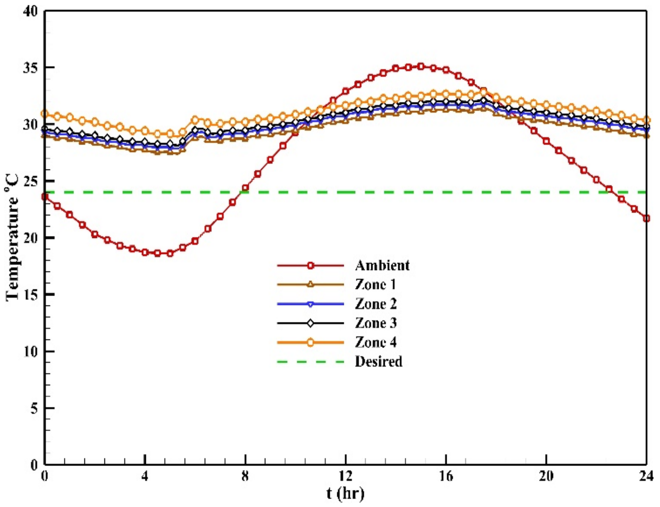


Figure 8. Transient dynamics of the indoor office temperature without using cooling system

Figure 9 represents the indoor temperature variation on the considered hot summer day using the cooling system. Using the cooling system results in keeping the indoor temperature in the desired thermal comfort range. As discussed in the heating system analysis, the thermostat monitors the indoor temperature and sends a control signal to turn the cooling unit fan on or off. The cooling air is supplied to the space by turning on the fan, reducing the indoor temperature, and satisfying the cooling load. As the people exit the office in the evening, the forced occupancy function turns off the fan and the indoor temperature grows in the absence of the cooling system.

Interestingly, since the cooling system meets the thermal loads during daytime hours, the office experiences lower indoor temperatures in the evening than the scenario where no cooling system is used.

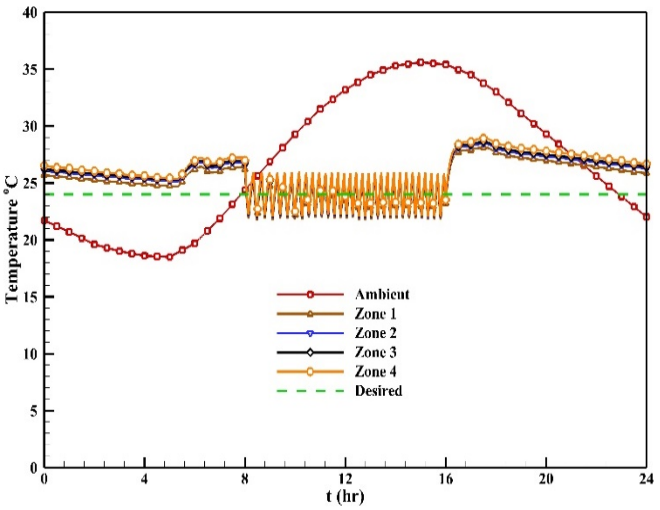


Figure 9. Transient dynamics of the office indoor temperature using cooling system

Figure 10 depicts the transient dynamics of the cooling system. This figure shows the ETCs outlet temperature, storage tank outlet temperature toward the ETCs, and supply air leaving the air handling unit. The ETCs outlet temperature grows in the beginning of the morning and increases the solar intensity. This temperature reaches up to nearly 100 °C at noon and reduces in the evening by reducing the solar intensity. This hot water-glycol mixture is used to heat the recirculating hot water that runs the single-effect absorption chiller. Fortunately, the high solar intensity in Kerman results in a high-temperature water-glycol mixture and, consequently, recirculates the hot water used in the refrigeration cycle. The hotter the recirculating water, the higher the COP. The tank outlet temperature has the same trend as the ETCs outlet temperature. However, the difference between the tank and the ETCs outlet temperatures implies the amount of thermal energy delivered to the recirculating water in the heat exchanger. When the solar intensity is low in the beginning of the morning, the auxiliary furnace must heat the recirculating hot water in the refrigeration cycle.

The supply air temperature profile shows that the fan works in specific periods when the thermostat sends an ON signal. This important issue shows the significant impact of the installed thermostat on saving energy and controlling the indoor temperature in the desired temperature range. When the fan is working, the supply air temperature is nearly 12 °C, which is a suitable temperature for cooling a space.

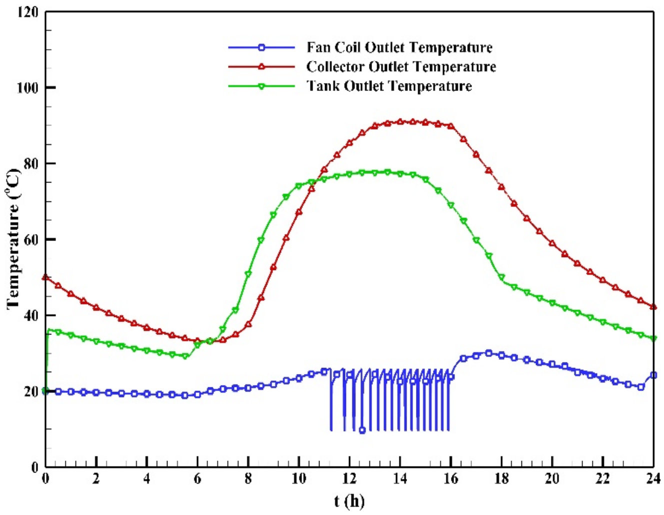


Figure 10. Transient dynamics of cooling system

Building insulation is an affordable approach to optimizing energy consumption in a building and minimizing its heat exchange with its hot or cold ambient. Since insulation materials have low thermal conductivity, the conduction heat exchange with the outside environment through building envelopes reduces drastically. Hence, the energy consumed to provide thermal comfort will be saved. Table 3 shows the main characteristics of the building envelope in the commonly-insulated scenario.

Table 3. Main characteristics of commonly-insulated envelope

Insulation type	Envelope	U-value (W/m^{2}K)
Thermally commonly-insulated envelope	External walls	1.567
	Internal walls	1.732
	Roof	1.654
	Floor	1.234
	Window	2.58

This section analyzes the effects of building envelope characteristics on the transient dynamics of indoor office temperature. To this end, a commonly insulated building is considered, while the size and configuration of the SHC system are the same as those in the scenario discussed in the previous sections. Figure 11 shows the transient indoor temperature on a cold day when a commonly insulated envelope is used. According to Figure 11, the indoor temperature is far from the desired setpoint in the beginning of working hours, and this situation lasts till noon. Interestingly, the internal gains and solar radiation on the building surface help the indoor temperature increase during daytime hours in this scenario, but the thermostat does not turn off the heating system. This issue proves that the cold outside temperature can easily affect the indoor temperature due to unsuitable insulation. Great heat losses through the building envelope cause the indoor temperature to slowly reach the desired set point compared to the scenario with the well-insulated envelope (Figure 6). Furthermore, the indoor temperature decreases drastically by turning off the SHC system and approaching outside temperature due to heat conduction through the building envelope.

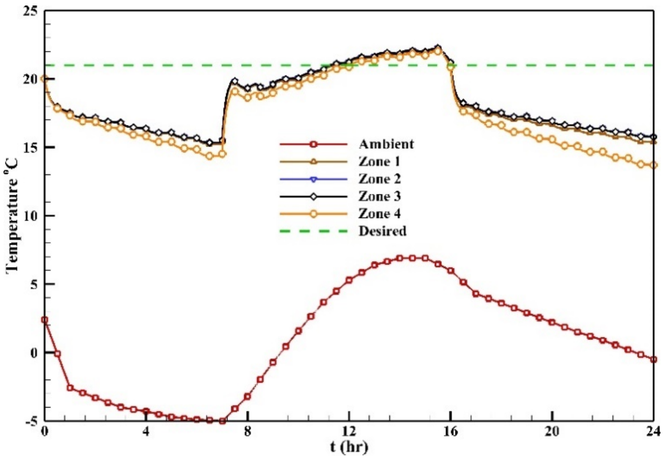


Figure 11. Transient dynamics of the indoor office temperature using heating system with commonly-insulated envelope

Figure 12 shows the indoor temperature on a hot summer day when a commonly insulated envelope is used. The indoor temperature in the commonly insulated building is higher than that in the well-insulated building in the beginning of the morning. Hence, the SHC system needs to meet higher cooling loads at 8:00 A.M. when the system turns ON. Since the simulation was carried out on hot arid climate conditions, the outdoor temperature would decrease drastically at night. Therefore, the energy saved in the envelope mass during daytime hours causes the indoor temperature not to change remarkably at night. Then, the system can start on summer mornings more easily than on winter mornings with severe cold conditions at night.

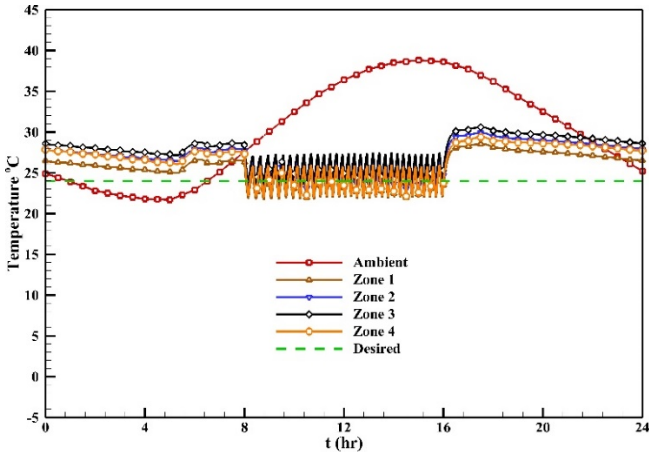


Figure 12. Transient dynamics of the indoor office temperature using cooling system with commonly-insulated envelope

Table 4 represents a brief comparison between the current and previous studies. These studies assessed the indoor temperature dynamics when an SHC system was used to provide thermal comfort in a building. Each study investigated a crucial factor that affected the indoor temperature dynamics of a building. Like the current study, these investigations illustrate that SHC systems can promisingly meet the required thermal load and maintain the zones temperatures in the desired temperature range.

Table 4. Brief comparison between available studies

Reference	Method	SHC system type	Target
Alibabaei et al. [13]	Numerical approach using MATLAB-TRNSYS co-simulator	Solar-powered heating system	Investigation on effectiveness of different predictive strategy planning models in Canada
Rosato et al. [24]	Numerical approach using TRNSYS software	A centralized solar hybrid heating and cooling system	Study on performance of proposed system from energy, environmental and economic points of view in Italy
Altun and Kilic [21]	Numerical approach using TRNSYS software	Solar-powered absorption cooling system	Investigation on performance of cooling system in different climate conditions in Turkey
Figaj and Zoladek [20]	Experimental and Numerical approach	Solar-powered heating & cooling system	Study on solar contribution in heating and cooling in Poland

6. CONCLUSIONS

Nowadays, fossil fuels are consumed mainly to meet energy demands in buildings. However, this approach is beginning to change toward using renewable resources due to the global warming crisis. Recently, novel techniques have been developed to use renewable energy for meeting heating & cooling requirements, which are the major energy consumers in buildings. Iran has great potential in solar energy that provides an opportunity to convert incoming solar energy to heating & cooling energy. This study investigated the possibility of using solar energy to meet heating & cooling loads in an office building in Kerman with hot arid climate conditions. The transient simulation software, TRNSYS, was used to carry out the simulation and evaluate the transient dynamics of the indoor building temperature and SHC system. The obtained results demonstrated that:

- The indoor air temperature without a heating & cooling system was far from the desired thermal comfort range.
- The indoor office temperature was a function of outside air temperature and envelope mass without using heating & cooling systems. The energy saved in the building envelope was released during the afternoon and affected indoor temperature.
- The solar-powered heating system could meet the heating load in the office building and provide thermal comfort conditions.
- The maximum ETCs and storage tank outlet temperature on cold winter days reached nearly 70 °C and 50 °C, respectively. On the other hand, due to higher solar intensity on hot summer days, the maximum outlet temperature of the ETCs and storage tank reached nearly 100 °C and 80 °C, respectively.
- Indoor temperature specified whether the occupant thermal comfort would be satisfied or not. When no heating or cooling system is used, the indoor temperature is far from the desired temperature on cold winter or hot summer days. In this case, during working hours, the indoor temperature reaches nearly 15 °C on cold winter days and 34 °C on hot summer days.
- Using the SHC system caused the indoor temperature to be in the desired range during working hours. In this case, the indoor temperature oscillated between 20 °C to 24 °C and 23 °C to 27 °C on cold winter and hot summer days.
- The supply air temperature leaving the air handling unit is a suitable range using the developed SHC system. The supply air temperature was nearly 50 °C and 12 °C on cold winter and hot summer days, respectively.
- An axillary furnace was required in the solar-powered heating system when the solar intensity was low in the beginning of the morning.
- The solar-powered cooling system met the cooling load in the office building. However, in the beginning of the morning, the axillary furnace must heat hot water in the refrigeration cycle.
- The thermostat is an affordable approach to monitoring the indoor temperature and control the SHC system. The thermostat saves energy by turning the air handling unit off when the indoor temperature is in the desired temperature range.
- The thermostat assists the indoor temperature to be in the desired range according to the ASHRAE standard (21 °C in winter and 24 °C in summer) and provide thermal comfort in the office.
- A suitable dead band for the thermostat helps the indoor temperature oscillate within the thermal comfort temperature range and increase the lifecycle of the SHC system.
- Suitable envelope insulation helps the indoor temperature reach the desired temperature sooner and remain in this range for a longer period.
- In arid climate conditions, the outside temperature decreases drastically at night, especially in cold winters. In the commonly insulated building, the indoor temperature is significantly affected by the outdoor conditions at night.
- In the commonly insulated building, the indoor temperature is far from the desired setpoint in the beginning of the morning. In this case, the indoor temperature reaches 21 °C (setpoint temperature) at noon. This issue illustrates the remarkable effects of the building's heat exchange with surroundings through its envelope.

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