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Experimental and Theoretical Study to Invest Solar Energy for Operating Water Coolers

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Abstract

This work concerns with the investment of solar power to run water coolers . Four water coolers with 20 liters operational capacity are used for eight hours. It was a design calculations required to set up a full solar system. And have been performed calculations design in two stages to get the desired results, the first theoretical and that on the basis of which require the construction of the solar system, solar panels number six with a capacity of 100 watts and four inverters capacity of 1000 watts with 12 volts as parts mainly effective with the controllers of charging and battery with container number four In order to run the system. But that did not happen and did not operate the system, only third hour later got a hard landing.The second is experimental design process and that on the basis of which require the construction of the solar system solar panels are eight with capacity of 100 Watts and four inverters capacity of 1000 watts with 24 volts as parts effective principally with the controllers of charging and battery container with the number four, which gave the functioning effectively for eight hours and achieve the desired results of this research, which it installed on the surface of renewable energies technology center in University of Technology. In order to discuss the main factors affecting the solar panels the following parameters should be measured such as the output power, the ability of output flow and the surface temperature, and the efficiency of photoelectric conversion and working hour. Where the measuring devices are available in the lab of energy and renewable energies technology centre in University of Technology .

1.<u>Introduction</u>

Solar cell is the core component of photovoltaic power generation system. The photoelectric conversion efficiency of a solar cell is about 6-17% in commercial application [1]. Most of the radiation has been converted into heat, which results in high temperature of the solar cell and low efficiency. According to Weng *et al* [2], the temperature increase of 1K corresponds to the reduction of the photoelectric conversion efficiency by 0.2%-0.5%. In addition, long-term high temperature of the solar cell will shorten its service life. Therefore, solar cell cooling is of essential importance. Water-cooling methods are both commonly used in solar cell cooling [2-4]. Thermal tube cooling is deemed to be a promising cooling technology [5-7]. Encountered by the successful world wide effort to protect the ozone layer, scientists and engineers have been committed to minimize and reverse the harming environmental effects of global warming. Global warming occurs when carbon dioxide, released mostly from the burning of fossil fuels (oil, natural gas, and coal) and other gases, such as methane, nitrous oxide, ozone and water vapor, accumulate in the lower atmosphere. As results of the rapid growth in world population and the economy, especially in developing countries, total world energy consumption has increased and is projected to increase by 71% from 2003 to 2030 [8]. Fossil fuels continue to supply much of the energy used worldwide, and oil remains the primary energy source. Therefore, fossil fuels are the major contributor to global warming. The awareness of global warming has been intensified in recent times and has reinvigorated the search for energy sources that are independent of fossil fuels and contribute less to global warming. Among the energy sources alternative to fossil fuels, renewable energy sources such as solar and wind garner the public's attention, as they are available and have fewer adverse effects on the environment than do fossil fuels. [9]. Thermal energy obtained from the sun with a solar thermal system can be used for domestic water heating, and heating or even cooling of buildings. Solar domestic hot–water systems prevail because the hot–water requirement can be well covered by the solar energy offer. Air–conditioning systems are the dominating energy consumers in buildings in many countries, and their operation high electricity peak loads during the summer [10]. The solar cooling technology can reduce the environmental impact and the energy consumption issue raised by conventional air–conditioning systems.The solar thermal energy and its use for building heating and domestic hot–water (DHW),have been described and performed an energetically analysis of the solar heating systems. Also, this paper provides a review of the available cooling technologies assisted by solar energy and their recent advances. The sun radiates considerable energy onto the earth. Putting that diffuse, rarely over 950 W/m^2 work energy has led to the creation of many types of devices to convert that energy into useful forms, mainly heat and electricity. Worldwide, solar energy use varies in application and degree. In China and, to a lesser extent, Australasia, solar energy is widely used, particularly for water heating. In Europe, government incentives have fostered use of photovoltaic and thermal systems for both domestic hot–water and space heating. In the Middle East, solar power is used for desalination and absorption air–conditioning. Solar energy use in the United States is relatively modest, driven by tax policy and utility programs that generally react to energy shortages or the price of oil [11]. The equipment technology for building solar heating systems is already well put into place in a series of countries like Germany, France, Russia, Israel, Japan, USA, Australia, and Canada. In Romania, the concerns in the field of solar energy culminated in 1979, by implementing domestic hot–water systems for dwelling buildings. Timisoara was the first city where a whole district "Zona Soarelui" was provided with this type of installations. To these add up some hot–water systems for agriculture or industry. [12]. Solar radiation reaches earth's surface as: direct solar radiation (solar constant is 1355 W/m^2) and diffuse solar radiation.. The total radiation received from the Sun, of a horizontal surface at the level of the ground, for a serene day, is the sum of the direct and diffuse radiations. Direct radiation depends on the orientation of receiving surface. Diffuse radiation can be considered the same, irrespective of the receiving surface orientation although in reality there are small differences. Figure.1 represents the proportion of the diffuse radiation in total radiation.

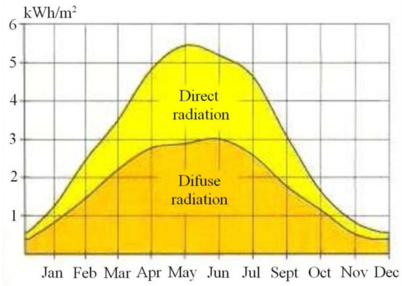


Fig. 1 Total and diffuse solar radiation

Unitary thermal energy received from the sun, measured at the level of earth's surface, perpendicularly on the direction of solar rays, for the conditions where the sky is perfectly clear and without pollution, in the areas of Western, Central and Eastern Europe, around noon, can provide maximum 1000 W/m^2. This value represents the sum between direct and diffuse radiation. Atmosphere modifies the intensity, spectral distribution and spatial distribution of solar radiation by two mechanisms: absorption and diffusion. The absorbed radiation is generally transformed into heat, while the diffuse radiation is resent in all the directions into the atmosphere. Meteorological factors that have a big influence on the solar radiation at the earth's surface are: atmosphere transparency, nebulosity, clouds' nature, their position. Romania disposes of an important potential of solar energy due to the favorable geographical position and climatic conditions. On 1 m^2 plate horizontal surface, perpendicular to the incidence direction of the sun's rays, can receive an a energy of 900 to 1.450 kWh/year, depending on the season, altitude and geographical position. The daily mean solar radiation can be up to 5 times more intense in summer than in winter. There are situations in winter, under favorable conditions (clear sky, low altitude etc.) values of approx. 4–5 kWh/(m^2 day) received solar energy, the solar radiation being practically independent of the environment air temperature. Quantifying this value related to Romania's annual energy requirement situated around the value of 260,900,000 MWh, around year 2011, is obtained an energy of approx. 285,000,000,000 MWh/year radiated by the sun in the country's territory. This represents Romania's total energy consumption for a period of 1092 years. Solar cooling technology can be classified into three categories: solar electrical cooling, solar thermal cooling, and solar combined power and cooling. Thermal energy produced from the solar energy can be transformed to useful cooling and heating through the thermo chemical or thermo physical processes by using thermally activated energy conversion systems. Thermally activated energy conversion systems are further classified into three categories: open sorption cycles, closed sorption cycles, and thermo–mechanical systems. Solid and liquid desiccant cycles represent the open cycle [13].

2. Theory

2.1 Design and calculations

Each Solar panel (PV) is rated by its DC output power. Currently the best commercial solar panel (PV) efficiency is around 17.4%. Solar panels are normally 12V DC output. In large solar panel 24V or 48V DC output also seen. Normally a few common specifications are seen all types of solar panel Like Nominal voltage, Maximum Voltage, Open circuit Voltage, Maximum Current, Short Circuit Current, Maximum System Voltage, and Maximum Power.The technical specification used of a solar panel are given in table(1)

Table. 1: Technical specification of solar panel

Model	Sp20 125*125/4@36
Cell material	Mono crystalline
Maximum power (Watts)	100 Watts
Cell Grade (A, B, C, D)	A
Nominal voltage (Volts)	12 V
Maximum voltage (Vmp – Volts)	17.9 V
Open circuit voltage (Voc – Volts)	21.5 V
Maximum current (Imp – Amp)	5.88 A
Short circuit current (Isc – Amp)	6.55 A
Maximum system voltage (Volts)	480 V
Cell efficiency %	17%
Dimensions	Length= 120 mm, Width= 68 mm, Thickness= 35 mm
Weight (Lbs)	40 lbs
Cell size	125*125/4 mm
Cell quantity	176
Frame structure (Material)	Extruded anodized heavy aluminum
Encapsulation	EVA
Rear side	DuPont Tedlar (TPT)
Glass thickness (Inch)	3.2 mm
Max. wind resistance	65 m/s – 145 MPH
Max. hail diameter size/speed	1+Inch @50 mph
Max. load capacity	200 kg/m^2
Output tolerance	±3%
Temperate coefficient of Isc	-(010+/-0.01)% / °C
Temperate coefficient of Voc	-(0.38+/-0.01)% / °C
Temperate coefficient of power Voc	-0.47% / °C
Temperature range	-40 °C to + 80 °C
Kind of connection	Water proof junction box, can be customized
Guarantee of power	90% within 10 years 80 25 years
Kind of glass	Low Iron, high transparency tempered glass
SLA Battery Voltage	12 V

Maximum Power: it means it can deliver maximum 100 Watts electricity. Maximum Voltage: it means its maximum output voltage is 17.9 V. Open Circuit Voltage: It means the voltage without load. It is sometimes given the symbol Voc Maximum Current: It means the maximum output current. Short Circuit Current: It means the current of short circuit of solar panel. Maximum System Voltage: It means that, when we connect solar panel in series then maximum voltage limit is 480V so we could connect (480/4*17.9)=6 solar panel in series. If we need to design 4 water coolers. To calculate the solar system we have to measure:

1. Solar Panel
2. Charge controller
3. Battery
4. Inverter (for AC output)

Figure. 2: Simple DC solar system

If a subscriber wants to setup a solar system (12 V DC)
The load for the water cooler =100 Watts. Now, if we want 8 hours as operation time so,
The total load (8 ×100watt) = 800 (watt).
To measure the battery ampere for the above load.
Volt = 12
I = 800/12= 67 AH
Battery is needed 12 volt, 67 AH.
Now to calculate the solar panel:
Generally a battery charging current = 10% of it's AH
Charging current = 67 A (67/10= 6.7 A)
Solar panel needed = 6.7 A * 12 V= 80 watt
So recommended the charge controller is 12 Volt, 67 Amp
Thus a solar system is calculated. (System loss is not added with this measurement, so approximate 25% system loss will be added). So from calculations
1. Solar panel =80 Watt, 100 watt (100 watt is available)
2. Battery = 12volt, 67AH (67AH, 100AH battery available)
3. Charge controller = 12 volt, 10A (10A charge controller available).

2.2. Efficiency of Solar panel

The efficiency of solar panel can be evaluated as :

$$Efficiency = \frac{\text{output power}}{\text{input power}} * 100\%$$

Here output power is the power we get from solar panel. Input power is the light fall in solar panel. The light comes from sun in earth surface is $1M^2$=1KW. It means from 1M2 space we could get maximum 1KW energy. If a 1M2 (dimension) solar panel deliver 170 Watts power then the efficiency of solar panel is [14] :

The figure. 3, below illustrated the experimental design of solar system of this research which it installed on the surface of renewable energies technology center in University of Technology.

Figure. 3: Experimental design of solar system

3. The general information of solar system component:

3.1. <u>Components</u>.

The first component needed is one or more Solar Panels. They supply the electricity and charge the batteries. There are three basic types of solar panel as below:

1. Monocrystalline solar panels : The most efficient and expensive solar panels are made with Monocrystalline cells. These solar cells use very pure silicon and involve a complicated crystal growth process. Long silicon rods are produced which are cut into slices of .2 to .4 mm thick discs or wafers which are then processed into individual cells that are wired together in the solar panel. The figure. 4, below show the solar panel using in this study.

Figure. 4: Monocrystalline Solar Panel 12 Volt 100 Watt

2. Polycrystalline solar panels: Often called Multi-crystalline, solar panels made with Polycrystalline cells are a little less expensive & slightly less efficient than Monocrystalline cells because the cells are not grown in single crystals but in a large block of many crystals. This is what gives them that striking shattered glass appearance. Like Monocrystalline cells, they are also then sliced into wafers to produce the individual cells that make up the solar panel.

3. Amorphous solar panels: These are not really crystals, but a thin layer of silicon deposited on a base material such as metal or glass to create the solar panel. These Amorphous solar panels are much cheaper, but their energy efficiency is also much less so more square footage is required to produce the same amount of power as the Monocrystalline or Polycrystalline type of solar panel. Amorphous solar panels can even be made into long sheets of roofing material to cover large areas of a south facing roof surface.

3.2. <u>Charge Controller:</u>

A Charge Controller is needed to prevent overcharging of the batteries. Proper charging will prevent damage and increase the life and performance of the batteries. Now, why a Charge Controller is necessary Since the brighter the sunlight, the more voltage the solar cells produce, the excessive voltage could damage the batteries. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array rises, the charge controller regulates the charge to the batteries preventing any over charging.

3.3. <u>Inverters:</u>

The Power Inverter is the heart of the system. It makes 220 volts AC from the 12 volts DC stored in the batteries. It can also charge the batteries if connected to a generator or the AC line.

For 12v applications an inverter is not required. An inverter should only be required when it is necessary to convert the 12v input to power a 220v standard application.

3.4. <u>Batteries:</u>

the storage Batteries store the electrical power in the form of a chemical reaction. Proper wires & cables are used to connect different parts of the experimental set.

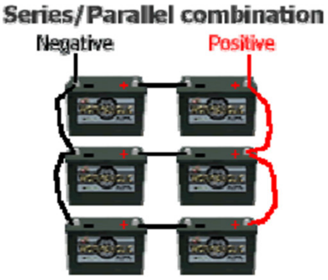
3.5. <u>Connecting the Charge Controller:</u>

After connecting the Solar Panels to the input terminals of the Charge Controller using the above chart, the same size wire to connect the Charge Controller output to the batteries can be used since these wires will carry no more current than the solar panel wires and will probably be located pretty close to the batteries anyway.

3.6. <u>Connecting the Power Inverter:</u>

The Power Inverter is next. Both the Power Inverter and the Batteries require the largest wires in the system. During operation, the AC produced by the Power Inverter draws considerable amps from the batteries. Not only are very large wires required, but they should not exceed 6 feet in length to reach the batteries. These wires are like the large battery cables in cars. Use the largest size possible. An AC appliance drawing 10 Amps (like a microwave or vacuum cleaner) will require 100 Amps at 12 volts DC.

3.7. Connecting the Batteries:



The batteries are last. They will also require very large cables like the large battery cables in cars. The full current to the loads and also the full charging current flow thru the entire battery bank. Connect all the batteries with large high quality cables. Check out the battery Wiring Diagrams tutorial for examples of Series and Parallel wiring techniques that allow the use of battery voltages of 2, 4, 6, or 12 volts.

3.7.1. Use parallel wiring to increase current (power):

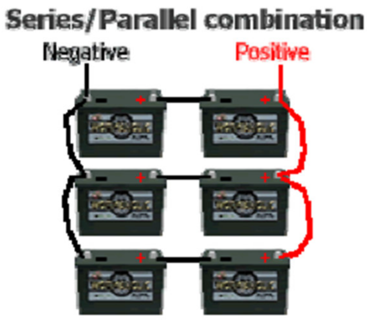
This diagram shows a parallel circuit to increase current or power. Assume that we are using 12 volt batteries. The power of all 3 batteries add to give us the effect of a battery 3 time as powerful but the voltage stays the same at 12 volts. Parallel wiring increases current but the voltage does not change. This is the wiring used when jump starting a car for example.

3.7.2. Use series wiring to increase voltage:

This diagram shows a simple series circuit to increase the battery voltage level. Assume that the really big 4 volt industrial batteries were used.

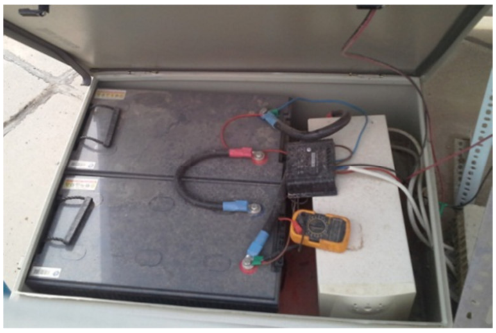
The voltage of all 3 batteries add to give us the effect of a battery 3 times the voltage or in this case a very large 12 volt battery. In this circuit the current is the same as the current in just 1 of the batteries. But since the 4 volt industrial batteries are very large, we have in effect created a huge 12 volt battery.

3.7.3. Use series & parallel wiring in combination:



This diagram shows a combination series and parallel circuit to increase both the battery current and voltage level at the same time. Assume this time we are using 12 volt batteries. The left to right series connection add the two 12 volt batteries to make 24 volts. And, since we did this 3 times and then connected each group of 2 (now 24 volts) in parallel we end up with one very large 24 volt battery. It has twice the voltage of a single 12 volt battery and 3 times the current or power because all 3 groups are wired in parallel [15].

3.8. Container (box)
A container is needed to keep batteries, charge controller from damage and increase the life performance components.



4- Results and discussion
Figure. 5, shows a comparison between the theoretical and the experimental results. It was found from the figure in the theoretical side be the greatest output power at the third hour of the operation, after that gets flop for lack of the system's ability to continue store of energy in batteries. Practically have been processed to get the greatest output power at the eighth hour of the operation, as is shown in the figure.

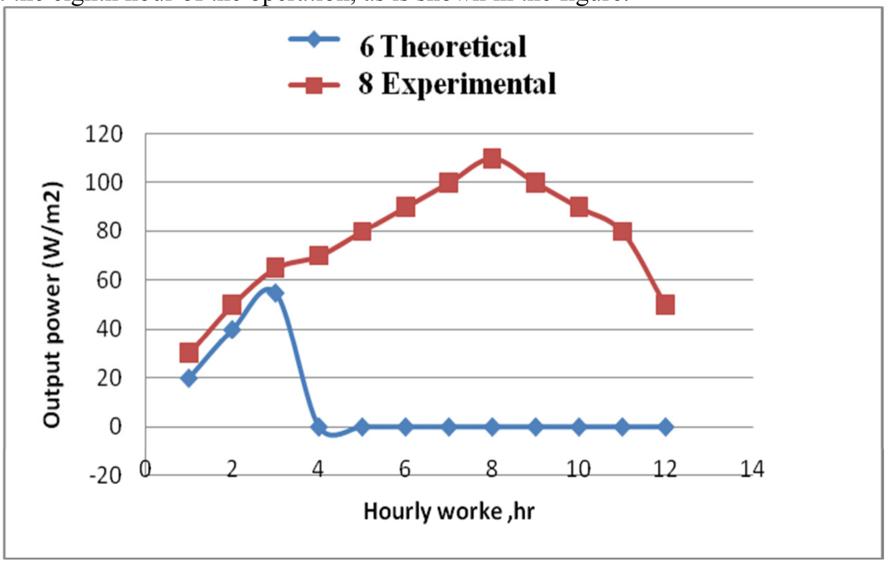


Figure5, Comparison of hourly work between six and eight solar panels versus Output power

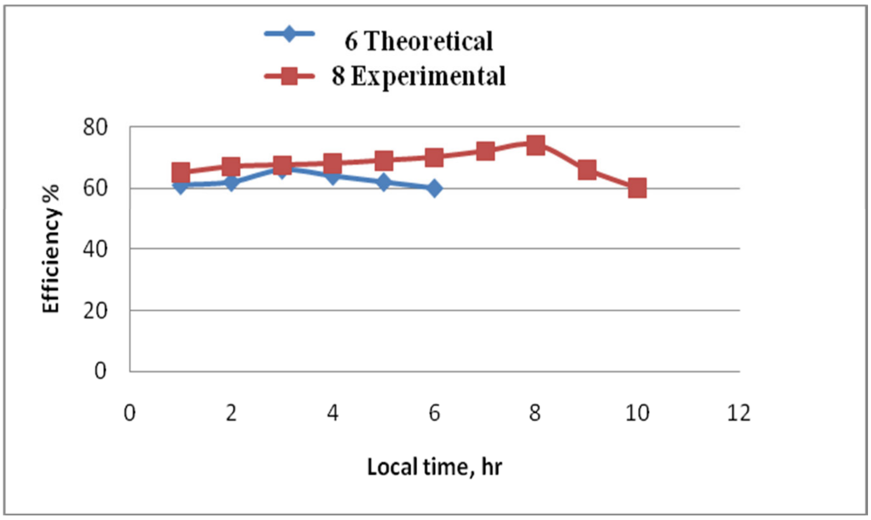


Figure.6: Comparison of hourly efficiency between six and eight solar panels versus time

The solar panel efficiency is discussed and shown in figure. 6. The maximum panel efficiency could reach 78% at the eight hour of the operations in the experimental work, while the efficiency could reach 64% at third hour of the operations in the experimental case.

Figure. 7, shows the panel efficiency versus the temperature for the theoretical and experimental work. We noticed that for the temperature greater than about 22°C the two system provides a higher efficiency which varies due to the range of inverter volts.

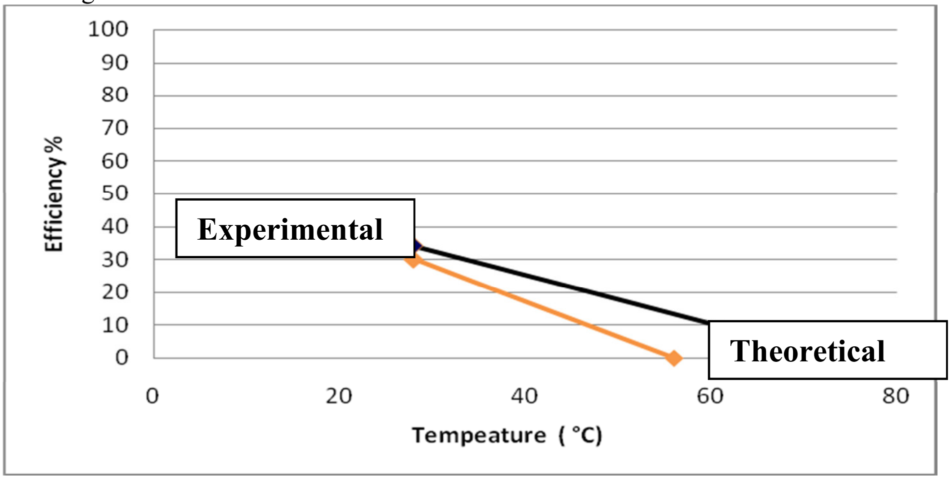


Figure.7: Efficiency of six and eight solar panels versus temperature

The average solar radiation versus time during the test is shown in figure.8, the solar radiation change with time and reached the highest value at the noon.

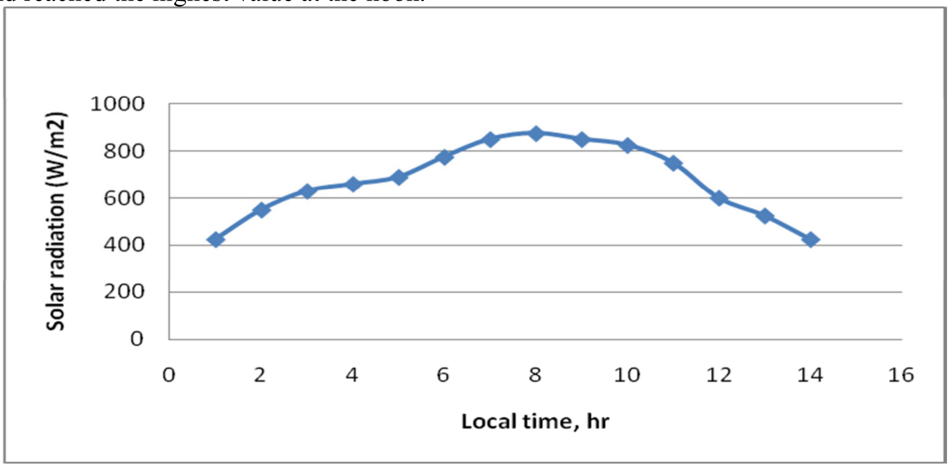


Figure.8: Daily change of the average solar radiation on the solar panel

5- Conclusion

From the experimental and theoretical study of the solar panel system it can be concluded that:

1- The theoretical results showed that the maximum output power could reach at third hour of the operation and the efficiency could reach 64% using a six solar panel and 12 volts inverter.
2- The experimental results showed that the maximum output power could reach at eight hour of the operation and the efficiency could reach 78% using a eight solar panel and 24 volts inverter.

It can widely used for water coolers of educational institutions, hospitals, restaurants, laboratories, office, etc. In conclusion this new system design has desired cooling performance and it can be well applied in the solar water heater system.

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