# Design And Implementation of Solar Cell System To Operate Water Dispenser

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## Abstract:

**This research studies the application of solar energy in operating system of water dispensers. Four water dispensers are used with capacity of (20) liters each a. These dispensers worked along (eight) hours. The design calculation has been performed into two stages to get the desired results. The first stage was the theory which requires the construction of the solar cells system. In order to run this stage we used (6) solar panels with capacity of (100 w) each, (4) inverters with capacity of (1000 w & 12 v) , charging controllers , batteries and (4) containers. But this system worked along (three) hours only where later got a hard landing. The second stage is experimental design process which requires the construction of the solar system. In this stage we used (8) solar panels with capacity of (100 W), (4) inverters with capacity of (1000 w & 24 v) , charging controllers ,battery and (4) containers which gave the functioning effectively for (eight) hours and achieved the desired results of this research. The design and implementation solar cells system of this research was done in the University of Technology. In order to get the desired goal of this research, the research had discussed factors that affect the solar panels such as the output power, the temperature of the surface, the photoelectric conversion efficiency, irradiance solar and working hours.**

**Keywords: Solar Photovoltaic Cells (PV), Cooler System , Water Dispenser, Maximum Power, Monocrystalline cell, Charge controller, Irradiance Solar.**

# تصميم وتنفيذ نظام خلايا شمسية لتشغيل براد مياه

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**المستخلص :**
**يدرس هذا البحث تطبيق الطاقة الشمسية في انظمة تشغيل برادات المياه. استخدمت اربعة برادات مياه بسعة (٢٠) لتر لكل واحد منها حيث عملت طيلة (٨) ساعات من التشغيل .اجريت الحسابات التصميمية على مرحلتين من اجل الحصول على الاهداف المطلوبة من البحث. تضمنت المرحلة الاولى الدراسة النظرية التي تطلبت استخدام نظام خلايا شمسية تمثلت بـ (٦) الواح شمسية سعة كل منها (١٠٠ واط ) ,(٤) محولات بسعة (١٠٠٠ واط & ١٢ فولت ), مسيطرات شحن , بطاريات مع (٤) حاويات للعمل . لكن لم تشتغل المنظومة سوى (٣) ساعات فعلية فقط بعدها حصل الهبوط الحاد. اما المرحلة الثانية فقد تضمنت الجزء التجريبي لتصميم النظام الذي اعتمد في بناءه (٦) الواح شمسية سعة كل منها (١٠٠ واط ) ,(٤) محولات بسعة (١٠٠٠ واط & ٢٤ فولت ), مسيطرات شحن , بطاريات مع (٤) حاويات للعمل حيث امكن تشغيل المنظومة لمدة (٨) ساعات فعلية ومن ثم تحقيق النتائج المطلوبة من البحث . تم تصميم وتطبيق المنظومة في الجامعة التكنولوجية .ومن اجل الحصول على الهدف المطلوب من البحث فان البحث قد ناقش العوامل المؤثرة على الالواح الشمسية مثل القدرة الخارجة , درجة حرارة السطح, كفاءة الخلايا الشمسية ,الاشعاع الشمسي و ساعات العمل .**

## 1. Introduction:

Solar Energy is becoming an important source of energy all over the world, especially in the developing countries. It is one of the most talked-about alternative energy sources in the world today . Enough energy comes from the sun in one hour to power the global population for a year. Sunlight is a totally renewable resource (unlike oil, coal and natural gas) . The high prices of fuel and oil in all countries of the world led to the use of renewable energy which helps to produce electricity . Renewable energy has the largest share acts collapse in research and applications to the field of solar energy conversion into electricity. Photovoltaic (often abbreviated as PV) is a simple and elegant method of harnessing the sun's energy . Solar cell which is the main component of PV module is unique in that they directly convert the incident solar radiation into electricity, with no noise, pollution or moving parts , making them robust, reliable and long lasting saving a lot of cost in transportation. Higher temperatures of weather led to raise electricity demand for cooling system and decrease demand for heating system which reduces electricity production from thermal power plants. [1, 2]. Solar energy is the best way for cooling, more solar radiation led to better cooling with high efficiency of work .

It is important to understand that cooling is one of the most consumed electric power sectors,one can see what is installed in the dashboard of any refrigerator, for example, that consumption is about the (540 watt) in the event that the refrigerator-sized up to (20 cubic feet) . Clearly, the absence of quite a big problem in (540watt), but there is a real problem in the continued consumption of electricity to continue to work for (15 hours) a day. The central air conditioning is electric sink itself when it needs up to approximately (5000 watt). To bring the picture how much the (watts) can do, we can imagine that (100 watt) is capable of running high-glow and (150 watt) lamp capable of running color TV measuring (25 inches). The solar cooling technology can reduce the environmental impact and the energy consumption. Therefore, the current paper makes references to generate energy by solar and its use for cooling water. This paper provides a review of the available cooling technologies assisted by solar energy and their recent advances . Solar radiation reaches earth’s surface as direct solar radiation (solar constant) and diffuse solar radiation. The constant value of the solar is (1355 W/m$^2$). The total radiation received from the Sun, of a horizontal surface at the level of the ground, for clear 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. [3, 4]

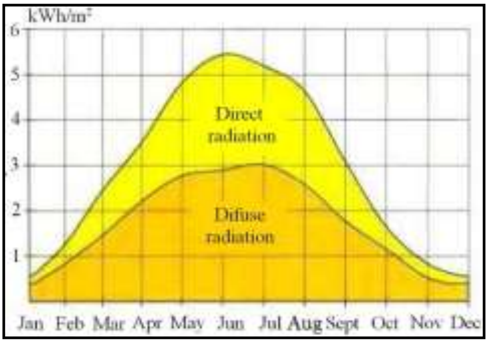


**Fig. 1: Total direct and diffuse solar radiation**

Generally the absorbed radiation is transformed into heat, while the diffuse radiation is resent in all the directions into the atmosphere [5, 6, 7]. Meteorological factors that have a big influence on the solar radiation at the earth's surface are (atmosphere transparency, nebulosity, clouds' nature, their position). On (1 m$^2$) plate horizontal surface, perpendicular on the incidence direction of the sun's rays, can be received 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 (5times) more intense in the summer compared with winter. There are situations when in the winter under favorable conditions (clear sky, low altitude) can be reached values of approx . [(4–5 kWh)/(m$^2$ day)] received solar energy the solar radiation being practically independent of the environment air temperature[8, 9]. An application system of PV can built in additive to the building, and that happens in cooperation between many various disciplines such as civil engineering ,construction engineering and design of photovoltaic systems. The integrated photovoltaic systems with the building (BIPV) can provide services; one of these services using photovoltaic to operate water dispensers at homes [10] . Solar powered cold water dispenser uses solar energy as input power to the refrigerating system . Which provide us zero running cost, and zero pollution to the environment as it doesn’t involve power which is generated from coal, gases, nuclear plant etc [11]. On the other hand there are some operating conditions which result in non-uniform insolation of PV array, such as shadow, clouds, dirt, debris, bird droppings, string-to-string imbalance, different orientations, tilts, panel aging, and so on. If several cells in a series PV module are mismatched, these cells will limit the output current of normal cells. This may lead to decreasing the output power, and can even present hot-spot which cause damage to the cells. The main aim of this paper is to provide a researcher with the fundamental knowledge on design and building the blocks of PV cell based on theoretical and experimental systems of PV cells that used in our water dispensers regarding on sun radiation and tilt angle. [12]

## 2. Theoretical part:

### 2.1 Design and calculations

Solar panel (PV) is a device which can convert energy from light energy (photon) to electrical energy. Each panel 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. Table. 1, illustrated a technical specification (backside of a solar panel) given below:

**Table. 1: Technical specification of solar cell module**

| | |
|---|---|
| Model | Sp20 125*125/4@36 |
| Cell material | Mono crystalline |
| Max 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 cm, Width= 68 cm, 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 at 50 mph] |
| Max. load capacity | [200 kg/m$^2$] |
| Output tolerance | [±3%] |
| Temp. coeff. of ( Isc) | [-( 10/-0.01)]% / °C |
| Temp. coeff. of (Voc) | [-( 0.38/-0.01)]% / °C |
| Temp. coeff. of power(Voc) | (-0.47)% / °C |
| Range of temp. | (-40 to 80) °C |
| connection Kind | Water proof junction box can be specified |
| Power guarantee | [(90)% within (10 )years] |
| Glass kind | 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)

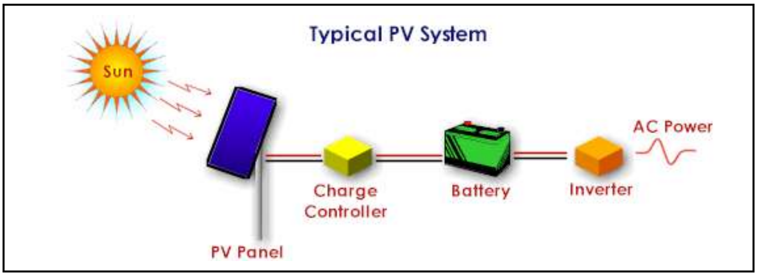


**Fig. 2: Simple DC solar system**

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).
The battery ampere for the above load can be measured.
(V=12) , [(I = 800/12) = 67 AH]
Battery is needed (12 v &67 AH) .

To calculate the solar panel:
The battery charging current is equal to (10% ) of it’s (AH)
Charging current is equal to (67 A) so (67/10= 6.7 A)
The solar panel needed is [ (6.7 A * 12 V)= 80 watt]
So the recommended the charge controller is [(12v) & (67 A)]
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 = (12v& 67AH). (67AH, 100AH battery available)
3. Charge controller = (12 v) & (10A). (10A charge controller available) .[13]

## 2.2. The Efficiency of Solar Cell ($\eta$):

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

The expression of solar cell efficiency denoted to the most commonly used parameter to compare the performance of one solar cell to another.The efficiency refers to the part of energy in the form of “sunlight” that can be converted by means of photovoltaic into electricity. The output power ($P_o$) is the power that occurs from solar panel while the input power ($P_{in}$) is the light fall in solar panel. The light comes from sun in earth surface ($P_{in}$) is ($1KW/1M^2$) or ($100\ mW/1cm^2$).
Figure (3) shows the experimental design of solar system of this research which it installed in the University of Technology.

**Fig. 3: Experimental design of solar system**

## 3. The solar system component:
## 3.1. The Components:

The term of solar panel refers to a panel designed of the solar system .It is used to supply the electricity and charge the batteries. There are three basic types of it as below:

1. **The Monocrystalline Type**: Monocrystalline cell is the most efficient and expensive solar panels. Pure silicon is used in these solar cells which involves a complicated crystal growth process. Long rods of silicon are produced and cut into slices of (0.2 to 0.4 mm) thick discs or wafers processed into individual cells wired it together in the solar panel. Solar panel used in this study shown in figure (4).

**Fig. 4: Monocrystalline solar panel**
**12 Volt 100 Watt**

2. **Polycrystalline Type:** This type is called "Multi-crystalline". It is abit less expensive and slightly less efficient than Monocrystalline types because the cells are not grown in single crystals but in a large block of many crystals which gives them that striking shattered glass appearance. (Polycrystalline and Monocrystalline) cells are sliced into wafers to produce the individual cells that make up the solar panel.
3. **Amorphous Type:** In this type a thin layer of silicon deposited on a base material such as metal or glass to inspire the solar panel so it is not really "crystals". This type of solar panels are much cheaper but their energy efficiency is also much less. More square footage is required to produce the same amount of power as the Monocrystalline or Polycrystalline types 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.[14]

## 3.2. The Charge Controller:


**Fig. 5: The charge controller**

A charge controller is an essential part of nearly all power systems that charge batteries. Charge controller is to safely charge a battery at the correct charge rates and protect the battery from overcharge. It increases the life and performance of the batteries and will block any reverse current from the batteries at night "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 overcharging. Figure (5) shows the charge controller.

### 3.3. Inverters:

Figure (6) shows the Power Inverter. Inverters play a crucial role in any solar energy system and are often considered to be "the brains of the system". An inverter's basic function is to "invert" the (DC) current output into (AC) current. It makes (220 v) AC from the (12 v) DC stored in the batteries. It can also "charge" the batteries if connected to a generator or the (AC) line.

**Fig. 6: The power inverter**

In application systems of (12v) an inverter is not required. Inverters should only be required when it is necessary to convert the input (12v) to the power of (220v) standard application.[14]

### 3.4. Batteries:

**Fig.7: The storage batteries**

Figure (7) shows the storage batteries which are the last step of any designing system of solar cells. Electrical power usually needs to be available when the sun is not shining, it usually necessary to store electricity. In she normal storage of the electrical power in the form of a chemical reaction. Without storage we would only have power when the sun is shining or the generator is running. In any system of solar cell there are four basic components: (the Solar Panels, a Charge Controller, a Power Inverter, and the Storage Batteries). It is necessary to take into account the proper lengths & sections of wires and cables which connect everything.

### 3.5. The Charge Controller Connection:

In solar applications, charge controllers may also be called solar regulators and they represent an essential part of nearly all power systems that charge batteries**.** Considerable efficiency gains of any solar systems can be achieved, particularly when the (PV) array is located at some distance from the battery . It may use the same size wire to connect the charge controller output to the batteries since these wires will carry no more current than the solar panel wires and will probably be located close to the batteries.

### 3.6. The Power Inverter Connection:

The largest wires of the system are used in both the (Power Inverter and the Batteries). In any solar system design there is tendency to produce (AC) from the Power Inverter .In these systems not only very large wires are required, but they should not exceed (6 feet) in length to reach the batteries. These wires are like the large battery cables in cars.. An (AC) appliance drawing (10 A) will require (100 A) at (12 v) DC. Even large cables will get warm. [15, 16]

## 3.7. The connection of batteries:

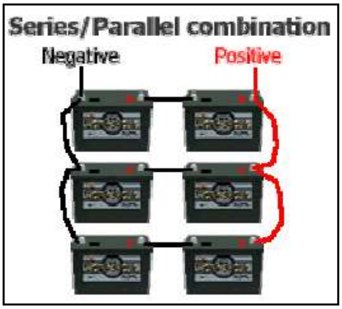


**Fig.8: The connections of batteries**

It is known that the connection of batteries is the main part of (PV) design, so it must choose cables with large high quality. Figure (8) shows the battery wiring connection of "series &Parallel" wiring techniques that allow the use of battery voltages of (2, 4, 6, or 12 v) . Our new "Battery Bank Designer tool" will show how to connect the batteries for these various voltage systems.

### 3.7.1. Increasing current (power) by using parallel wiring:


**Fig .9: The parallel wiring**

A simple parallel circuit as in figure (9) is used to increase the (current or power). The power of all (3) batteries is added to give the effect of a battery (3) times as powerful .The voltage stays the same at (12v). The parallel wiring is used to increase current while the voltage does not change.

**3.7.2. Increasing voltage by using series wiring:**

A simple series circuit. as in figure (10) shows the increasing voltage level we battery. Suppose of use really big (4 v) industrial batteries.


**Fig. 10: The simple series wiring**

The all (3) batteries voltages are added to increase the effect of the battery voltage (3) times ,or in this case a very large (12 v) battery compared with the current which is the same as the current in just one of the batteries. But since the (4 v) industrial batteries are very large, we have in effect created a huge (12 v) battery.

### 3.7.3. Using series & parallel wiring in combination:

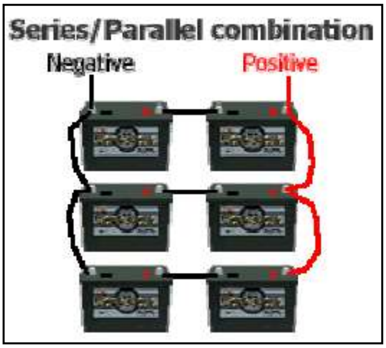


**Fig. 11: The combined wiring**

Figure (11) shows the (series – parallel) connection ccts which is called a combined wiring connection ccts of batteries. This connection is used to increase the level of (current & voltage) of battery at the same time. Two batteries of (12 v) are used in the series (left – right) connection which led to obtain (24v) batteries. Each group of (24v) is then connected in parallel (this process is done three times), then it ends up the batter with one very large (24 v) battery. It has (twice the voltage) of a single (12 v) battery & (three times the current or power) because all of three groups are wired in parallel [16, 17].

### 3.8. Container (box)

A container is needed to keep batteries, charge controller from damage and increase the life performance components. Figure (12).

**Fig.12: The container**

## 3.9: Water dispenser

Water dispenser is one of the modern devices that are used for heating and cooling water in indoor buildings .Different types of water dispenser are used such as tabletop, freestanding, bottom load and direct piping one. The solar cell powered water dispenser can be known as a device that is used for heating and cooling the water and distributes it with the support of solar energy. Figure (13) & Table.2 shows the water dispenser which used in application of this work.

**Table.2: The specification of water dispenser**

| | |
|---|---|
| **Model No** | **CS-DM012** |
| **Heat power** | **500w** |
| **Cold power** | **90w** |
| **Total power** | **590w** |
| **Rated frequency** | **50Hz** |
| **Rated voltage** | **220v □** |
| **Hot water temperature** | **85-95 $^0$C** |
| **Cold water temperature** | **5-10 $^0$C** |
| **Cooling rating electric current** | **0.7A** |
| **Type of climate** | **ST** |
| **Refrigerant cold** | **R134a** |
| **Quantity of refrigerant cold** | **35g** |

**Fig.13: Water Dispenser**

## 4. Results and discussion

Theoretical and experimental results shown in figure(14) elucidate a comparison between them .From the figure it can be seen that the theoretical side be the lesst 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 it has been processed to get the greatest output power at the eighth hour of the operation, as shown in fig (14) below.

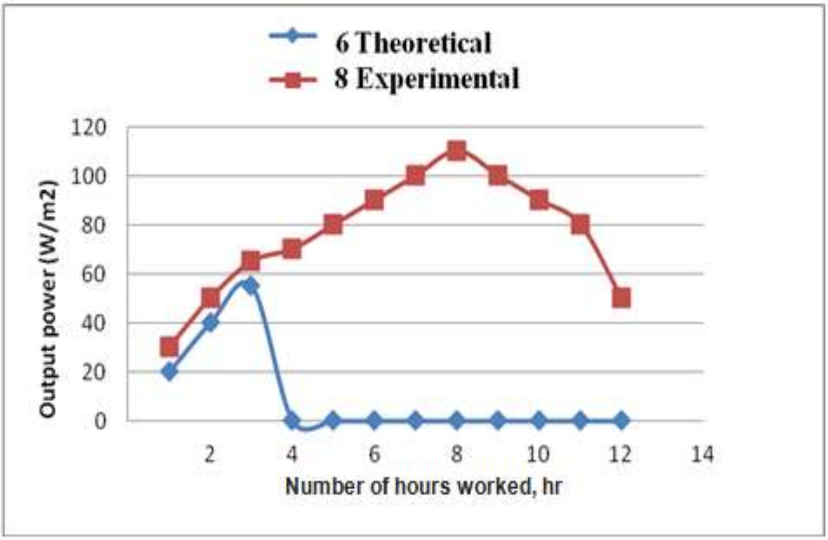


**Figure.14 Comparison of hourly work between theoretical and experimental solar panels versus output power**

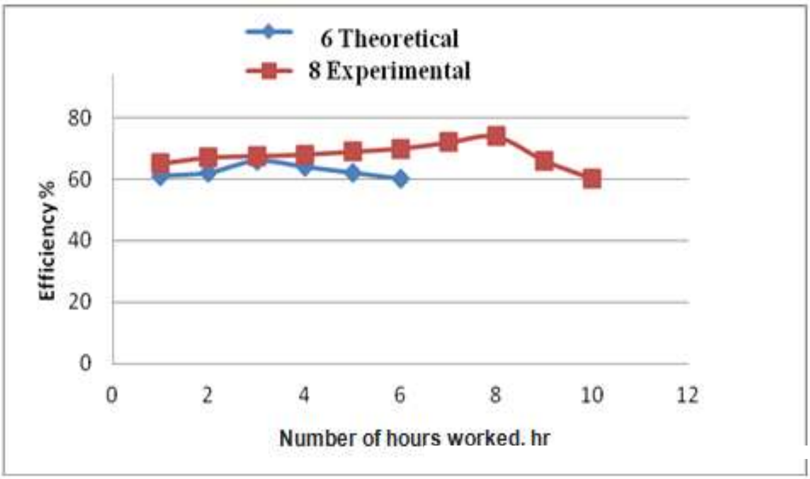

**Figure.15: Comparison of hourly efficiency between theoretical and experimental solar panels versus number of hours worked**

The solar panel efficiency is discussed and shown in figure (15) .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(16) shows the panel efficiency versus the temperature for the theoretical and experimental work. We noticed that for the temperature greater than (22°C) the two systems provides a higher efficiency which varies due to the range of inverter volts.

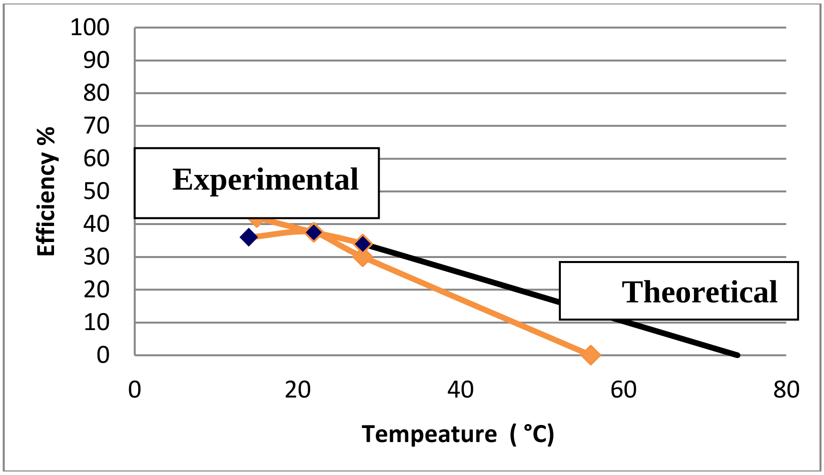


**Figure.16: Efficiency of theoretical and experimental solar panels versus temperature**

Figure (17) shows the hourly irradiance on a horizon for Baghdad city for the fifteenth day of January and June taking into accounts the effect of the climate factors such as dust and clouds effect.

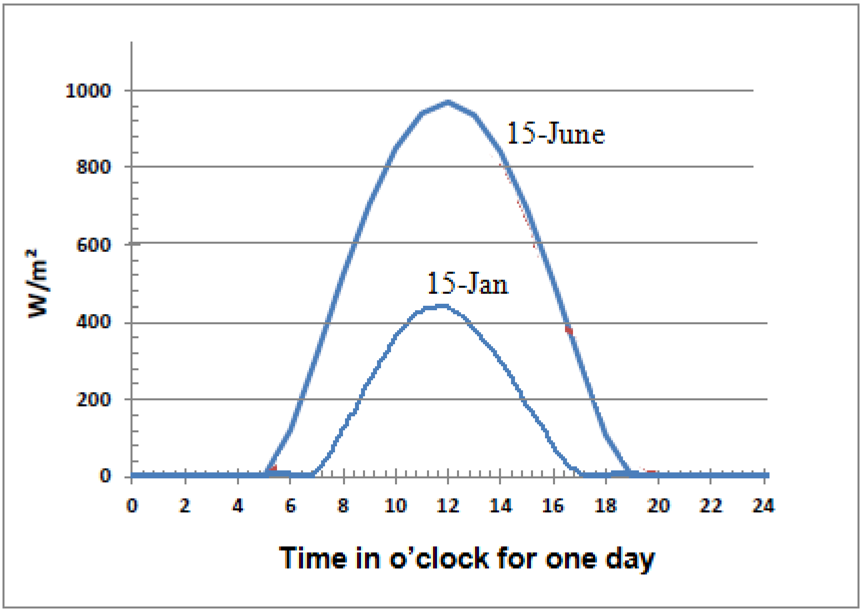


**Figure (17): Hourly irradiance on a horizon for15-Jan and 15-Jun.**

The optimal tilt angle has been obtained by varying the slope of the solar surface from (0°) up to (90°), and then the solar radiation is calculated. Table (3) illustrates the yearly solar irradiance with different tilt angles.

**Table (3): Yearly solar irradiance with different tilt angles.**

| Tilt angle | 0° | 10° | ***20°*** | ***30°*** | ***35°*** | 40° | 50° | 60° | 90° |
|---|---|---|---|---|---|---|---|---|---|
| Annualls average irradiance (kWh/m$^2$/day) | 5.3 | 5.6 | ***6*** | ***6.08*** | ***6.04*** | 5.9 | 5.6 | 5.1 | 2.8 |

The table shows that the maximum yearly solar radiation is at tilt between (30°) and (35°). This also can be seen from Figure (18). Therefore, it was concluded that the yearly optimal tilt angle is approximately equal to the latitude of Baghdad city (33.33°).

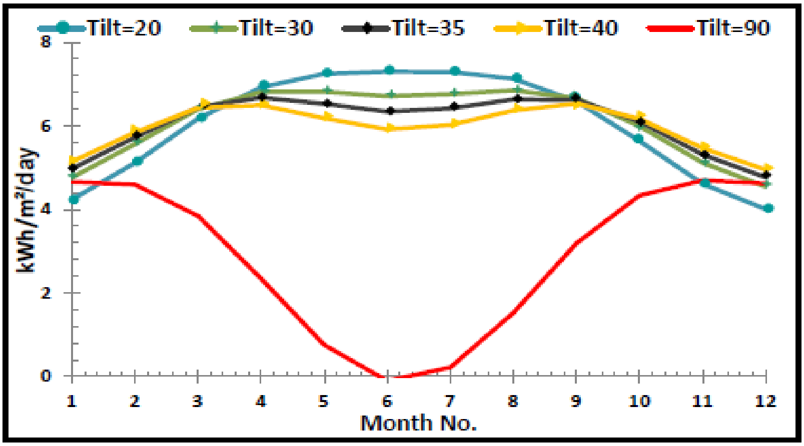


**Figure (18): Monthly pattern irradiance with different tilt angles.**

Figure (19) shows the average solar radiation versus time during the test in the solar radiation change with actual (8) hours run time that the system worked.

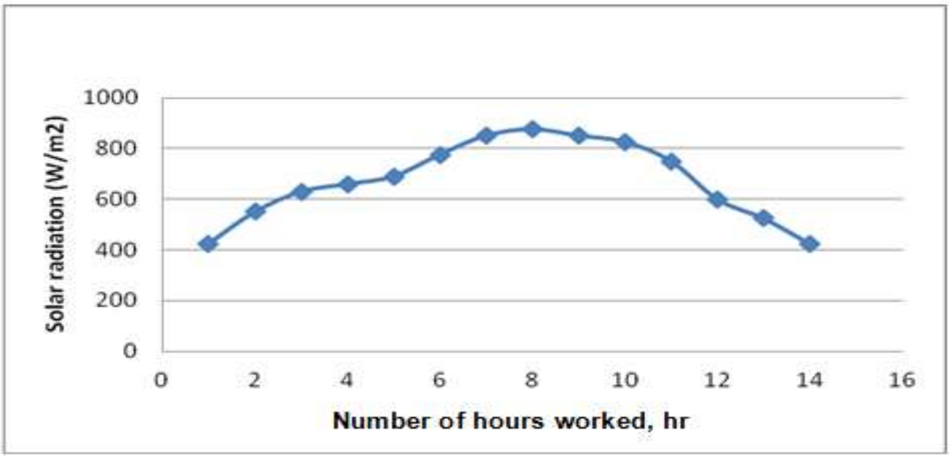


**Figure.19: The average solar radiation on the solar panel along actual run of (8) hours**

## 5. Conclusion:

From the performed work with case study used in this paper, the following points can be concluded:

1-The peak load arises and grows depending on the climate conditions such as high temperatures.

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

3-The results of experiments showed that the maximum output power could reach at eight hours of the operation and the efficiency could reach 78% at using eight solar panels and (24 volts) inverter.

4- From solar radiation analysis, the yearly optimal tilt angle is (33°) (towards south) which approximately equals the latitude of Baghdad city, but in this case, losing amount of solar energy will occur especially in wintery months, so it is important to suggests suitable angle of work in winter such as (40°- 45°).

5- Because batteries are expensive, it is necessary to suggest methods to store this energy and discharge it in the proper time.

6-It can widely be used for water coolers of educational institutions, hospitals, restaurants, laboratories, offices, etc. because it reduces the wastages of electricity and it can be well applied in study of the solar water heater systems.

7-It can offer a solution for cooling systems in those areas where it is impossible to access electricity or when doing trips.

8- Iraq is one of the countries that support the prices of electricity generated by oil derivatives for its citizens, so it must study the correct economic feasibility that required generating energy by solar cells to obtain a reduction in the cost of one watt produced by this kind of generating.

9- Efforts sho uld be intensified to use modern software in modeling and building programs that support the work of solar energy systems because they take into account the continuity of electricity flow during ( 24 h ) .

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