Improving the Solar Panel Efficiency by Using Cooling and Cleaning Techniques

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Abstract

This paper is a contribution to research work which aims at ending the electricity crisis in Iraq. The electric power stations, which use conventional fuel, are unable to provide the growing population with electricity all day-long. Moreover, electric distribution lines are sometimes exposed to attacks by terrorists.

This paper recommends solar energy as the optimum solution to the electricity problem in Iraq, since it is both renewable and friendly to the environment.

The paper also concentrated on reliability techniques to improve the efficiency of the solar energy system. This was achieved by means of designing and constructing a cooling system that consists of fans, sprinklers and wipers to eliminate excessive heat from solar panels when temperature rises to maximum levels. Sprinklers and wipers are also useful for cleaning the panels because dust is a negative factor which undermines the generation capacity of solar panels.

The cooling system is operated by means of a microcontroller that is programmed through Proteus 8, Arduino, and Matlab2016. Statistics reveal that a cooling system has significantly improved the productive capacity of the solar system and it can achieve an energy gain of (**34.55%**).

Keywords: Renewable energy, Solar cells, Microcontroller, Sprinklers, Fans, Wipers.

الخلاصه

ان الهدف الرئيسي من هذا البحث هو المساهمة في انهاء ازمة الكهرباء في العراق، ذلك لان محطات الطاقة الكهربائية التي تنتج الطاقة بالطرق التقليدية تعجز عن توفير الكهرباء للمواطنين بشكل دائم ومستمر. وإضافة الى ذلك، فان خطوط نقل الكهرباء تتعرض احيانا الى الهجمات الارهابية.

ان هذا البحث يوصي باستخدام الطاقة الشمسية لانها تمثل الحل الامثل لمشكلة الكهرباء في العراق، فهي طاقة متجددة وصديقة للبيئة. وقد ركز هذا البحث على تطوير تقنيات فعالة من شأنها تحسين اداء منظومة الطاقة الشمسية، وتم ذلك من خلال تصميم وبناء منظومة تبريد مؤلفة من مراوح ومرشات مائية وماسحات لتخفيض درجات الحرارة في الالواح عندما تشتد الحرارة في ساعات الذروة في فصل الصيف، كما تعمل المرشات المائية والماسحات كأدوات لتنظيف الالواح من الاتربة التي تؤثر سلبا وتضعف اداء وكفاءة المنظومة في انتاج الطاقه الكهربائية. لقد تمت السيطره على عمل منظومة التبريد والتنظيف بواسطة جهاز تحكم (مايكروكنترول) تمت برمجته من خلال برامج:- (Proteus 8) و (Arduino) و (Matlab2016). وتشير الاحصائيات الى ان منظومة التبريد ترفع الطاقة الانتاجية لمنظومة الطاقة الشمسية وتحقق ربحا في الطاقه بمعدل (**34.55%**).

الكلمات المفتاحية: الطاقة المتجددة، الخلايا الشمسية، المايكروكنترول، المرشات المائية،المراوح، الماسحات.

1. Introduction

The demand for energy is constantly increasing due to the fast growth in world population and the remarkable developments in the technological and industrial sectors, **Das *et.al.*, 2016**. Researchers and decision makers must work together to find effective solutions to the energy crisis, which is considered one of the major problems facing the modern world nowadays. Countries all over the world are adopting various strategies, plans and techniques to improve their economic status and provide against future energy shortage, (**Omer and Abdeen ,2008)**. But the more serious problem is the possibility that all efforts directed at achieving economic growth may end in failure due to the fact that conventional energy sources (oil and coal) are constantly consumed and may end from the world sooner or later. Another problem which threatens human societies is the environmental pollution resulting from burning conventional fuel to provide energy in various parts of the world. Developing countries, in particular, face great difficulty in providing sufficient energy to meet the requirements of their growing populations. Though enormous research work has been

done to improve energy generation capacity, many areas in developing countries are still deprived of electric power services,(**Demirbas and Ayhan , 2005)**

Researchers have found that non-conventional, renewable energy sources represent the best solution to the energy crisis and to avoid any environmental disasters in the future, (**Jacobson *et.al.*, 2011)**. The sun is in fact the most enormous source of renewable energy, and solar energy reaches the earth in the forms of light and heat. Solar energy may represent an ideal alternative to other renewable energy sources, especially in Iraq, which enjoys a long summer season and sunny days almost all the year round. Research work revealed that Iraq and other Asian countries may fulfill their need of electricity by relying on solar energy alone. It is to be regretted that solar radiation, which has such great potential to generate electric power and serve humanity is not properly utilized and is subject to wastage every day, especially in countries that receive sunlight for very long periods throughout the year, **(Das *et.al.*,2017)**.

Unlike oil and other conventional energy sources, the process of generating solar energy does not have a negative impact on the ecological system. Solar energy can be utilized in numerous fields such as agriculture; industry as well as cooling, heating, lighting and other home applications, since it is inexhaustible and freely available in nature. The solar panels industry witnessed remarkable development in recent years, **(Jiang, 2008)**.

This research paper is an attempt to offer an overall, panoramic view of the solar energy system, its main advantages with special emphasis on means and techniques to improve the performance level of the solar panels and ensure a higher energy output by providing the solar system with fans, sprinklers and wipers which operate as cooling and cleaning devices for the panels to eliminate excessive heat, which undermines the productive capacity of the panels when temperature rises to high levels in summer **(Chaichan *et.al.*, 2016)**. Experiments proved that a solar system provided with a cooling and cleaning system can achieve an energy gain of (34.55%) if compared with a system that lacks the cooling factor. Results were analyzed and calculated by using (Matlab and Proteus) programs.

2. Related Work

Electricity is essential to all modern societies to meet human needs in numerous fields such as lighting, heating, cooling and industrialization. Researchers in many countries are trying to find viable solutions to the energy crisis by considering cheap and eco-friendly alternatives to conventional energy sources, i.e. oil and coal which are costly and harmful to the environment.

Many researchers agree that solar energy represents the best solution to the energy crisis in many parts of the world, since the sun is the most powerful, inexhaustible, potential source of energy available in nature.

This study refers to several related research papers for the sake of comparison and contrast and in order to enhance the solar energy system proposed in this study with ideas and techniques exploited by previous researchers.

(Sumit *et.al.*, 2014). This research paper concentrates on developing a cooling system consisting of a water pipe-line on the rear sides of solar panels. The system is also provided with a thermostat for measuring panel temperature. The sprinkler is designed to operate and sprinkle water only when panel temperature rises to high levels. The sprinkler also helps to remove the dust which normally accumulates on the surface of the solar panel.

(Moharram *et.al.*, 2013). This study offers a cleaning system which uses non pressurized water as well as surfactants to clean the PV panels. The cleaning system

proposed in this study is actually applied in a PV power plant installed in Cairo, Egypt to test its applicability in dusty regions.

It is quite evident that my study shares with the two research papers, discussed briefly above, a common interest in the vital role of a cooling system in improving the operational efficiency of PV panels by using sprinklers to cool and clean them. But it is also true that the cooling system proposed in my paper includes fans and wipers which are not exploited in the two research projects mentioned above. Fans and wipers are essential to maximize generation of electric power and minimize water used in the cooling and cleaning process.

3. Solar cells technology

A solar panel may be defined as a device which can convert sunlight into electric power. It is in fact one of the most intelligent inventions in the field of energy since the sun is the most enormous and inexhaustible source of energy in nature, **(Strantzali, and Aravossis,2016)**. A solar panel is sometimes referred to as (PV) which is the abbreviation of (Photovoltaic), i.e. light – electricity. A solar panel is a collection of solar cells. Solar cells absorb the energy of the sun and generate electric current. A solar cell or a PV cell generates a small amount of electric power, but a large number of solar cells spread over a large area can produce enough power for practical purposes,(**Mohd *et.al.*,2008).**

Experiments proved that directing the solar panels towards the sun is a decisive factor in maximizing energy generation capacity. But when temperature rises to maximum degrees, the PV panels must be cooled to maintain their operational efficiency. In order to achieve this goal, the solar panels are provided with fans, sprinklers and wipers to operate as cooling and cleaning devices. Experiment has proved that this cooling system has contributed to a better operating efficiency of PV panels, **(Thomas *et.al.*, 2016)**.

Solar energy systems use semiconductor material to induce electricity, in which silicon is commonly used. Various forms of silicon such as monocrystalline silicon, polycrystalline silicon, and microcrystalline silicon are commonly used as semiconductors in solar systems. The PV cell works on the principle that the electrons are activated from lower energy state to higher energy state by giving additional energy from the sunlight, **(Ribeiro *et.al.*, 2001)**. This activation will in turn create a number of holes and free electrons in the semiconductor thus giving electricity,(**Qiao, 2013)**. The solar energy system also includes controlling devices, electronic equipment, electrical connections and mechanical devices to ensure better productive capacity. PV systems are rated in peak Kilowatts (KWP) which is an amount of electrical power produced by a PV system when the sun is directly overhead on a sunny day,(**Sakthivel and Arun, 2016)**. It is noteworthy that much research work was carried out to develop an efficient, highly productive solar energy system. The solar panels industry witnessed remarkable development in recent years. Now one can say that it is a flourishing industry, which doubles its production every two years with an average increase of 49% since 2003. Experiments indicate that a well-developed and well-maintained PV panel can operate for ten years if 90%of its capacity was used. However, it can operate for 25 years if only 80% of its capacity was used,**(Kazem *et.al.*, 2017)**.

4. Techniques for improving the operational capacity of PV panels

PV panels include solar collecting components such as flat plates and evacuated tubes which are successfully used for heating and cooling purposes due to their efficiency and low cost. This solar system involves three processes, **(Lund, 2006)**:

1) Absorption of sunlight.
2) Conversion of light into electricity
3) Storage of electric energy

5. Applications of solar energy

Solar energy can serve human societies in numerous fields since it is eco-friendly, inexhaustible and freely available in nature. It is now used for heating, cooling and lighting purposes. It is also used for running a large diversity of machines and equipment as well as to supply power and heat to various industries, **(Alizadeh *et.al.*, 2016).**

This part of the paper offers a brief description of major applications of solar energy which are available now in modern societies as a result of long and hard research work aimed at upgrading solar industry to serve mankind now and in the future. Here follows a summarized account of major applications of solar energy, **(Verma *et.al.*, 2016):**

*PV-systems for household services

PV panels installed on roofs or walls of buildings can be very useful to provide electricity, particularly in remote or rural areas where electricity network services are not available. Surplus energy produced within the building can be fed into the national electrical system. Electricity produced in this way represents the cheapest and most efficient provision of energy for residential areas.

*Solar energy for irrigation systems

Solar energy is used in various countries to irrigate field crops in non-electrified areas. Irrigation is carried out by using an electrical motor which is activated by a microcontroller. This irrigation system which is provided with electric power by a solar energy system is designed to store energy and operate by dripping or sprinkling crops to avoid wastage of water resources. The solar system can also be used to operate pumps which draw water from wells for irrigation purposes.

*Wastewater treatment

Human societies all over the world produce enormous amounts of wastewater every day as a result of numerous human activities and industrial processes. This huge amount of wastewater represents a serious threat to man and nature if left without treatment. Wastewater treatment is a complicated and expensive process which requires a lot of energy. However, solar energy can be very useful, as a cheap alternative to expensive fuel, to operate treatment machinery to eliminate environmental pollution.

6. Experimental Setup

An experimental setup has been developed to test the influence of cooling and cleaning processes by using fans, sprinklers and wipers on the operational efficiency of the solar energy system.

The experimental setup consists of six major components, **(Rupali ,2015):**

1) Solar panel

Features

- Maximum Power (Pmax): 200W
- Maximum Power Voltage(Vmpp): 26.3V
- Maximum Power Current (Impp): 7.61A
- Open Circuit Voltage (Voc): 32.9V
- Short Circuit Current (Isc): 8.21A
- Max System Voltage: 600V

2) Microcontroller(PIC 16F877A)

Features

- Clock speed is high with the rate of 20 MHz.
- Flash program memory: 8Kx14 words.
- Data memory (RAM):368x8 bytes.
- EEPROM data memory: 256x8 bytes.
- High speed in executing instructions.
- Very high efficiency and accuracy.
- Low cost.

3) Wiper

The wiper is activated by the microcontroller to clean the solar panel using DC motor which rotates forward and reverse. The cleaning process is achieved by an up and down movement of the wiper on the solar panel.

4) Valve

Features

- Flexibility in design and installation.
- Non-rising flow control handle adjusts water flow as needed.
- Normally closed, forward flow design.
- Voltage:24 VAC 50/60 Hz

5) Sprinkler

Features

- Uniform distribution of water on the solar panel surface.
- Efficient watering. Use up to 30% less water.
- Spacing:(1.7 to 4.6 m)
- Pressure:(1.0 to 2.1bar)
- Optimum pressure:(2.1 bar)

6) Temperature and Humidity Sensor type (DHT11)

Features

- Excellent stability and great reliability.
- Supply current: 0.3mA.
- Power supply: DC (3.5 – 5.5V)

Methodology of the solar system (on page.6) includes a detailed presentation of the operational mechanism of the cooling and cleaning system.

7. Methodology of the solar system

The methodology of the solar energy generation system is based on using fans and sprinklers to cool and clean the PV panels during hours of excessive heat in summer time, particularly in Iraq and various Asian countries, where the temperature rises above 50^{o}. This cooling is essential because the PV panels are made of silicon, which cannot function properly in very high temperature. Experiment has shown that excessive heat has a negative impact on the generation capacity of the panels. It is also true that dust can undermine the efficiency of the PV panels. To avoid any downfall in the amount of electric power produced, the PV panel is cleaned by sprinklers which spray water on panels and also wipers which are used to remove the dust from the panel surface thoroughly. This is clearly shown in **Fig. 1**.and **Fig.2**.

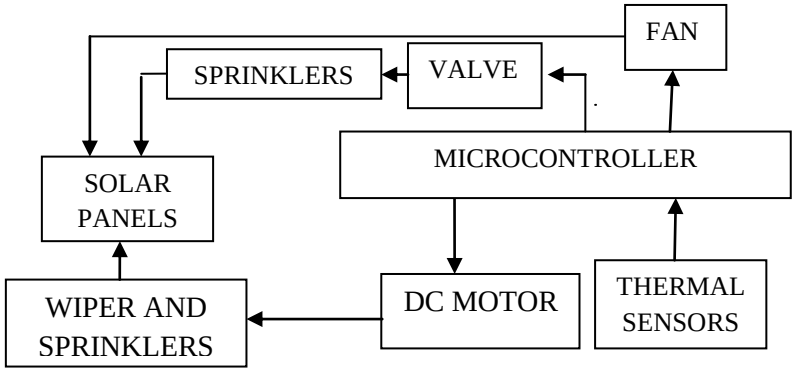

Figure1. Block diagram illustrating cooling and cleaning system

Figure 2. Cooling and cleaning system

The overall operational mechanism of the solar energy system may be summarized as follows:

- In the early hours of the day, the microcontroller is programmed to operate the sprinklers and wipers to clean the solar panel of dust. This process continues for 2 minutes and then the sprinklers and wipers are automatically switched off.
- The PV panels are provided with a sensor which signals to the microcontroller when temperature rises above 25^{o}.
- The microcontroller analyzes the signal and operates the fan to cool the PV panel.
- When temperature rises to very high degrees and the fan fails to cool the panel to the desired degree, the microcontroller sends a signal to the sprinklers to start work.
- When the weather improves and temperature decreases, the sensor gives signal to the microcontroller, which in turn signals to the sprinklers to cease operating.
- When the cooling process is no longer needed as temperature falls even more, the microcontroller signals to the fans to stop.

These processes are shown in **Fig. 3, Fig. 4& Fig 5.**

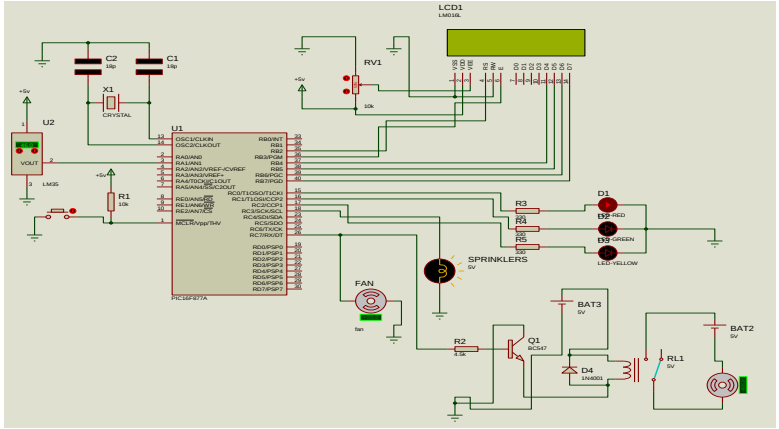

Figure 3.Cooling and cleaning system of sprinklers and fans constructed according to proteus program.

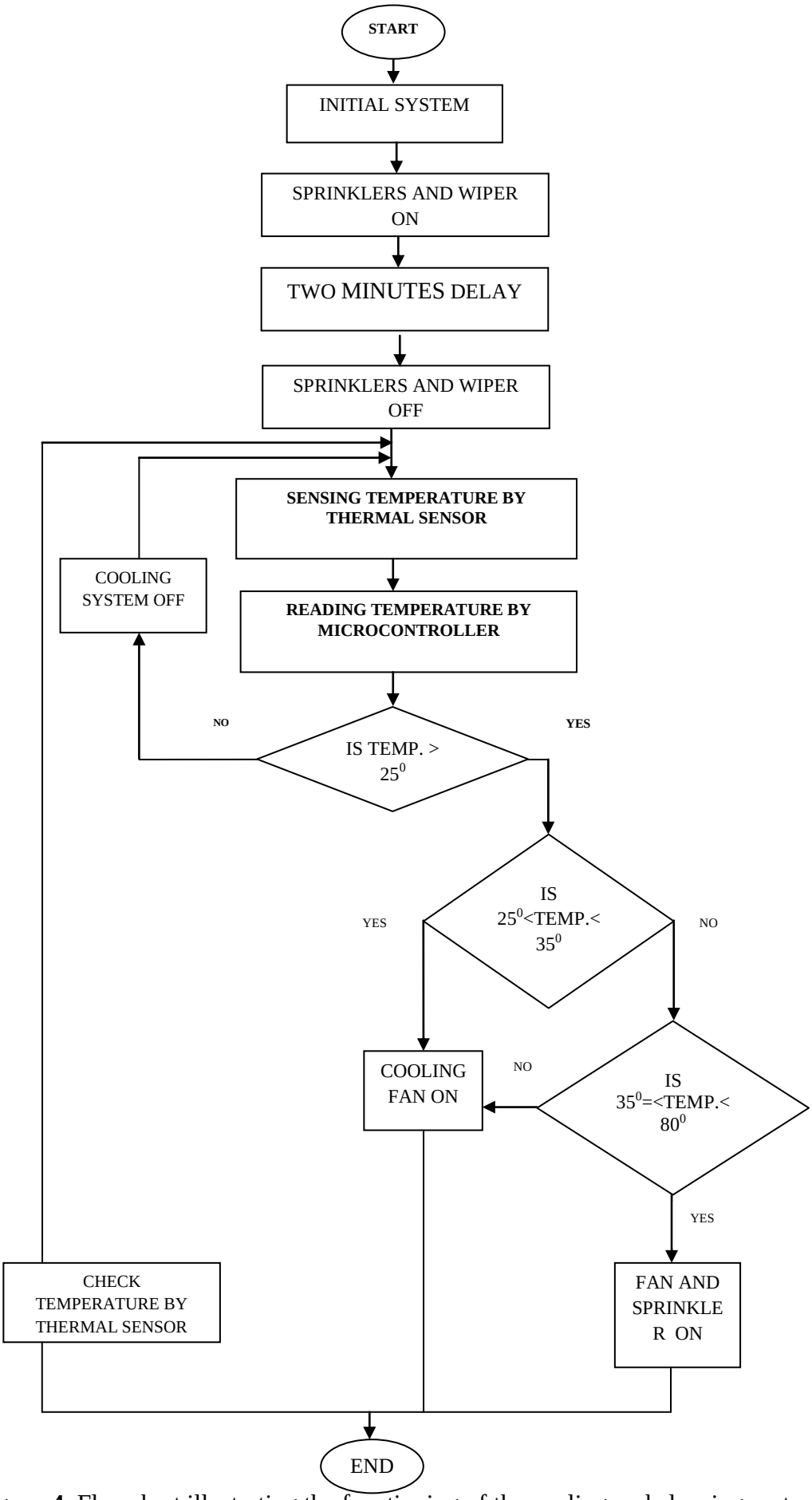

Figure 4. Flowchart illustrating the functioning of the cooling and cleaning system.

Figure 5. An operational system for sensing and reading temperature and humidity levels by using microcontroller

8. Results and data analysis

Shortage of electricity provision is a phenomenon in Iraq, particularly in summer when temperature rises to very high degrees leading to excessive use of cooling equipment by citizens, and therefore causing great consumption of electric power which exceeds the productive capacity of the national electric system in Iraq. This research paper offers solar energy as the best solution to the electric energy crisis in Iraq. To achieve this goal the paper concentrates on designing and building a solar energy system, which can provide an abundant amount of electric power to put an end to the electricity problem in Iraq. This solar system operates very efficiently during the early hours of the day in summer time. But as the PV panels get hot due to the rise in temperature, they lose some of their productive capacity. Therefore they are provided with fans for cooling purposes. But when temperature rises to maximum levels, the fans alone fail to lower the temperature of the PV panels to the desired level, and therefore sprinklers and wipers are used to cool the panels and clean them of the dust which is also considered a negative factor that undermines the efficiency of PV panels.

To test the efficiency and reliability of this solar system in electric power generation, a summer day was randomly chosen, and readings of voltage, current and temperature were recorded (at different times of the day) for the solar energy system which does not use any cooling devices. These readings were compared to relevant figures taken for the solar system which is provided with fans. Readings were also recorded for the solar system which includes a cooling system consisting of fans, sprinklers and wipers. The results of tests and comparisons (which are shown in **Table 1**, **Fig. 6**, **Table 2** and **Fig. 7**) clearly indicate the high efficiency and stability of the solar energy system which is supported by a cooling and cleaning system that uses fans, sprinklers and wipers. No fluctuation or failure in its generation capacity was noticed in comparison with the system that uses only fans or the one which uses no cooling devices at all.

Table1. The current, voltage and power values of solar panels with no cooling devices in comparison with solar panels with cooling fans in a summer day in Iraq.

Time	Solar panel without cooling			Solar panel with a cooling fan			Temp (C^o)
	Current (ampere)	Voltage (volt)	Power (watt)	Current (ampere)	Voltage (volt)	Power (watt)	
5:00am	1.7	14.3	24.31	1.7	14.3	24.31	25
6:00am	1.8	14.6	26.28	2.1	14.8	31.08	27
7:00am	2.5	15.4	38.50	2.7	15.8	42.66	30
8:00am	2.7	15.6	42.120	3.8	16.27	61.826	35
9:00am	4.9	15.9	77.9100	5.2	16.8	87.36	39
10:00am	5.9	16.2	95.5800	6.1	16.9	103.00	41
11:00am	4.8	16.1	77.2800	6.5	16.7	108.50	44
12:00pm	3.8	16.4	62.3200	6.3	16.5	103.9	45
1:00pm	3.7	16.2	59.9400	5.1	16.1	82.11	46
2:00pm	2.6	15.3	39.7800	4.7	15.7	73.790	49
3:00pm	1.5	15.1	22.6500	4.3	15.9	68.370	48

4:00pm	1.6	15.6	24.9600	3.9	16.1	62.790	46
5:00pm	2.6	15.8	41.0800	4.3	16.2	69.660	43
6:00pm	3.2	15.9	50.8800	4.5	16.42	73.890	41
6:30pm	3.9	16.2	63.1800	4.6	16.5	75.90	40

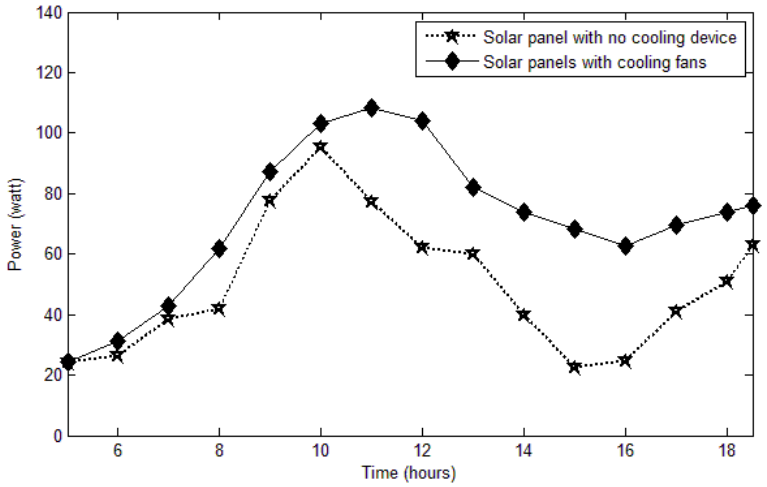

Figure 6. Power vs. time for solar panel with no cooling vs. solar panel with cooling fan.

Table 2. The current, voltage and power values of Solar panel with fan cooling and Solar panel with fan and sprinklers cooling and cleaning in a summer day in Iraq.

Time	Solar panel with fan cooling			Temp. C° before cooling	Solar panel with fan, sprinklers and wiper cooling and cleaning			Temp.C° After cooling
	Current (ampere)	Voltage (volt)	Power (watt)		Current (ampere)	Voltage (volt)	Power (watt)	
5:00am	1.7	14.3	24.31	25	2.7	14.67	39.609	23
6:00am	2.1	14.8	31.08	27	2.8	15.28	42.784	25
7:00am	2.7	15.8	42.66	30	3.4	15.89	54.026	27
8:00am	3.8	16.27	61.826	35	5.2	16.39	85.228	29
9:00am	5.2	16.8	87.36	39	5.5	16.57	91.135	30
10:00am	6.1	16.9	103.00	41	6.9	17.14	118.26	31
11:00am	6.5	16.7	108.50	44	6.8	16.84	114.51	33
12:00pm	6.3	16.5	103.9	45	7.1	16.85	119.63	34
1:00pm	5.1	16.1	82.11	46	6.8	16.36	111.24	36
2:00pm	4.7	15.7	73.790	49	6.7	16.47	110.34	38
3:00pm	4.3	15.9	68.370	48	6.8	16.48	112.06	35
4:00pm	3.9	16.1	62.790	46	6.9	16.34	112.74	34
5:00pm	4.3	16.2	69.660	43	6.8	16.55	112.54	33
6:00pm	4.5	16.42	73.890	41	6.5	16.88	109.72	31
6:30pm	4.6	16.5	75.90	40	6.4	16.37	104.76	30

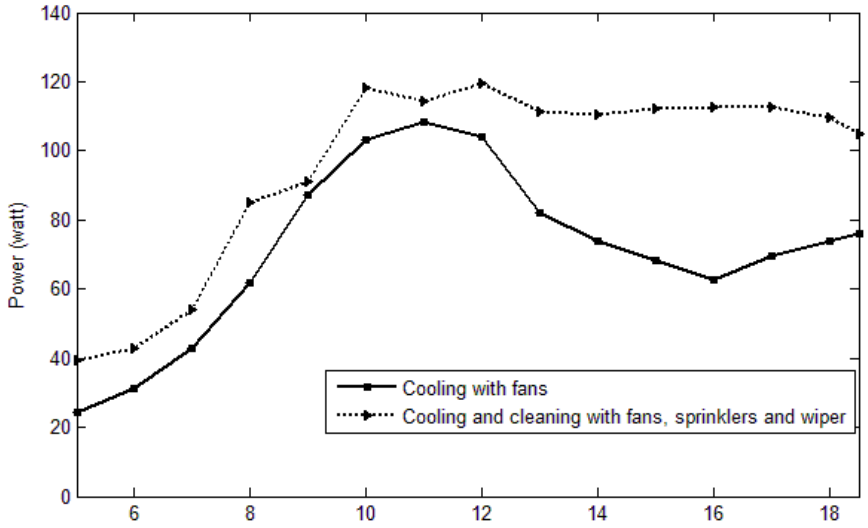

Figure 7. Power vs. time for solar panels with fans only compared to solar panels with fans, sprinklers and wipers**.**

Table 3. includes a summary of the results of the comparison between the solar system which is supported by a cooling system of fans and a solar system which uses a cooling and cleaning system consisting of fans, sprinklers and wipers. **Table 3**. shows clearly that a cooling and cleaning system can achieve power gain of **34.55%.**

Table 3. Energy and relative power gain values of two forms of cooling and cleaning of the solar panel.

	Solar panel with fan cooling	Solar panel with fan, sprinklers and wiper cooling and cleaning
Energy (kwh)	1.0691e+03	1.4386e+03
relative power gain %	-	34.55%

9. Conclusions

It is a well-known fact that the electricity crisis in Iraq has a negative impact on all sectors of life, including agriculture, industry and other social and economic activities. Therefore, this paper is a contribution to the efforts which aim at solving this problem by offering alternatives to conventional energy sources. The paper comes to the conclusion that solar energy represents the best solution to the electricity problem in Iraq since it is eco-friendly and available for long hours especially in summer. The main advantages of the proposed solar energy system are:

(1) Simplicity of design.
(2) High production capacity.
(3) Relatively low cost.
(4) Long duration which may last for 25 years if 80% of its productive capacity was used.

Experiments revealed that using fans to cool overheated PV panels in extremely hot summer days represents a positive factor that improves the efficiency of PV panels. But the mechanism of the solar system was even more significantly improved by providing the system with sprinklers and wipers to cool and clean the PV panels. This cooling and cleaning system (fans, sprinklers and wipers) is activated by a microcontroller.

In addition to their essential role as cooling devices, sprinklers are very useful for cleaning the panel of the dust which must be removed to maintain the efficiency of

PV panels. On the other hand, the fans, which are used for cooling the PV panels, can also help to economize on sprinkling water. .The results of this research also indicate that the use of a cooling and cleaning system increased the productive capacity of the solar system by (**34.55%**).

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