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Energy Saving in Batteries Using the Photovoltaic System

Ali Mahmood Ibrahim[1] , Asst Prof. Dr. Ramzi R. Ibraheem[2] , Asst. Prof. Rizgar Bakr Weli[3]
[1] Ministry of Electricity-KRG, [2,3] Department of Mechanics and Mechatronics, College of Engineering, Salahaddin University-Erbil, Erbil, Iraq.
[1] ali.mahmood8599@yahoo.com, [2] ramzi.ibraheem@su.edu.krd, [3] rizgar.weli@su.edu.krd

ABSTRACT

Photovoltaic panels are used to generate electricity directly or indirectly. in the case of indirect, the energy should be saved in batteries and then it can be used and in this case, the inverter is required to change the direct current of the batteries(DC) to operate alternating current(AC) loads. This paper concentrates on saving energy in batteries and investigating the process of charging and discharging the batteries to operate selective loads in the paper. Using the photovoltaic panels to store energy in batteries, the results reveal that one photovoltaic panel of(80 W) is placed towards south at a tilt angle of 36^o; it could generate (224 W.hr) of energy that was obtained by charging a(65 A.hr) lead-acid battery for 13 hours in April. Using two solar panels each of(80 W)is connecting parallel,(915.6 W.hr) of energy generated in May while using three units in parallel connection the electricity generated was near to that of two panels as the battery reaches nearly the full charge. Ambient temperature rise harms solar panels and leads to a decrease in the efficiency of the solar panel.

Keywords: Battery charging; Photovoltaic panels; Inverter; Energy saving.

حفظ الطاقة في البطاريات باستعمال اللوحات الضوئية

علي محمود ابراهيم[1]، رمزي روفائيل ابراهيم[2]، رزكار بكر ولي[3]
[1] وزارة الكهرباء -حكومة اقليم كردستان
[2،3] قسم هندسة الميكانيك و الميكاترونيك، كلية الهندسة، جامعة صلاح الدين-اربيل، العراق
[1] ali.mahmood8599@yahoo.com, [2] ramzi.ibraheem@su.edu.krd, [3] rizgar.weli@su.edu.krd

ملخص البحث

تستخدم الألواح الضوئية لتوليد الكهرباء بشكل مباشر أو غير مباشر. في حالة غير مباشر ، يجب حفظ الطاقة في البطاريات ومن ثم يمكن استخدامها وفي هذه الحالة ، فإن العاكس مطلوب لتغيير التيار المباشر(تيار مستمر) للبطاريات الى (التيار المتردد) حتى نستطيع تشغيل احمال.

تركز هذه البحث على توفير الطاقة في البطاريات والتحقيق من عملية شحن البطاريات وتفريغها لتشغيل أحمال انتقائية في البحث. ، النتائج بينت أن لوحًا ضوئيًا واحدًا بقوة (80 واط) يوضع باتجاه الجنوب بزاوية ميل تبلغ 36 درجة ؛ يمكن أن ينتج طاقة (224 واط.ساعة) وقد تم الحصول في شهر نيسان عليها عن طريق شحن بطارية رصاص حامضية (65 أمبير.ساعة) لمدة 13 ساعة. وعند باستخدام اثنين من الألواح الشمسية كل واحد(80 واط) يربط بالتوازي في شهر ايار ، تم الحصول على طاقة مقدارها(915.6 واط .ساعة)، في حين عنداستخدام ثلاث وحدات تربط بالتوازي كانت الطاقة المتولدة قريبه من حالة استخدام وحدتين من اللوحات الضوئية والسبب يعود الى سعة البطارية المحدودة والتي تشحن بالكامل تقريبا . درجات الحرارة المحيطة المرتفعة لها تأثير سلبي على الألواح الشمسية.

الكلمات الدالة: شحن البطاريات، لوحات الضوئية، العاكس، حفظ الحرارة

1. Introduction

Environment pollution day by day increase via raised industrial sector and population growth, to dwindle risks emission gases in the world renewable energy used as a source of electricity production, solar energy is the source of energy which is free from carbon emission. Converting solar energy to electricity due to a device called the photovoltaic cell. Souvik and Jasvir [1] Measured the amount of incident solar radiation and concluded that it significantly determines the electricity produced by photovoltaic (PV) systems in Patiala; Hand calculations were available for May and June which offers the highest solar radiation. Possible plant capacity is estimated for an arbitrarily chosen area. Alaa M. Abdullah. [2] Proposed to shed light on alternative energy to the era of beyond oil for a rich oil country like Iraq, showing the opportunities and reasons that make solar energy the best alternative source after oil, she claimed to use the high solar energy intensity in Iraq especially as the maximum sunshine hours is approximately more than 3000 hours/year. Iraq is a global source of clean energy due to the natural sources of solar and wind. V.K.Sethi et al [3] used nanotechnology in solar PV cells to get cheaper solar cells and with higher efficiency. As the absorption effectiveness would increase. Utilizing nanotechnology in the inexpensive solar cell would help to maintain the environment and reduced the manufacturing cost. Jignesh kumr et al. [4]

used solar photovoltaic systems for energy saving in green buildings. Green building has to save water 36-40%, save energy 30-40%, and save material 25-40% compared to a conventional structure. Sandeep and Vijay. [5] Studied on a hybrid model of a solar / wind in Simulink, which used the battery as its storage system. Two renewable power sources are connected to a power grid with complex electrical interactions. The study showed that a standalone solar photovoltaic energy system could not supply reliable power during non-sunny days. The independent wind system cannot get the constant load demands due to significant fluctuations in the magnitude of wind speeds during the year. Due to this concept, energy storage will be essential to compensate for the change in wind speeds. Solar PV units minimize energy storage demand. Ionel Laurentiu Al Boteanu et al. [6] reviewed the main methods to increase the efficiency of photovoltaic systems by applying the maximum power point tracking method, the orientation of photovoltaic panel, reducing the temperature of photovoltaic cells are detailed. These methods are verified by numerical simulation, using dedicated software and experimental. Ashish S. Ignore and Bhushan S. Rakhonde. [7] investigated a hybrid power generation system to include wind energy and solar energy. They showed that it has higher efficiency. It can provide electricity to remote places where the government is unable to reach, reducing the cost and transmission losses. Also that it is a cost-effective solution for a generation. It only needs an initial investment. It also has a long life span. Overall it is a right, reliable, and affordable solution for electricity generation. Bhalchandra V Chikate, Y. A. Sadawarte [8] studied factors affecting the performance of solar cells, and they confirmed that the high voltage produced at low temperatures in other hands the cell loses voltage in high temperatures. Furkn Dincer and Mehmet Emin Meral [9] studied critical factors that affect the efficiency of solar cells, they concluded that the most important factors are temperature, energy conversion effectiveness, and peak power point tracking. reducing the reflection of the incident light will lead to better energy efficiency. C. Marimutho and V. Kirubakaran [10] investigated the factors affecting solar PV cell through Matlab/Simulink model, they emphasized that the two main factors are of most importance which is the solar radiation and temperature.

2. Theory

2-1- Electricity production using photovoltaic panels(PV):-

Power output can be calculated at each load from the following equations:

$$P = V * I \quad (1)$$

Where; I current in Amperes, V voltage in Volts and P is the instantaneous power (in Watts) which are generated and the total energy production for the whole hour is determined by multiplying power by the number of hours at which PV produces energy. Or the total energy production for the entire day is determined by multiplying power by day length. The theoretical day length (td) can be calculated from the following equation:

$$td = \frac{2}{15}.\cos^{-1}(-\tan\emptyset.\tan\delta) \quad (2)$$

Figure(1) shows the declination δ that shows the sun altitude in the sky. the angles north of the equator are taken as positive, and angle south of the equator is taken negative, then at any given day of the year, n, the declination can be found from:

$$\delta = 23.45.\sin\left[\frac{360(n-80)}{365}\right] \quad (3)$$

Where n is day number and equal to one on the first January, 46 on 15th of February, 74 on the 15th of March, and so on for other days of the year [11]. Equation (3), is only a good approximation since the year is not exactly 365 days long, and the first day of spring is not always the 80th day of the year. In any case, to determine the location of the Sun in the sky at any time of day the following angles should be defined with aid of Figure (1).

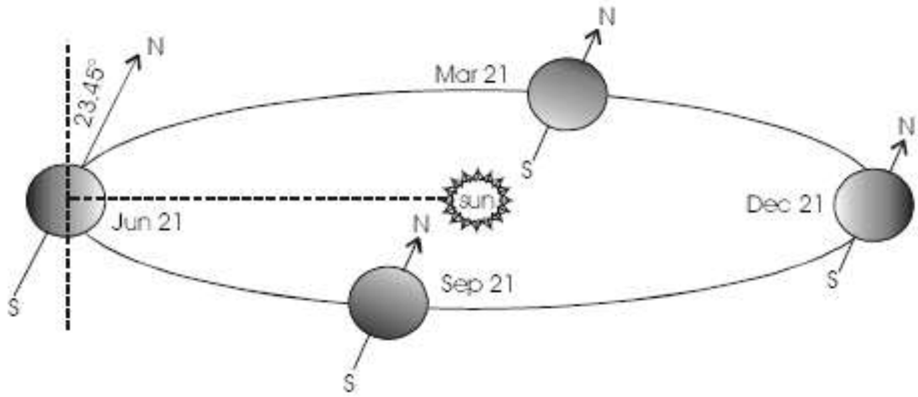

Fig. 1 The orbit of the earth and the declination at different times of the year[12].

The line perpendicular to the earth surface represents the Zenith and the Zenith angle, θz is characterized by the angle created between the zenith and the sun. the declination can be related to the zenith angle at solar noon by noting that the sun is directly at its top point in the sky at solar noon.

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$$\theta_z = \emptyset - \delta \qquad 4$$

Where $\emptyset$ is the latitude, or angular distance from the equator since when the declination and latitude are the same, the zenith angle is zero? Note that this Relationship only holds at given latitude at solar noon, since both Ø and δ are constant for any given day in any given location. However, as the time differs from solar noon, it is evident that the sun will no longer be overhead, and, hence, the zenith angle is no longer zero. Equation (4), however, is useful for determining the highest point in the sky reached by the sun on any particular day of the year at any specific latitude. It is also helpful in determining that the highest point of the sun in the sky will be at $\theta z=\emptyset-23.45^o$ and the lowest point of the solar noon sun in the sky will be at $\theta z=\emptyset + 23.45^o$, provided that $\emptyset> 23.45^o$. It is particularly interesting to note that if $\emptyset> 90^o – 23.45^o= 66.55^o$, then the nadir point of the sun in the sky is below the horizon, meaning that the sun does not rise or set that day. The situation in Polar Regions, which are subject to periods of 24 hours of darkness. These same regions, of course, are also subject to equal periods of 24 hours of sun six months later. If $\emptyset< 23.45^o$, will at some time during the summer be negative.

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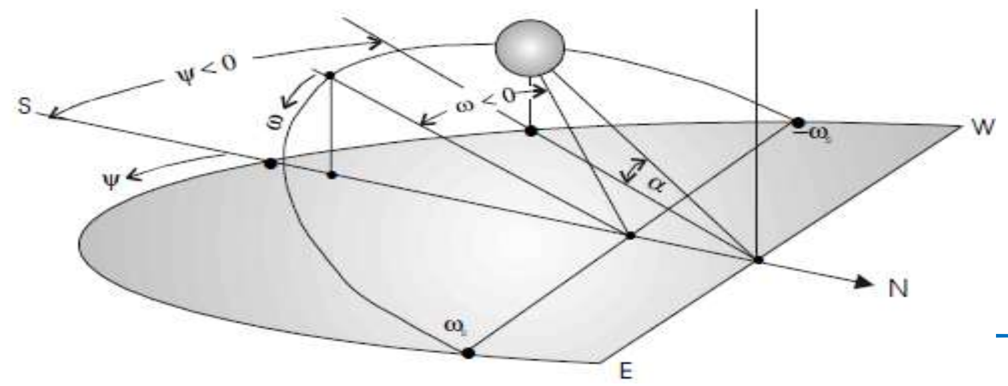

Fig. 2 Sun angles, showing altitude, azimuth, and hour angle [12].

In many publications, the azimuth angle is referenced to the north, such that solar noon appears at $\psi = 180^o$. Another useful, albeit redundant, angle in describing the location of the sun due to the solar noon is called the hour angle that represents the angular deviation of the sun from the solar noon based on 360 degrees of rotation.

$$\omega = \left(\frac{(12 - T)}{24}\right) * 360 = 15 * (12 - T) \quad (5)$$

Where T is the day time expressed concerning solar midnight, on a 24-Hour clock. As example, for T = 0 or 24 (midnight), $\omega = \pm 180^o$ and for T = 10 A.M., $\omega = 60^o$. By relating ω to the other angles previously discussed, it is possible to show that the sunrise angle is given by.

$$\omega_s = cos^{-1}(-tan\emptyset . tan\delta) \quad (6)$$

This equation applies to both sunset and sunrise so that the day length should be found by multiplying ωs by 2.

2-2 Energy generation

Energy is a measurement that represents the multiplication of power by time, and the unit is (W.hr) or (kW.hr). The PV panel of 80 Watts produces 80 W.hr if subjected to solar insolation for one hour, and this value is not constant for all days due to the variation of weather conditions [13]. The total energy production in the day is given:

$$E = P * td \quad (7)$$

Where E can be represented as the monthly average daily energy production per module area and the total energy production in W.h /m^2 [11].

3. Experiments and Calculations

The main components of the system are as follows:

1- Three solar models (panels) of 80W with the following specifications see table 1.

Table 1 specification of the solar panels.

Cod	50166
Type	FVG 36-125
Model	FVG 80M-MC
Model efficiency	12.49%
Cell efficiency	15%

Power peak (W)	80W
Vm (voltage at maximum p.)	18.2 V
Im (maximum current)	4.40 A
Voc (open circuit voltage)	22.1 V
Isc (short circuit current)	4.87 A
Power tolerance	+/- 5%
Maximum system voltage	700 V
Electrical specification at AM 1.5 1000W/m^2	25^{o}C

2- To batteries of 65 Ampere. hour, lead-acid type.

3- An inverter of 1000 volt.Ampere

3-1 Energy generation using one solar panel, 80W, and one battery.

The first arrangement of the system is as follows:

1- One solar panel of 809W capable to give 19-volt output.

2- One battery of 65Ampere-hour to store energy to be used later at night.

The inverter to convert the DC from the battery of 12 Volts to AC Current with 220 Volts. The solar module is placed with, an inclination angle β of 36^o with horizontal oriented towards the south, and this tilt angle is found by another researcher in this field [14]. One solar panel is used to store energy in the battery for different durations; from one to thirteen hours. And then the inverter is used to take the energy stored in the battery to operate loads of 28 W or 128 W which are of two bulbs of (18 and 10) Watts and one bulb of 100 W. The schematic diagram of the system is shown in Figures (3) and Figure (4).

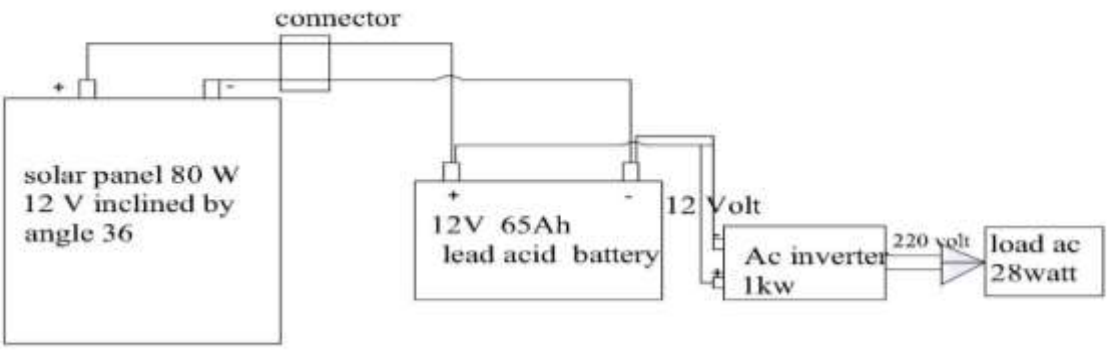

Figure 3 block diagram of the PV system.


Figure 4 the photography of the one-panel solar panel system connections and components.

The recorded and measured data with the calculated terms are tabulated in table 2.

Table (2) Energy stored in the one Battery 65Ah by one Solar panel of 80 W in April.

Test No.	Battery Charging time, hour(s)	Charging period of one battery	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	7:20-8:20	28	0.33	9.24	April 4th 2016
2	2	8:40-10:40	28	1	28	April 4th 2016
3	3	10:40-1:40PM	28	2	56	April 4th 2016
4	4	9:30-1:40PM	28	2.8	78.4	April 5th 2016
5	5	7:55-12:55PM	28	3.4	95.2	April 6th 2016
6	6	8:45-2:45PM	28	3.9	109.2	April 7th 2016
7	7	6:55-1:35PM	28	4.3	120.4	April 9th 2016
8	8	8:40-4:40PM	28	4.7	131.6	April 10th 2016
9	9	9:30am-6:30pm	28	5.2	145.6	April 11th 2016
10	10	8:00am -6:00pm	128	1.3	166.4	April 13th 2016
11	11	7:00am-6:00pm	128	1.4	179.2	April 15th 2016
12	12	6:00am-6:00pm	128	1.5	192	April 16th 2016
13	13	5:00am-7:00pm	128	1.75	224	April 17th 2016

Base on the maximum current output in the PV panel is 4.4 Ampere and multiplying this by a total of 13 hours of charging, the result is 57.2 A.h, which means the battery capacity of 65 A.h will not be charged fully. Table 3 shows the results obtained for the same configuration of table 1 in the month of June.

Table 3 Energy stored in the one Battery 65Ah by one Solar panel of 80 W in June.

Test No.	Battery Charging time, hour(s)	Charging period of one battery	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	900:am-10:00am	28	0.6	16.8	June 1st 2016
2	2	8:40am-10:40am	28	1.3	36.4	June 2nd 2016
3	3	9:00am-12:00pm	28	2.4	67.2	June 3rd 2016
4	4	8:00am-12:00pm	28	2.9	81.2	June 4th 2016
5	5	8:00am-1:00pm	28	3.6	100.8	June 5th 2016
6	6	8:45-am-2:45pm	28	4	112	June 6th 2016
7	7	7:35am-1:35pm	28	4.5	126	June 7th 2016
8	8	8:40am-4:40pm	28	4.9	137.2	June 8th 2016
9	9	9:00am-6:00pm	28	5.7	159.6	June 9th 2016
10	10	8:00am-6:00pm	128	1.5	192	June 10th 2016
11	11	7:00am-6:00pm	128	1.7	217.6	June 11th 2016
12	12	6:00am-6:00pm	128	2	256	June 12st 2016
13	13	5:00am-7:00pm	128	2.5	320	June 13th 2016

In the second test, two solar panels are used to store energy in the battery of the configuration of the rig as shown in Figure 5.

Figure 5 Energy generation by two solar panels of 80

Similar to the first system, the solar panels are used to store energy in the battery for the different duration from one to thirteen hours and then using this energy for an AC load of 28 W to determine the optimum time for charging the battery by two solar panels. Different loads are used such as (28W) AC and (218 W). The system is shown in Figure 5. The data related to charged and consumed energy are shown in table 4 and table 5.

Table 4 Energy stored in the two Batteries 65Ah by two Solar panels of 80 W in May.

Test No.	Battery Charging time, hour(s)	Charging period of one battery	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	8:20am-9:20am	28	0.83	23.24	May 4th 2016
2	2	10:15am-12:15pm	28	2	56	May 7th 2016
3	3	7:00am-10:00am	28	4.42	123.76	May 8th 2016
4	4	9:30am-1:30pm	28	5.6	156.8	May 9th 2016
5	5	7:50am-12:50pm	28	7	196	May 10th 2016
6	6	6:55am-1:55pm	28	10	280	May 11th 2016
7	7	6:00am-1:00pm	28	12	336	May12th 2016
8	8	6:00am-2:00pm	218	2	436	May13th 2016
9	9	8:20am-5:20pm	218	2.5	545	May14th 2016

10	10	6:00am-4:00pm	218	3	654	May15th 2016
11	11	7:00am-6:00pm	218	3.5	763	May16th 2016
12	12	6:00am-6:00pm	218	3.8	828.4	May17th 2016
13	13	6:00am-7:00pm	218	4.2	915.6	May18th 2016

Table 5 Energy stored in the two Batteries 65Ah by two Solar panels of 80 W in June

Test No.	Battery Charging time, hour(s)	Charging period of one battery	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	8:00am-9:00am	28	0.89	24.92	June14th 2016
2	2	10:00am-12:00pm	28	2.1	58.8	June15th 2016
3	3	7:00am-10:00am	28	4.7	131.6	June 16th 2016
4	4	9:30am-1:30pm	28	5.8	162.4	June 17th 2016
5	5	7:50am-12:50pm	28	7.2	201.6	June 18th 2016
6	6	6:55am-1:55pm	28	10.5	294	June 19th 2016
7	7	6:00am-1:00pm	28	12.7	355.6	June 20th 2016
8	8	6:00am-2:00pm	218	2.3	501.4	June 21st 2016
9	9	8:20am-5:20pm	218	2.8	610.4	June 22nd 2016
10	10	6:00am-4:00pm	218	3.2	697.6	June 23rd 2016
11	11	7:00am-6:00pm	218	3.6	784.8	June 24th 2016
12	12	6:00am-6:00pm	218	3.9	850.2	June 25th 2016
13	13	6:00am-7:00pm	218	4.5	981	June 26th 2016

3-3 Energy Generation using three Solar panels of (80W) and two batteries with different load.

The third group of tests is done similar to the previous section by using three solar panels and the system is shown in Figure 6.

Figure 6 Energy Generation by three Solar panels of 80 W.

Similar procedures of tests are repeated as in the two previous cases to determine the optimum time of charging to serve the AC loads of (18W) and (200W) the results are shown in table 6 and table 7.

Table 6 Energy saving by three Solar panels 80w and two Batteries 65A in May.

Test No.	Battery Charging time, hour(s)	Charging period of two batteries	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	8:30am-9:30am	28	3	84	May19th 2016
2	2	7:40am-9:40am	28	5.1	142.8	May 20th 2016
3	3	7:50am-10:50am	28	7.58	212.24	May 21st 2016
4	4	9:40am-1:40pm	28	10	280	May 22nd 2016
5	5	7:50am-12:50pm	28	11	308	May 23rd 2016
6	6	6:55am-1:55pm	218	1.9	414.2	May 24th 2016
7	7	6:00am-1:00pm	218	2.2	479.6	May 25th 2016
8	8	6:00am-2:00pm	218	2.8	610.4	May 26th 2016
9	9	8:20am-5:20pm	218	3.5	763	May 27th 2016
10	10	6:00am-4:00pm	218	4	872	May 28th 2016
11	11	7:00am-6:00pm	218	4.4	959.2	May 29th 2016
12	12	6:00am-6:00pm	218	4.8	1046.4	May 30th /2016
13	13	6:00am-7:00pm	218	4.5	981	May 31st 2016

Table 7 Energy saving by three Solar panels 80W and two Batteries 65A.h in July 2016.

Test No.	Battery Charging time, hour(s)	Charging period of two batteries	AC Load, Watts	The working period of the load, hours	Saving energy, W.h	Date of test
1	1	8:30am-9:30am	218	0.3	65.4	July 1st 2016
2	2	7:00am-9:00am	218	0.5	109	July 2nd 2016
3	3	7:50am-10:50am	218	0.7	152.6	July 3rd 2016
4	4	9:40am-1:40pm	218	1	218	July 4th 2016
5	5	7:50am-12:50pm	218	1.2	261.6	July 5th 2016
6	6	6:55am-1:55pm	218	1.5	327	July 6th 2016
7	7	6:00am-1:00pm	218	1.9	414.2	July 7th 2016
8	8	6:00am-2:00pm	218	2.4	523.2	July 8th 2016
9	9	8:20am-5:20pm	218	2.85	621.3	July 9th 2016
10	10	6:00am-4:00pm	218	3.3	719.4	July 10th 2016
11	11	7:00am-6:00pm	218	3.7	806.6	July 11th /2016
12	12	6:00am-6:00pm	218	4.2	915.6	July 12th /2016
13	13	6:00am-7:00pm	218	4.6	1002.8	July 13th 2016

4- Results

One solar panel of 80 W is placed towards south at a tilt angle of 36^{o} as this angle was proven to be for annual operation [14]. The energy is stored by a charging lead-acid battery 65 Ah. An AC load was used to operate on the energy stored in the battery, but the battery gave DC, so the inverter was used to convert from DC to AC. Different loads were used 28 W, 128 W, and 218 W, and the results were tabulated in the tables above. Figure (7) shows the amount of energy stored when using one solar panel 80 W and one lead-acid battery 65 Ah in April of 2016; The battery was charged for a different number of hours duration from one to thirteen hours and the number of hours for charging depended on day length (i.e., the day of the year from January till December). The amount of energy saved at each hour was shown in Figure (7) that the number of charging hours increased, the amount of energy stored was also increased. The maximum energy stored from one solar panel for thirteen hours of charging in a day in April was 224 W.h.

The second set of tests were carried out using two solar panels of 80W parallel, to charge the battery for a different number of hours and the energy was extracted from the battery to operate the AC loads as mentioned in the previous procedure. Table (4) represented the data from two solar panels parallel to charge the battery. Figure (7) shows that the amount of energy stored by two solar panels of 80 W in the lead-acid battery 65 Ah in May 2016. It was clear that an amount of energy of 915.6 W. h should be extracted from the battery to energize the AC load.

The third set of tests were carried out using three solar panels of 80 W parallel to charge the two batteries which are connected in parallel for a different number of hours and the energy was extracted from the battery to operate the AC loads as mentioned in test one. Table (6) represented the data from three parallel solar panels to charge the battery. Figure (7) shows that the amount of energy stored by three solar panels of 80 W in the lead-acid battery 65 Ah in May 2016. It was clear that an amount of energy of 1090 W.hr should be extracted from the battery to energize the AC load; the stored energy is obtained in the process of charging the battery by three solar panels for 13 hours in a day in May 2016.

Figure 7 also displays the difference between the three tests. It was clear that as the number of panels increases the amount of energy-storing would increase, and that is due to the high potential of the higher number of panels over one panel for charging. A person could find the difference between the energy stored in the cases of two and three panels was small and that could be returned to the fact that the battery reached the full charging condition.

Figure 7 shows the amount of energy stored in the battery in April and May for three cases: using one solar panel, two solar panels, and three solar panels. The Figure shows that an increasing number of solar panels will lead to more energy storage.

Figure 8 shows the amount of energy stored in the battery in June and July for three cases: using one solar panel, two solar panels, and three solar panels for charging the battery. The difference for a case of two solar panels or three solar panels is small and this could be returned to the full charging of the batteries due to the high rate of solar intensity in these two months.

Figure (9) shows the amount of energy stored by three solar panels of 80 W in July and May. The amount of energy saved by three solar panels of 80 W in July is less than the energy stored in May due to the decrease in efficiency of solar panels in July due to the increase of ambient temperature.

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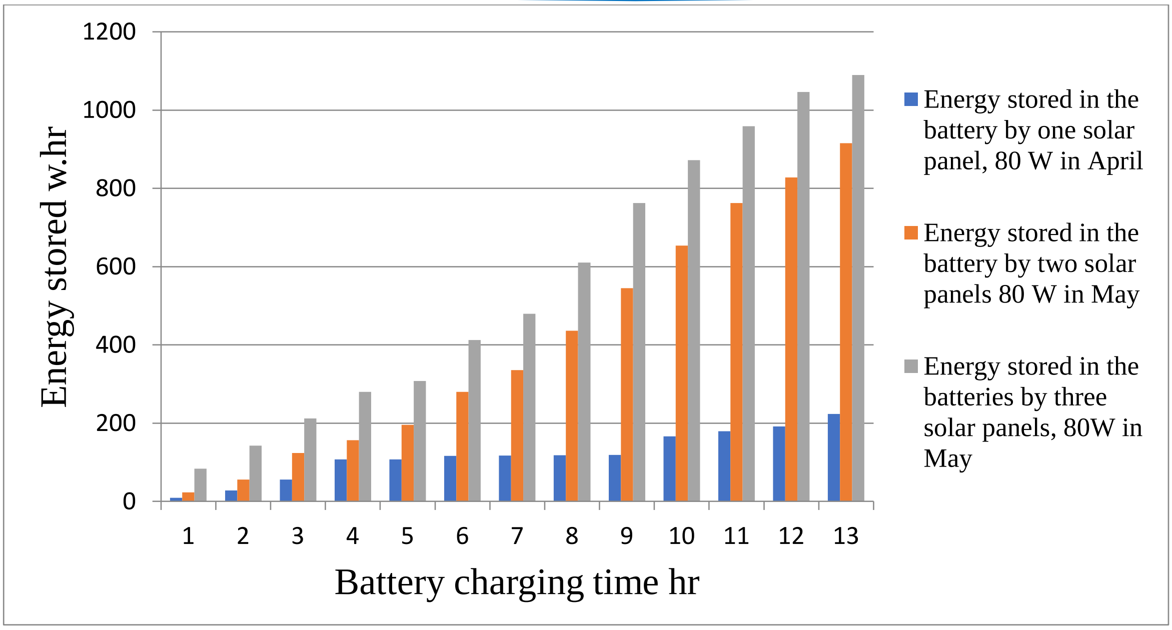

Figure 7 Energy stored in the Batteries by one, two, and three Solar panels of 80 W.

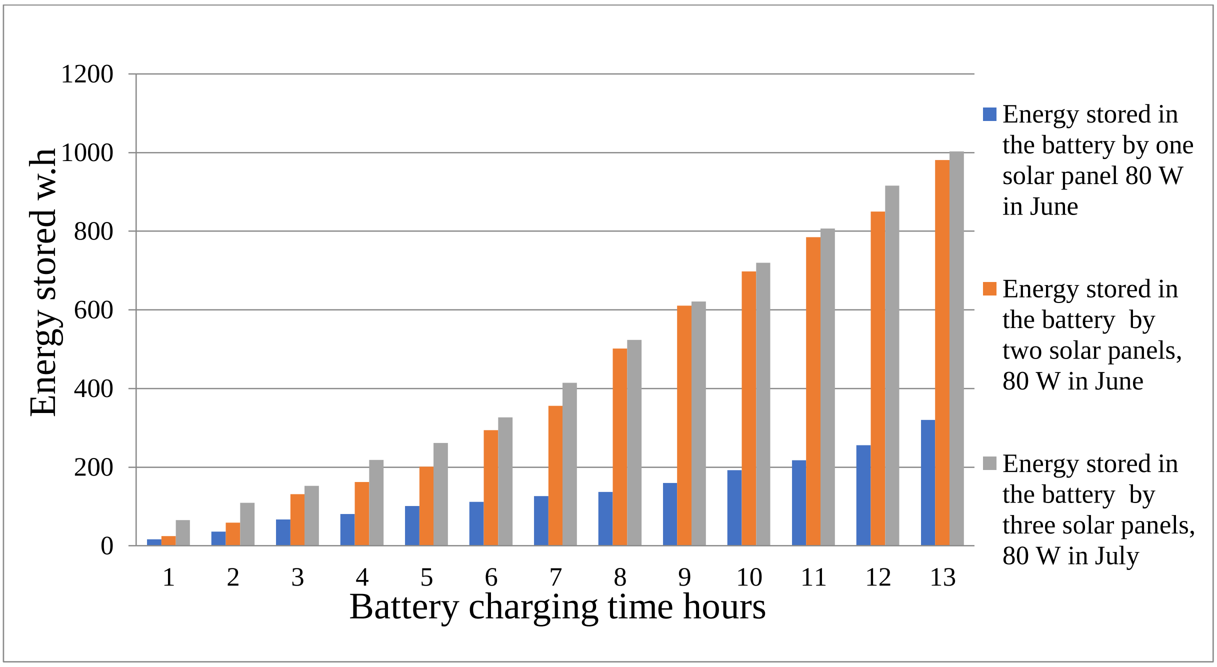

Figure 8 Energy Stored in the Battery by one, two and three Solar panels, of 80 W in June and July.

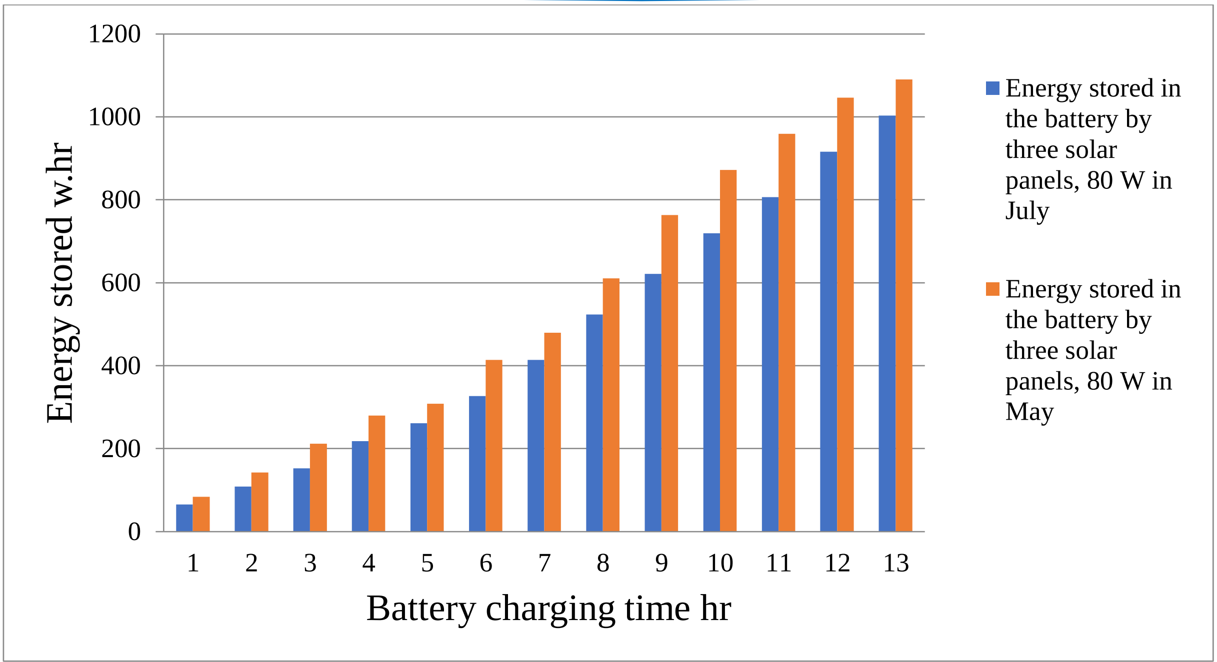

Figure 9 Energy Stored in the Batteries by three Solar panels 80 W in May and July.

5-Conclusions:

1- Using more than one panel gives better results than that of one panel.

2- The difference between charging the battery with two solar panels and three panels is not too big, so using two solar panels is preferable to reduce system cost.

3- High ambient temperature will lead to lower efficiency of the solar panels as noticed in the results for months May and July.

4- Higher storage capacities are needed when a higher power output is required.

5- Recommendations to future work

- Using data loggers to save the data on the hard disk.
- Using more than three panels in series and in parallel to get different array combinations and charging batteries of 12-volt or 24-volt design.
- Using the gel battery which is preferable for deep discharging without affecting the age of the battery.

- using of charge controller for saving the battery from overcharging

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