THE FEASIBILITY OF SOLAR ENERGY IN KIRKUK CITY THROUGH USING PV MODULE

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ABSTRACT

The total solar energy intensity on the horizontal surface measured for the Kirkuk city. This is obtained by measuring the short circuit current induced from standard PV module consisting of 36 PV cell connected in series. The measurement performed at each hour of daylight for a period of one year. The measured data compared with data obtained theoretically from the empirical formulas, which indicates that the theoretical prediction of the solar energy intensity is 31% larger than the measured values. The result indicates that the Kirkuk city receives a large quantity of solar energy, because the percent of the sunshine hour to the cloud covered hour is found to be 89%. Comparative cost analysis of the electricity from the PV solar cell and diesel system shows that the electricity from PV solar system at Kirkuk city is cheaper than that obtained from diesel system of about 40.6% when 15 year working period is considered.

KEYWORDS

Solar energy, Photovoltaic (PV) solar cell,

INTRODUCTION

Following the oil crises of the 1970s, energy experts start to explore whether solar based power generation held potential as an alternative petroleum-based fuels. Development of solar energy has been progressed considerably since then, and the cost of the solar power decreased with comparison with the petroleum. In recent years a new factor is added to the weight of solar energy which is the environmental effects. The excessive use of the oil increases the air pollution which has many dangerous effects on human life. One of the most dangerous effect which threats the life on the earth is the green house effect. Green house effect is the increase of the temperature of the earth due to increase of the CO_2 gas in the earth atmosphere which causes several dramatic changes in the climate of the earth.

The solar energy could be used for heating directly or indirectly by using solar collectors[1], or used to generate electricity via photovoltaics cell (PV). The PV cells convert the solar radiation directly into electricity by using solid-state junctions[2]. The main advantage of the PV cells is long life, estimated to be 15 year with no need for maintenance and their main drawback is low efficiency and high initial cost.

Historically the first solar cell is constructed by Charles Edgar[2] in 1883 at it's efficiency was less than 1%. Since then the progress in PV cell technology include increasing the efficiency and reducing their cost and weight by using different materials and improving production processes . In present day the silicon PV cells efficiency has reached 24%[3] in laboratory test conditions and silicon PV modules now available commercially have an overall efficiency of about 16% [3].As efficiencies have risen , module price have fallen to around 4$ per Watt.

In this paper the electrical power produced by standard PV module is measured in Kirkuk city for period of one year. From collected data the solar energy intensity is calculated and electricity cost comparison with the diesel generator is made from economical point of view .

EXPERIMENTAL SETUP

The total solar energy intensity of the kirkuk city is measured by using standard PV module . The module used is BP275 manufactured by UK firm BP solar. and its data sheet is as shown in figure(1) The module consists of 36 series-connected monocyrstaline silicon cells which gives a short circuit current of 4.60A and open circuit voltage of 21.4 volt at standard test condition of 1000 W/m^2 insulation and air mass of 1.5.

The short circuit current is measured by using digital multimeter of type Kaise (Sk-6160) . The measurement is performed by fixing the module horizontally over flat stand. To eliminate the reflected solar radiation effect, the measurement is performed at an open field . The data is recorded at each hour of the day light for a period of one year starting from 1/1/2004 to 1/1/2005 .

THEORETICAL APPROACH

In order to calculate the solar intensity incident on the earth system, it is necessary to determine the amount of energy reaching the earth's atmosphere and surface. Two sources of variation in extraterrestrial radiation (I_o) must be considered[4]. The first is the variation in the radiation emitted by the sun, satellites measurements showed that the variation is limited within ±0.2 percent. The second is the variation of the earth-sun distance, over the year seasonally, which lead to variation of extraterrestrial radiation flux in the range of ±3%. The values of extraterrestrial radiation I_o can be obtained from the following empirical formula [5]

$$I_o = I_{sc}\left[1 + 0.033 \cos\left(\frac{360\ N}{365}\right)\right] \tag{1}$$

Where I_{sc}=1353 W/m^2 which is the intensity of the sun's radiant energy measured normal to the earth-sun line but outside the earth's atmosphere

N= is the day number in the year

Relating the solar intensity outside the atmosphere I_{sc} to the intensity on the earth's surface is a major problem because up to 70% of incoming radiation can be blocked by the atmosphere and cloud cover. Therefore the calculation of the solar radiation incident the surface (I_{DN}) is performed under very week assumption of clear day insolation. Which is given by [3]

$$I_{DN} = I_o \exp\left(\frac{-B}{\cos\theta}\right) \qquad (2)$$

Where B is extinction coefficient and calculated from the following empirical formula

$$B = 0.175[1 - 0.2\cos(0.93N)] - 0.0045[1 - \cos(1.86N)] \qquad (3)$$

And θ is angle of incidence, that is, the angle between the beam radiation on a surface and the normal to that surface, .and for horizontal surface is calculated from the following formula

$$\cos\theta = \cos\delta\cos\phi\cos\omega + \sin\delta\sin\phi \qquad (4)$$

Where ϕ is latitude, that is, the angular location north or south of the equator, north positive $-90^{\circ} < \phi < 90^{\circ}$.

δ is declination, that is, the angular position of the sun at solar noon with respect to the plane of the equator , and the values of δ is calculated from following empirical equation [5]

$$\delta = 23.45 \sin\left[\left(\frac{N-80}{370}\right) x 360\right] \qquad (5)$$

ω is the hour angle, that is, the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour . ω is calculated as following

$$\omega = \frac{Solar \quad Time \quad - 12}{15} \qquad (6)$$

where Solar Time=Standard Time $+4(L_{st}-L_{Loc})+E$

L_{st} is the standard meridian for the local time zone, and L_{Loc} is the longitude of the location in question in degree west. And E is the equation of time given in the following equation

$$E=9.87\sin 2C-7.53\cos C-1.5\sin C \qquad (7)$$

Where

$$C = \frac{360(N-81)}{364}$$

RESULTS AND DISCUSSION

The current induced from the module is measured for a period of one year at each hour of the day light. As the relation between the solar radiation intensity and the current produced from the PV solar cell is linear[6] then the current values could be transformed to the solar intensity by using the data sheet of the module which indicate that under standard test condition of 1000 W/m^2 the module produces 4.60 A. Therefore the measured current value is multiplied by 1000/4.60 to give the solar intensity in W/m^2. and it is as shown in figure (2). From this figure it is clear the random nature of the data which depend on the weather condition mainly. If it assumed that the values for irradiance less than 300 W/m^2 is for cloud covered day, from solar irradiance data its found that 89% of day hours are clear sky (suny day) and only 11% is cloudy . This value is very large if its compared with other locations for example for Hamburg, Germany it is 36% , Miami, Florida is 65% .and for Nice, France is 61% [5]. Figure (3) show the experimentally measured peak value of the irradiance at noon time plotted during day for one year. This plot indicates the random nature of the irradiance specially at the winter, due to the weather condition the irradiance value is fluctuated between 980 W/m^2 at clear sky day and less than 10 W/m^2 at cloud covered day. At the summer the fluctuating is less than the winter and it is between 600 W/m^2 and 900 W/m^2 and it is mainly due to the dust and smoke from the petroleum industry.

The total amount of solar energy received during the day for any day of the year is calculated by using trapezoidal integration method for the data of Figure(2) and the result is as shown at Figure(4) with the theoretical values calculated by trapezoidal integration of data obtained from equation (2). From this figure it is clear that the theoretical prediction of solar energy is very poor due to the random nature of the weather condition. The total amount of solar energy received per one year could be calculated by trapezoidal integration of data of figure (4) and it is found to be 2553002 Wh/m^2.year for experimental data and 3346316 Wh/m^2.year for theoretical data.

COST ANALYSIS OF THE PV SYSTEM

As it mentioned earlier in this paper, that the main advantage of the PV system to other methods of solar energy applications, is that the PV system converts sun light directly into electricity, which could be used to operate the equipment in normal houses. For house applications the PV modules could be installed over the roof of the house. The general system for this applications is as shown in figure (5) and its typically consist of the following components:

1. Solar photovoltaic modules
2. Storage Batteries and battery controller
3. Inverter
4. wiring, fuses and switches

To estimate the minimum number of modules needed and to make cost analysis with comparison with diesel system it assumed that the normal house equipment is as shown in table(1) with energy required and operation hour per day.From table (1) the total energy required is 4600 Wh/day and by assuming compensation for losses (30% of load) the total power will be 5980 Wh/day. From the data of figure (4) it is found that the day average electric power produced from one module is 645 Wh/day

Then the number of PV modules required is 5980/645=9.27, thus 10 PV modules is needed. If 12 volt battery is chosen for energy storage and for total appliance load of 5980 Wh/day the Ah (Ampere Hour) per day is 5980/12 =498.3 Ah/day. , thus the minimum battery capacity required is 498.3 Ah/day. It could be used five 100 Ah battery.

The cost of PV system and diesel system is categorized to the initial cost and Operation and maintenance (O&M) cost. For PV system the cost for 15 year operation is as detailed in table (2) which include PV modules, battery, converter, support structure and installation cost

The diesel engine required to operate the devices listed in table (1) is 1kW. For 15 year operation the cost is mainly the initial cost of equipment and the O&M cost which is as in table (3)

From tables (2) and (3) for a total life-cycle cost the PV solar system is cheaper than the diesel system with 40.6%. This number could be lower if the PV system is compared with the cost of national distributed electricity, because it will include also the cost of power grid and cost of land for equipment or rights-of-way for transmission and distribution lines. The cost of PV system could be reduced 34% if its used only at the daylight because there will be no need for batteries.

CONCLUSIONS

From the analysis of the collected data for the solar energy at Kirkuk city by using standard PV module, and also from the cost comparative analysis between PV solar system and diesel system for hosehold applications it could be conclude the following:

1. For solar system design the theoretical data for solar energy is un-adequate and experimental data is necessary because the random nature of the solar intensity. At the Kirkuk city the difference between the measured and theoretically calculated solar energy for one year was 31%.
2. The collected data indicates that the Kirkuk city has large percent sunshine hour, which it is about 89% of hours of days , when it is compared with the European cities.
3. A comparison of the cost of solar PV system and diesel system, should be based on the life-cycle cost. For Kirkuk city its found that the electricity from PV system is cheaper than from diesel of about 40.6%.
4. The cost of solar PV system could be reduced further if it used as an assistance to the national electricity , because there will be no need for the batteries. Without the batteries the system cost will reduces about 34%.

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Table (1) The appliance energy requirement for normal house equipment

Equipment	Appliance energy	Qu.	Wh/day
TV/SR	150 Watts x 6 hours/day	1	900 Wh/day
Large light	40 Watts x 6 hours/day	4	960 Wh/day
Small light	10 Watts x 6 hours/day	4	240 Wh/day
Refrigerator	100 Watts x 10 hours/day	1	1000 Wh/day
Deep Frezer	150 Watts x 10 hours/day	1	1500 Wh/day
Total			4600 Wh/day

Table (2) Solar PV system cost in Dollars for total appliance load of 5980 Wh/day

Cost item	No.	Unit cost	Total cost	Working life [year]
PV module	10	500	5000	15
Battery	5x5	50	1250	3x5
Converter	1x2	250	500	2x7.5
Support structur	1	100	100	15
Installation	1	50	50	
O&M			50	
Total			6950$	

Table(3) Diesel system cost in Dollars for total appliance load of 5980 Wh/day

Cost item	No.	Unit cost	Total cost	Working life
Diesel engin	8	400	3200	8x2
Installation	8	50	400	
Fuel (litter/day)	3	.3	4927.5	For 15 years
Oil, belt and filters		750	750	For 15 years
Maintenance (laber)		500	500	
Total			9777.5$	

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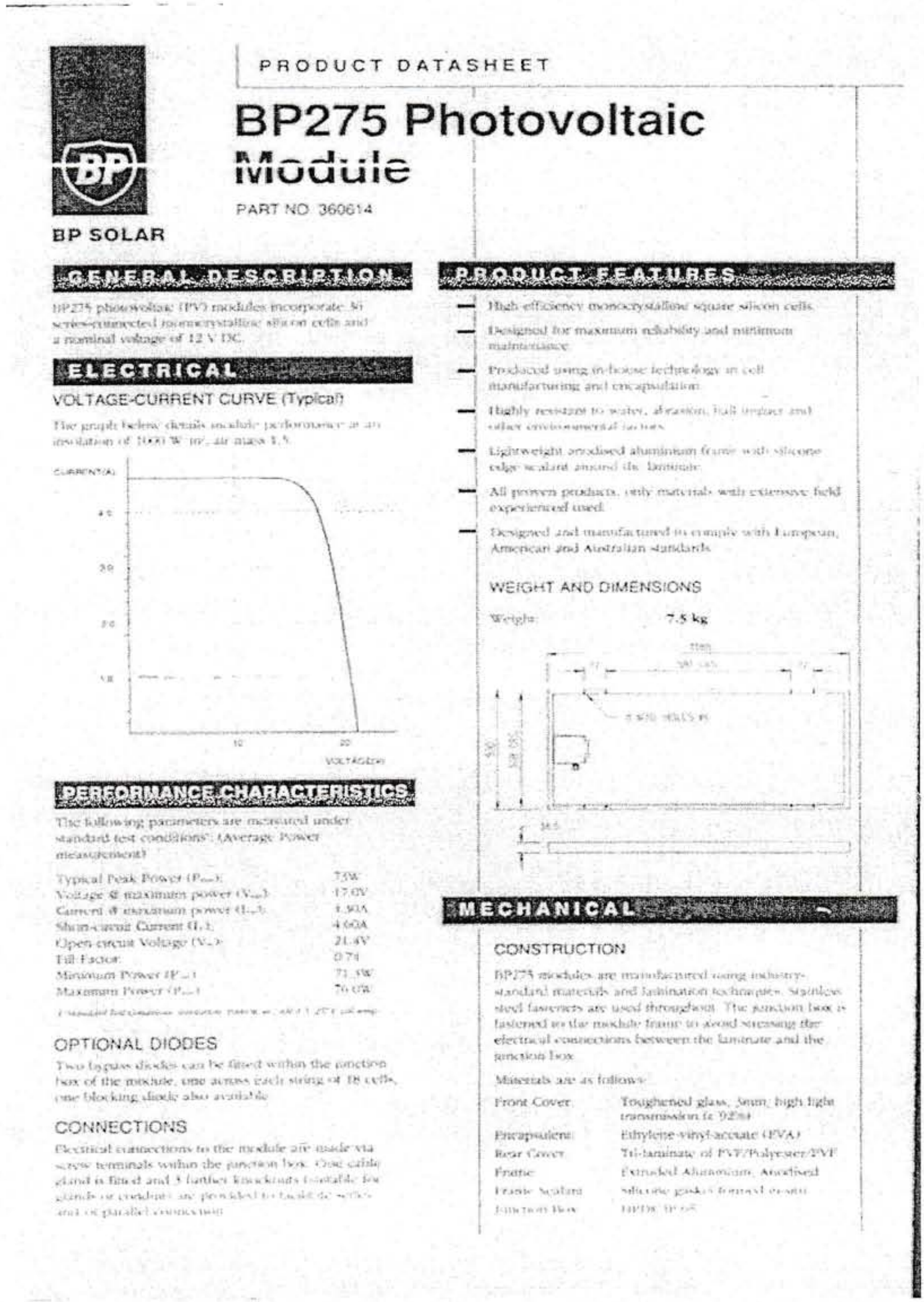

PRODUCT DATASHEET

BP275 Photovoltaic Module

PART NO 360614

BP SOLAR

GENERAL DESCRIPTION

BP275 photovoltaic (PV) modules incorporate 36 series-connected monocrystalline silicon cells and a nominal voltage of 12 V DC.

ELECTRICAL

VOLTAGE-CURRENT CURVE (Typical)

The graph below details module performance at an insolation of 1000 W/m², air mass 1.5.

PERFORMANCE CHARACTERISTICS

The following parameters are measured under standard test conditions (Average Power measurement)

Typical Peak Power (P_{max})	75W
Voltage @ maximum power (V_{mp})	17.0V
Current @ maximum power (I_{mp})	4.30A
Short-circuit Current (I_{sc})	4.60A
Open circuit Voltage (V_{oc})	21.4V
Fill Factor	0.74
Minimum Power (P_{min})	71.3W
Maximum Power (P_{max})	76.0W

OPTIONAL DIODES

Two bypass diodes can be fitted within the junction box of the module, one across each string of 18 cells, one blocking diode also available

CONNECTIONS

Electrical connections to the module are made via screw terminals within the junction box. One cable gland is fitted and 3 further knockouts (suitable for glands or conduits) are provided to facilitate series and/or parallel connection

PRODUCT FEATURES

- High efficiency monocrystalline square silicon cells
- Designed for maximum reliability and minimum maintenance
- Produced using in-house technology in cell manufacturing and encapsulation
- Highly resistant to water, abrasion, hail impact and other environmental factors
- Lightweight anodised aluminium frame with silicone edge sealant around the laminate
- All proven products, only materials with extensive field experience used
- Designed and manufactured to comply with European, American and Australian standards

WEIGHT AND DIMENSIONS

Weight: **7.5 kg**

MECHANICAL

CONSTRUCTION

BP275 modules are manufactured using industry-standard materials and lamination techniques. Stainless steel fasteners are used throughout. The junction box is fastened to the module frame to avoid stressing the electrical connections between the laminate and the junction box

Materials are as follows:

Front Cover	Toughened glass, 3mm; high light transmission (≥ 92%)
Encapsulant	Ethylene-vinyl-acetate (EVA)
Rear Cover	Tri-laminate of PVF/Polyester/PVF
Frame	Extruded Aluminium, Anodised
Frame Sealant	Silicone gasket formed in-situ
Junction Box	HPDE IP 65

Fig.(1) The data sheet of the photovoltaic module

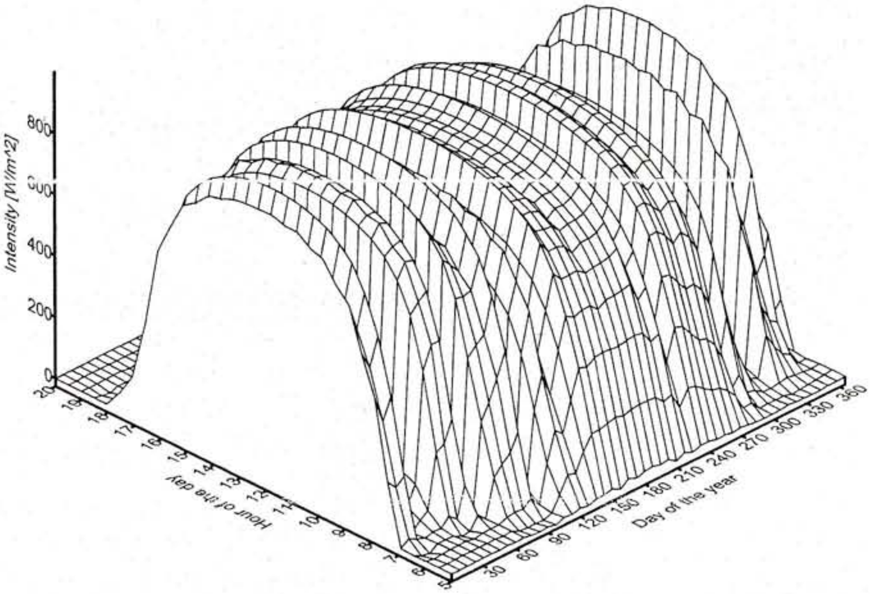

Fig.(2) Solar intensity at Kirkuk city at any hour for any day of the year The data sheet of the photovoltaic module

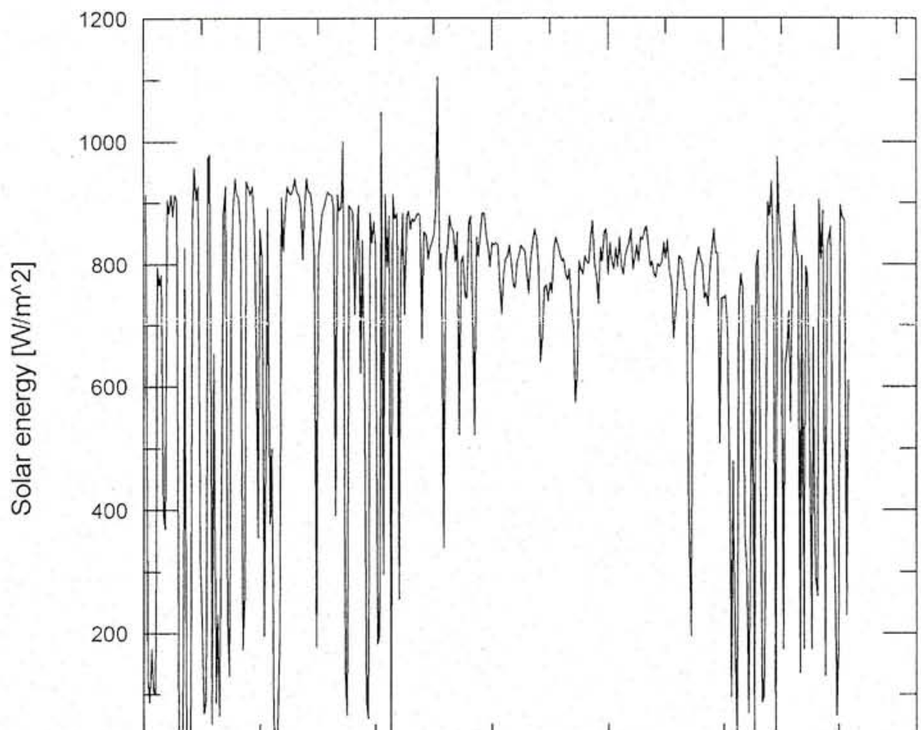

Fig.(3) Variation of the peak solar energy intensity at Kirkuk city for any day of the year The data sheet of the photovoltaic module

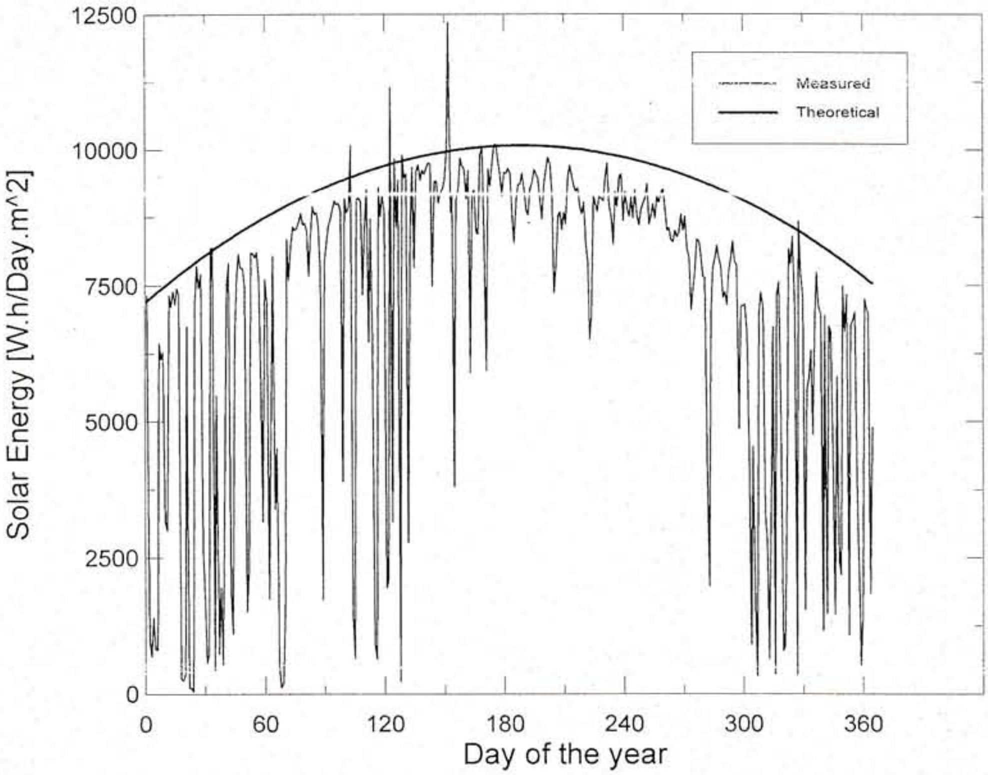

Fig.(4) Variation of solar energy at Kirkuk city with days of the year

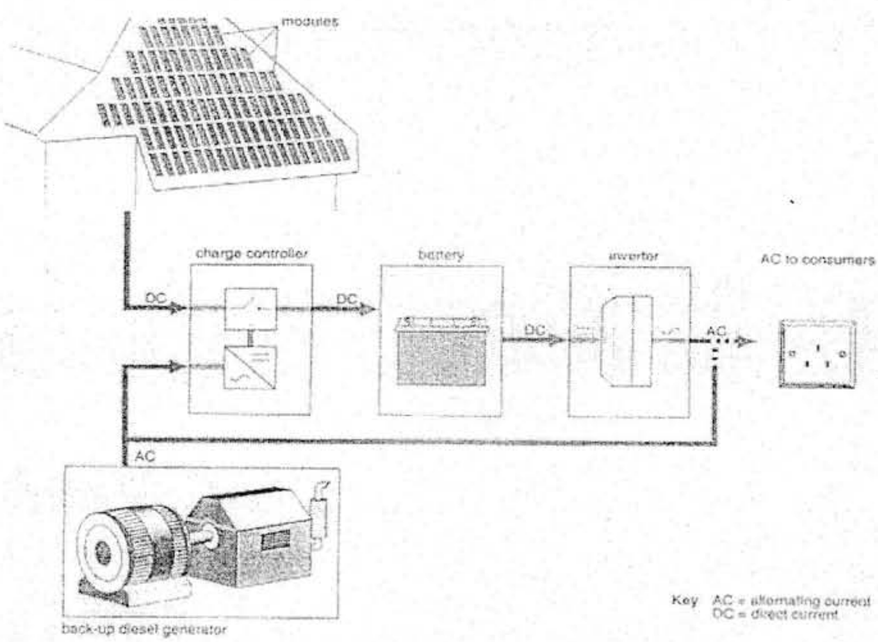

Fig.(5) The main components of the solar energy system

دراسة جدوى استخدام الطاقة الشمسية في مدينة كركوك من خلال استخدام الخلايا الكهروضوئية

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الخلاصة

تم قياس الإشعاع الشمسي الكلي الساقط على السطح الأفقي في مدينة كركوك وذلك من خلال قياس التيار المتولد في مصفوفة فوتوفولتائية قياسية متكونة من ٣٦ خلية فوتفولتائية مربوطة على التوالي.أجريت القياس لكل ساعة من ساعات النهار ولفترة سنة كاملة. تم مقارنة النتائج التجريبية مع نتائج النمذجة الرياضية وتبين ان قيم كثافة الطاقة الشمسية المستحصلة من النموذج الرياضي أعلى من القيم المقاسة بحدود ٣١%. اضهرت النتائج بأن مدينة كركوك تستقبل كمية كبيرة من الطاقة الشمسية بالمقارنة مع المدن الاوربية حيث ان نسبة الساعات المشمسة على الغائمة تبلغ ٨٩% . بالاستناد على القيم المقاسة تم اجراء مقارنة لكلفة الطاقة الكهربائية المنتجة من الخلاية الفوتوفولتائية ومن محركات الديزل . بينت المقارنة ان إنتاج الكهرباء من المنظومات الشمسية ارخص بنسة ٤٠,٦% من محركات الديزل اذا اخذ بنظر الاعتبار عمر تشغيل ١٥ سنة.

الكلمات الدالة
الطاقة الشمسية، الخلايا الكهروضوئية