Street and House Lighting Using Photovoltaic Panels

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Abstract-- In this work, the experimental investigation includes determination of (power output, monthly average daily energy generation, and efficiency) for the solar module (BP1211SR) at four different tilt angles (0°, 26°, 36°, 46°) in Erbil city (latitude=36°11' N, longitude=44° E, and 430m above sea level), also determining PV area required for demand loads after selecting the best tilt angle for Erbil city. The data has been taken for one year; the data of each month represents the average of (4-5) times in the month taken in three different day times. The experimental results show that maximum average energy production in Erbil city for one year is (781,080 W.h/m² day) recorded at angle (β=36°), resistance load (20Ω), and at solar noon (ω=0). The area required for the PV module depends on the demand load, and type of solar module, for example for house lighting (5A, 220V, for 6 hours) it will need (18.5m²) PV area, for street lighting a lamp of (200W, for 10 hours) need (5.6m²) PV area, and finally for DC power of (5A, 12V, for 6 hours) it needs (1m²) PV area.

Index Term-- Photovoltaic, solar system, lighting.

I. INTRODUCTION

Burning oil, coal and natural gas, pumps nitrogen oxide, sulfur dioxide, and other toxic metals into the atmosphere, directly causing pollution to our air, soils and waters. Nuclear fission produces radioactive waste material that will remain deadly for thousands of years, for which a safe method of storage has not been discovered yet. Every bit of energy generated cleanly reduces the amount of pollution added to the environment. Photovoltaic (generating electricity from sunlight) is a clean, affordable and available technology [1]. Karl E.Knap and Theresa L. Jester contribute to the growing literature on net benefits of renewable energy systems by conducting an empirical investigation of as manufactured photovoltaic mobile modules, evaluating both established and emerging products in their work [2]. Mike Taylor compared photovoltaic output with electric utility demand under various scenarios to determine photovoltaic capacity performance during periods of high electricity demand and certain months and times of day [3]. David L. King et al performed the equations and applications associated with the photovoltaic array performance model developed at Sandia National Laboratories. Electrical, thermal, and optical characteristic for photovoltaic module are included in the model and meteorological data [4]. M. Bakker, et al studied two prototypes of uncovered PVT (photovoltaic thermal) panel have been manufactured. The electrical module efficiency of the prototype has been founded to be 11.2% which is as expected [5]. Sioe-Yoo Kan and Ruben Strijk analyzed the energy saving and power management solutions necessary to improve the energy consumption efficiency in photovoltaic power production. In this research several methods to improve the efficiency of the energy chain are described [6]. Gang Li, et al studied a highly efficient polymer solar cell used, based on bulk hetero junction on polymer poly (3-hexylthiophene) and methanofullerene. By controlling the active layer, growth rate results in an increased whole mobility and balanced change transport [7]. Rizgar Bakir studied the power generation on horizontal surface by PV module, determining the monthly average daily electricity generation [8].

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II. Method

The instant power output from (0.08 m²) solar module at solar noon, can be calculated from the below equations after measuring (V) and (I) at different loads, each value of (V) and (I) represents the average value for one month.

\[ P = V \times I \]  

The total energy produced for one day is determined by:

\[ E = P \times t_d \]  

Where \( t_d \) is the day length can be expressed in hours as [9]

\[ t_d = 2/5 \cos^{-1}(-\tan \phi \cdot \tan \delta) \]  

and \( \delta \) declination can be calculated from the relation [9]

\[ \delta = 23.45 \times \sin \left( \frac{360}{\text{day}} \times \frac{284+\sin \phi}{365} \right) \]  

The value of (\( n \)) can be obtained from [9]. The total energy produced from \((1m^2)\) of the solar module for one day can be obtained:

\[ E_{0.08} = E/0.08 \]  

The average daily global irradiation for horizontal surface for any month (\( E_{\text{avg}} \)) can be obtained by multiplying the global irradiation outside the atmosphere (\( E_{\text{ext}} \)) obtained from (Average Daily global Irradiation for horizontal surface outside the Earth’s atmosphere) [10] by the clearness index (\( K_c \)), (diffuse fraction of sunlight, is the ratio of monthly averages of daily diffuse and extraterrestrial global radiation[11]) obtained from (Clearness Index map from January to December) [10] for Erbil city as:

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\[ E_{\text{avg}} = E_{\text{ext}} \times K_c \]
To calculate the global irradiation on a tilted surface, multiply the horizontal irradiation by the tilt factor \( f_\beta \), the ratio of solar irradiation on tilted PV array to global irradiation, given in (Tilt factors for latitude 36°) [10]

\[
E_{\text{terr}}(\beta) = E_{\text{terr}} * f_\beta \text{ (W.h/m}^2\text{.day)} ...
\]

Where \( \beta \) is the tilt angle \( \beta = (0, 26, 36, 46)° \) for the solar module.

The efficiency of the solar module is calculated by:

\[
\eta (\beta) = \frac{E_{\text{t}}(\beta)}{E_{\text{terr}}(\beta)} * 100 \% \quad \ldots \ldots \ldots (8)
\]

III. Experimental Work

The system consists of solar generator (module), the solar module type is (BP1211SR), with module area (0.08) m\(^2\). It consisting of (8×4) silicon cells; the cells are sandwiched between two panels of glass to protect them from mechanical and atmospheric damages, as it shown in figure (1). The module is connected to control box, the control box (photovoltaic solar energy unit system P9060) and module is manufactured by CUSSION, the control box is provided with a set of resistances, a voltmeter and ammeter. The resistances can be changed, it is including open circuit, varying load range (10-190) \( \Omega \), and short circuit, zero volt reading point is the one at which the array is completely short circuited (load=zero \( \Omega \)) and the current is a maximum, maximum voltage corresponds to the open circuit condition at which current is equal to zero, as shown in figure(2).

![Fig. 1. The solar module](image1)

![Fig. 2. The control box](image2)

The work place is located in Erbil/ Kurdistan Region/ Iraq, the geographical position, latitude 36° 11' North, longitude 44° East, and 430 meters above sea level. Data were taken at different solar times in the day (10:00 AM, 12:00 PM is solar noon which means that hour angle is zero, and a 02:00 PM). The module is set in position where no shadow falls on the module surface. The module is placed to face the south because the location is in the northern hemisphere, and the south facing is selected as it offers the most energy reception during one year period. The data were taken during a one year period and (four to five times) per month. Each time, four different angles were selected, which are 0°, 26°, 36°, and 46°. For each angle the resistance was changed from short circuit to 190 \( \Omega \) by increasing the resistance from 10\( \Omega \) to190\( \Omega \), and finally with open circuit. At each angle, different loads were applied to get the peak power production by the PV module; the voltage and current produced by solar module were measured from each resistance with four different angles.

IV. Results and Discussion

The calculation of the area required for certain loads is determined from results at different month of the year, it was clear from the results that the minimum amount of energy (worse month) is recorded in January as it is shown in figure (3). Four different angles are used to record data of power generation by solar module and according to the results obtained, the tilt angle (\( \beta=36° \)) with the horizontal is the best angle if it is taken as the overall energy generation all through the year as it is shown in figure (4). Figure (5) shows the monthly average efficiency for solar module (BP1211SR) at four different angles, it is clear that the best efficiency is in (March and November) in spring and fall. The power generation for the solar module (BP1211SR) is matching with the load resistance of (20\( \Omega \)); this situation is repeated for most month of the year as in figure (6). The maximum amount of power produced during the day is at 12:00 pm (solar noon, the time when the sun is highest in the sky) as shown in figure (7). Figure (8) demonstrate the area required for PV module at different loads by AC and DC power generation. It is clear from the figure that the area required is directly proportional to the load, and the area required for the DC load is smaller than that required for the AC load because of the low voltage of DC load, and these results are going well with the results reported by Michael et al [13].
CONCLUSIONS

1. The amount of energy production depends on the PV module efficiency and solar irradiation.
2. The amount of solar irradiation in any location depends on the altitude, latitude, time of day and year, weather conditions, and tilt angle.
3. Solar module current is proportional to irradiance, increasing the irradiance will increase the output current from
the solar module and the decrease in the irradiance will decrease output current. While the output voltage variation is not significant.

4. The PV module will receive maximum irradiation possible only if it is pointing perpendicularly toward the sun.

5. The maximum yearly average energy production in Erbil city, is at (β=36º).

6. The PV area requires depends on the solar module specification and the energy demand. PV area is directly proportional to the energy demand.

**Recommendations for Future Works.**

The main recommendations for the future work could be summarized as below:

1- Using different types of solar modules.

2- Cost estimations for the systems designed for certain position according to local market prices.

3- Studying the space available in local building designs.

**NOTATION**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
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<tr>
<td>E</td>
<td>Total Energy</td>
<td>(W.h/0.08 m².day)</td>
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<td>I</td>
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<td>(A)</td>
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<td>n</td>
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<td>P</td>
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<tr>
<td>V</td>
<td>Voltage</td>
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<td>Extraterrestrial Global Irradiation</td>
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<td>Terrestrial Average daily Global Irradiations for horizontal surface</td>
<td>(W.h/m².day)</td>
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<td>Terrestrial Average daily Global Irradiations for tilt surface</td>
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**REFERENCES**


