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SOLAR RADIATION STUDY IN BENGHAZI CITY AND MODELING, EXPERIMENTAL VERIFICATION OF A PV PANEL

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ABSTRACT

In this paper the radiation levels and information of the solar study in Banghazi City, Libya. Also the paper introduces an accurate PV module and panel electrical models. The model can be used for studying the characteristics of the PV module and panel under different modes of operations. In addition, the model can be used as a state observer and sensor-less control of the PV panel and the maximum power point tracking (MPPT) control. The validity of the obtained models are studied by the comparisons between the obtained practical results and these of simulation. According to the comparison results it is found that the deduced models can be considered as fair models.

لقد أصبح من المعروف الدور المهم الذي تلعبه الطاقات المتجددة في مجال إنتاج الطاقة الكهربائية أو في مجالات إنتاج الطاقات الأخرى. وحيث أن الطاقة الشمسية من أهم هذه الطاقات المتجددة لذا نرى منتجي الطاقة يتجهون وبشكل مستمر في استخدام هذه الطاقة لفوائدها المعروفة (مثل توفرها، رخصها، و تعتبر من الطاقات النظيفة). من هذا المنطلق يقدم هذا البحث أولا دراسة عن كمية الطاقة الشمسية المتوفرة في مدينة بنغازي- ليبيا على مدار السنة. بعدها تم دراسة نوع من أنواع اللوح الشمسي وتم استنباط النموذج (Model) الذي يمثل هذا اللوح حيث من الممكن استخدام النموذج في مجال التحكم الرقمي كذلك في مراقبة متغيرات اللوح باستخدام التقنية الرقمية باستخدام أقل متغيرات من الحالة الاعتيادية حيث سيتم طرح هذا الموضوع في البحوث القادمة لنفس الباحثين. تمت مقارنة النتائج العملية مع نتائج المحاكاة (Simulation) حيث تبين النتائج المستخلصة صحة النموذج المستنبط حيث يوجد تطابق جيد بين النتائج العملية والنظرية.

Keywords: PV Panel, Modeling, and Verification, Benghazi.

1. INTRODUCTION

The Photovoltaic (PV) systems technologies are rapidly expanding and have increasing roles in electrical power generations. This importance sprung from various advantages of solar energy such as time duration of installation and long life of exploitation, circuit simplicity, no need of moving part and realize a salient, not pollutant and renewable source of electricity [3,5].

The wide acceptance and utilization of the PV generation of electrical power depends on reducing the cost of the power generated and improving of energy of PV system can reach to about 20% [1].

The PV systems are by nature non-linear power sources and need an accurate model which takes to account all the necessary variables that affect the operation of PV-system (the most important variables are irradiance or radiation and temperature).

In addition the modeling of system introduces very important goals such as the performance study under the variations of model inputs, by the model ones can analyze the system under different modes of operation, and finally the model can be used a model reference or state observer [2].

This paper presents first a study of solar characteristics in Benghazi city (Libya) such as the installation of the panel, the radiation for multi weather conditions, daily power characteristics, and I-V characteristics for different values of radiation.

The main goal of the paper is to extract the module and panel mathematical models of the prototype LG-250-12 available in the department. After that the extracted models are examined and verified by the comparison of the simulation and experimental results of the module and panel. The main results presented are I-V and P-V characteristics for multi level of radiation, and the relation between the short circuit current and radiation level.

2. SOLAR CHARACTERISTICS STUDY IN BENGHAZI CITY.

Benghazi city (Libya) is located at a latitude of 32.06° at the northern hemisphere, so for best panel performance, the modules are mounted in such a way that it faces the south at an angle of 32.06° from the horizontal. It may be more convenient add an angle of 15° (to be 47°) in winter and subtract an angle of 15° (to be 17°) in summer.

Benghazi is one of cities with high solar radiation like the most cities in Libya. The average daily on array radiation measured in Benghazi city are listed in table (1) [10].

Table 1. Average daily on array radiation in Benghazi (array inclination =53°) [10]

Month	Radiation Wh/m^2	Mont h	Radiation Wh/m^2
Jan.	3942.88	Jul.	5833.25
Feb.	4574.16	Aug.	6130.30
Mar.	5315.27	Sep.	6617.13
Apr.	6029.02	Oct.	6383.54
May.	5567.35	Nov.	6079.52
Jun.	5554.17	Dec.	4675.60

Daily Power Curve

It is very important to represent the daily solar power curve because it gives a clear idea about the values of radiation in the zone you are working. So to obtain this curve, the pyranometer is installed (the instrument reads in mV and according to its specification each mV = 179.5322 W/m^2. The radiation readings are obtained during the day, and the relation between radiation and time are graphically represented. The sun's path at different times of the year for latitude of 32° N is estimated by using MATLAB program in this paper.

In relation to the experimental measurement in the site, three cases are recorded for Benghazi city normally; clear day dated on 25/05/2006, sunny day with scattered clouds dated on 27/10/2005, and cloud day dated on 21/02/2007. The solar power curves for these cases are represented in Figs. 1, 2 and 3 respectively, while Fig. 4 illustrates the simulation result of the sun's path for the last three cases.

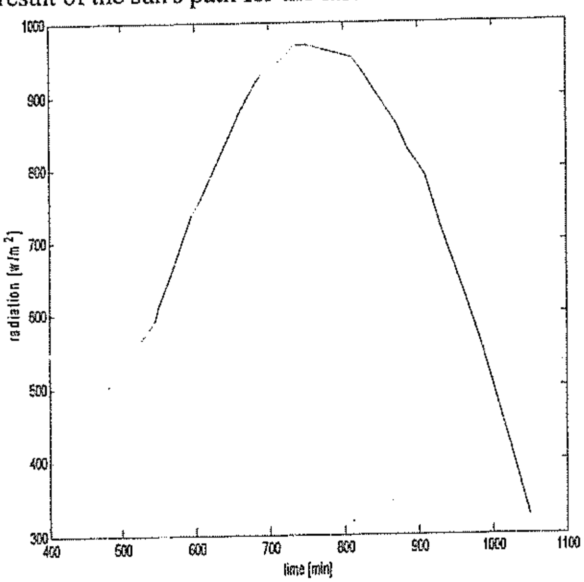

Fig. 1 Solar power versus time in 25/05/2006 at clear day.

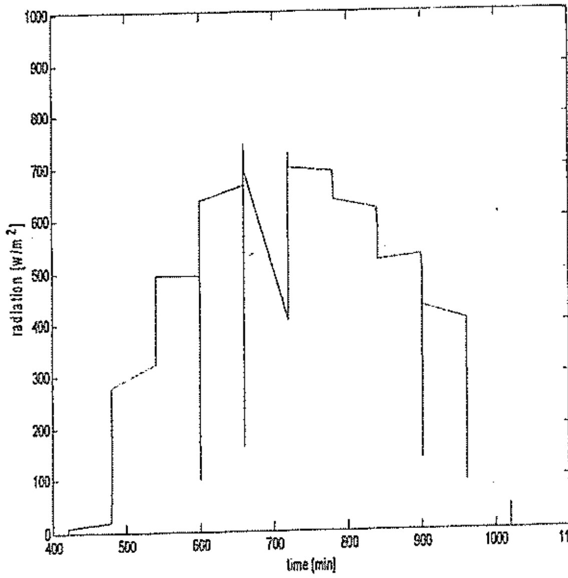

Fig. 2 Solar power versus time in 27/10/2005 at sunny day with scattered.

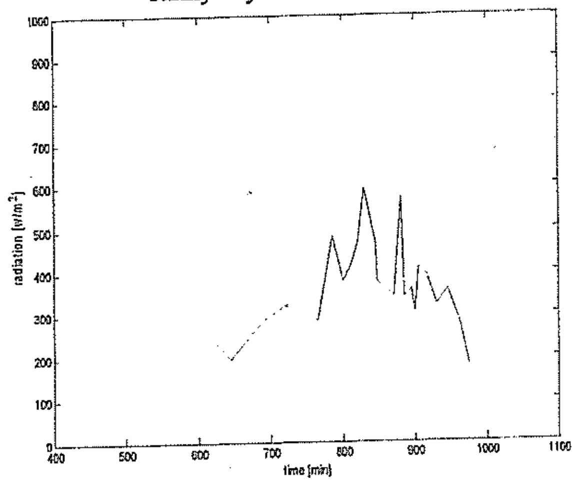

Fig. 3 Solar power versus time in 21/02/2007 at cloudy day.

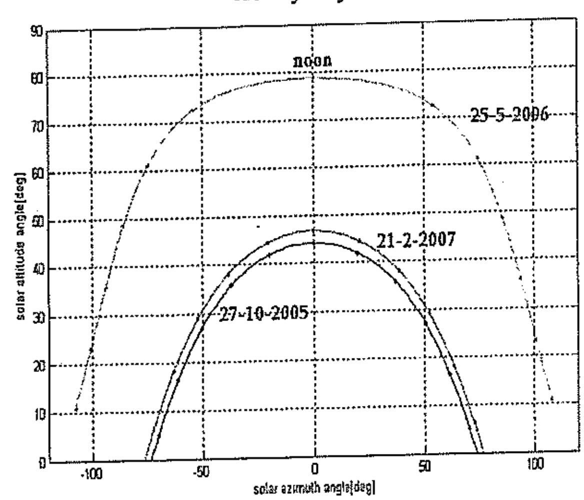

Fig. 4 Solar position (sun's path) for a latitude 32° N of Benghazi city in different days.

3. MODULE AND PANEL MODELS EXTRACTION.

A photovoltaic (PV) generator consists of an array of photovoltaic cell modules connected in series-parallel combinations to provide the desired DC voltage and current [9].

A solar cell is usually presented by an electrical equivalent one-diode model, as shown in Fig. 5. The model consists of current source, one diode, a series resistance, and a shunt resistance. The output of the current source is directly proportional to the light falling on the cell. The load current is the difference between the photo current I_{ph}, the normal diode current and the shunt current I_{sh} (R_{sh} usually assumed infinite).

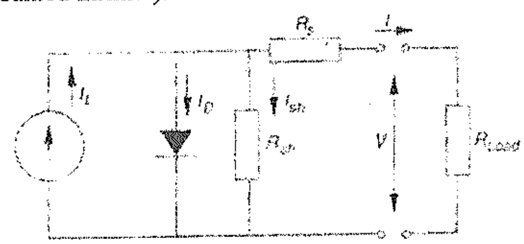

Fig. 5 The equivalent circuit for a PV generator.

The equation which describe the I-V characteristics of the cell is [2]

$$I = I_{ph} - I_D - I_{sh} =$$

$$= I_{ph} - I_s\{exp[q(V + IR_s)/nkT] - 1\} - (V + IR_s)/R_{sh} \qquad (1)$$

When $R_{sh} \cong \infty$, Eqn. 1 becomes:

$$V = -IRs + (nkT/q) \ln [Iph - I + Is) / Is] \qquad (2)$$

Where:

I	Cell output current.
V	Cell output voltage.
I_D	Normal diode current
Is	Reverse saturation current.
q	Charge electron = 1.6×10^{-19}.
K	Boltzman's constant = 1.38×10^{-23}.
T	Reference temperature in Kelvin =25+273= 298K.
n	Idealizing factor (diode quality factor).
Ko	Short circuit current temperature coefficient.
G_{st}	Solar intensity at standard condition.
G	Solar intensity at operating condition.
Rs	Series resistance.
Rsh	Shunt resistance.

When studying the PV model there are some important notifications in relation to parameters must be taken in mind, these are [2]

1. Cell temperature dependence of the diode saturation current Is.
2. Cell temperature dependence of the photo current I_{ph}.
3. Series resistance Rs, which gives a more accurate shape between the minimum power point and the open circuit voltage.
4. Shunt resistance R_{sh} in parallel with the diode it is usually assumed infinite.
5. The diode quality factor n ($1 \leq n \leq 2$).

The PV module considered in this research is LG-250-12 which produces 39 W, single crystal silicon, 5.9 Kg. 133X30.2X36 Cm, 36 series connected cells and its specifications listed in Table (2) while its typical V-I characteristics are shown in Fig. 6 according to its data sheet.

Table (2) LG-250-12 module specifications [4].

Reference temperature	T_{ref}	25°C
Open circuit voltage	V_{oc}	21.11 V
Short circuit current	I_{sc}	2.55 A
Voltage at maximum power	V_m	16.6 V
Current at maximum power	I_m	2.35 A
Maximum power	P_m	39 W
Number of series cells	N_s	36
Ideality factor	n	1.4
Solar intensity at st. Cond.	G	1000 W/m^2
Short circuit temp. coefficient	K_o	0.05×10^{-3}

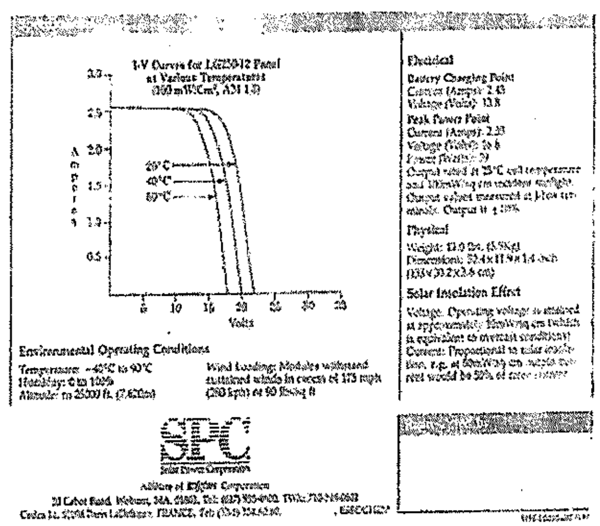

Fig. 6 LG-250-12 module characteristics [4].

In order to obtain the model parameters, the equations (1) & (2) and the data listed in Table (2) are used. The model parameters can be determined as follows:

$$I_s = 8.065 \times 10^{-16} (T_c)^3 exp\left[-31.112\left(\frac{298}{T_c} - 1\right)\right] \qquad (3)$$

It is clear that Is depends on Tc.

$$I_{ph} = 2.55 \times 10^{-3}\, G \qquad (4)$$

Rs = 0.014 Ω, for a single cell.

Then Rs of the module (the module is of 36 cells) is,

Rs = 0.014X36 = 0.504 Ω

Since the panel has 6 modules, so R_s for the panel is,

Rs=0.504 X 6 = 3.024 Ω

Substituting the values of Is, I_{ph}, and R_s in Eqn (2) to obtain the final expression which represent the PV module, that is

$$V = 4.35 \times 10^{-3} T_c ln\left[\frac{I_{ph} - I + I_s}{I_s}\right] - 0.504I \qquad (5)$$

For a PV panel is

$$V = 0.0261 T_c ln\left[\frac{I_{ph} - I + I_s}{I_s}\right] - 3.024I \qquad (6)$$

Where:

$$I_{ph} = 2.55 \times 10^{-3} G[1 + K_o(T_c - T_1)]$$

$$I_s = 8.065 \times 10^{-13} (T_c)^3 exp\left[-31.112\left(\frac{T_1}{T_c} - 1\right)\right]$$

4. SIMULATION OF PV MODULE AND PANEL.

Equations (5) and (6) deduced in the last section represent the model of PV module and panel respectively for general conditions, and can be noticed that the main variable that influence these equation and consequently the operation of module or panel are the radiation (G) and the cell temperature (Tc). So, the simulation results of the variation of each variable are presented. Figures. 7 & 8 show the simulation results of the PV module and panel for multi values of radiation respectively, while Figs 9 & 10 show the results for different values of temperature for module and panel respectively.

5. EXPERIMENTAL AND SIMULATION COMPARISON.

As mentioned later, in order to obtain a fair model it is necessary the comparison between the experimental and simulation results for the same conditions.

a) I-V Characteristics

In order to obtain comparison between the experimental and model simulation results of the PV module and panel, these results are represented in the same figure. Figure 11 represent the experimental and simulation results for the case of G=933.57W/m^2 and Ta= 28 °C of PV module.

Figure 12 represents the practical and simulation results for the case of $G = 789.94\ W/m^2$ and $T_a = 28°C$ of PV module.

The practical and simulation results of PV panel are represented as shown in Fig. 13 for the case of $G = 897.67\ W/m^2$ and $T_a = 32°C$. Another practical and simulation results of PV panel for the case of low value of $G = 359\ W/m^2$ and $T_a = 30°C$ are shown in Fig. 14.

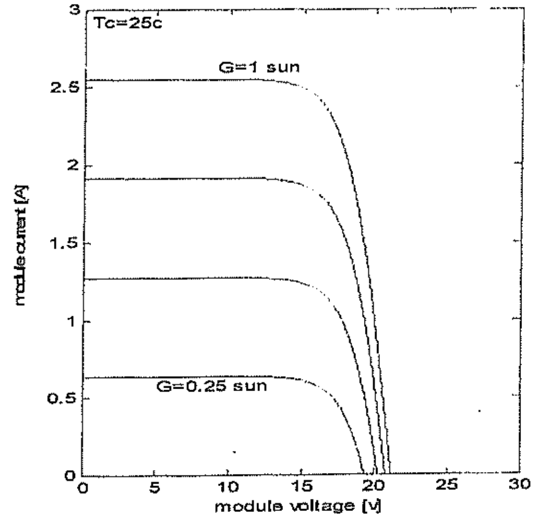

Fig. 7 I-V characteristics for PV module for different values of G.

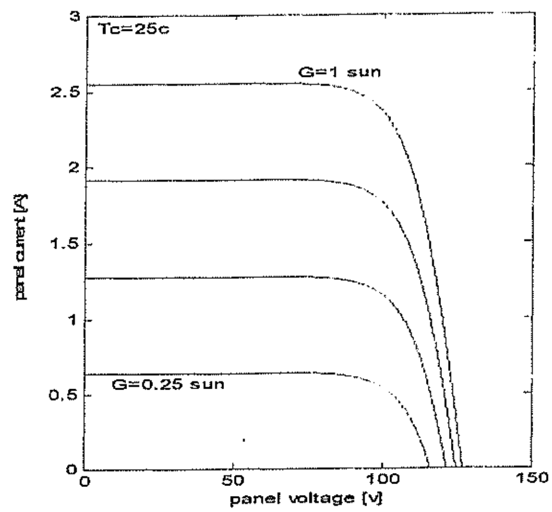

Fig. 8 I-V characteristics of the PV panel for different values of G.

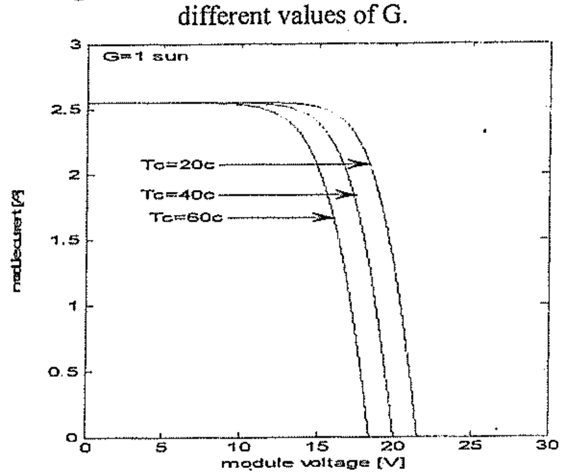

Fig. 9 I-V characteristics of the module for different values of Tc.

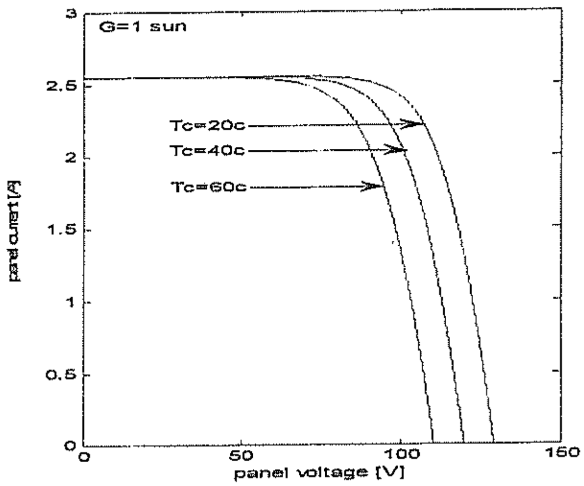

Fig. 10 I-V characteristics of the panel for different values of Tc.

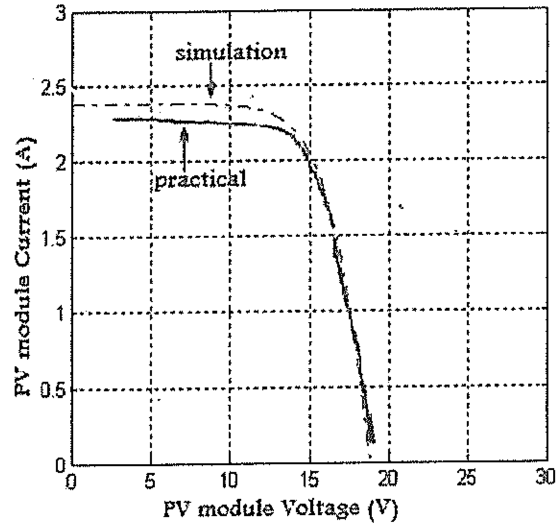

Fig. 11 Simulation and practical I-V curves (PV module) for G= $933.57 W/m^2$ and T_a= $28°C$.

b) Relation Between Isc and G

The practical and simulation comparison of relation between short circuit current between (Isc) and solar intensity (G) is illustrated in Fig. 15.

6. CONCLUSIONS.

The radiation measurement used here are beam and diffuse horizontal surface radiation gathered with a pyranometer located in Garyounis University, electrical and electronics engineering department, Benghazi. The data were taken for a different days of year.

Solar information about Benghazi city which is located at a latitude of 32.06° at the northern hemisphere are presented in this paper from which it is clear the radiation can be considered of high value.

PV module and panel type LG-250-12 mathematical models are extracted because of the extreme importance of modeling to make simple the study of module and panel characteristics in addition to use it as a model reference.

The practical study and results obtained are presented in the presented paper. The practical and model simulation results are compared and the results demonstrate the validity of the models extracted. Also a very important relation between short circuit current (Isc) and radiation (G) is deduced since this relation is an important one when we talking about the sensor-less control of power extracted from the PV panel (this is the point of the next research of the authors).

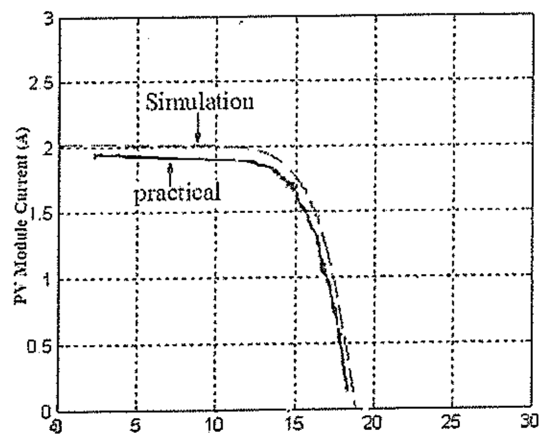

Fig. 12 Simulation and practical I-V curves (PV module) for G= 789.94 W/m^2 and T_a=$28°C$.

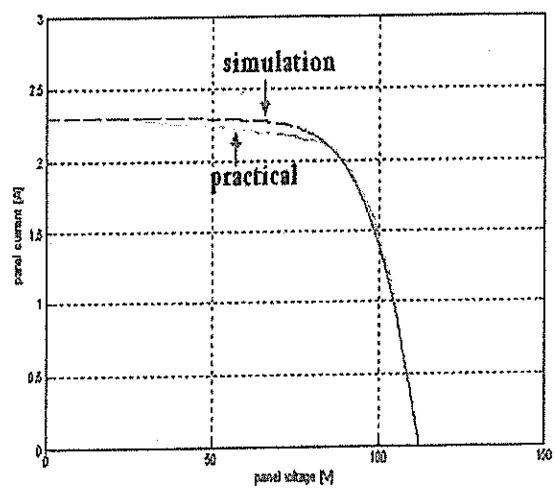

Fig. 13 Simulation and practical I-V curves (PV Panel) for G= 897.67 W/m^2 and T_a=$32°C$

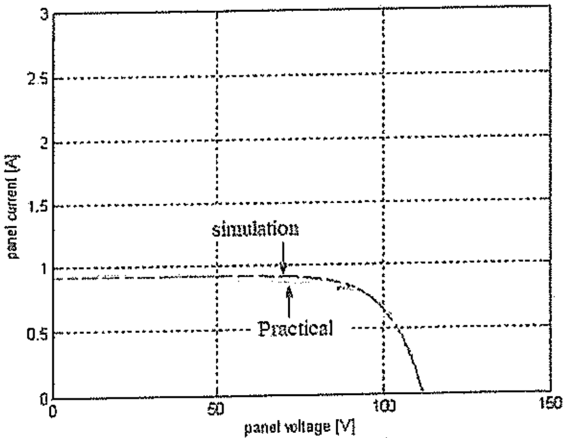

Fig. 14 Simulation and practical I-V curves (PV Panel) for 359 W/m^2 and $32°C$.

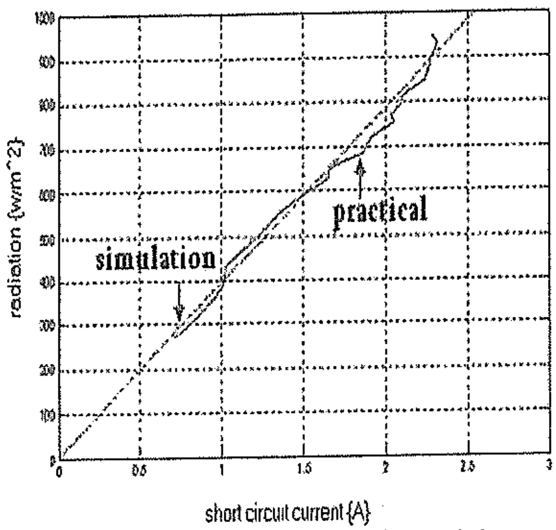

Fig. 15 Relation between (I_{sc}) and (G).

7. REFERENCES.

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