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A SIMPLE PV MODULE CHARACTERIZATION AND PREDICTION USING INCREMENTAL RESISTANCE TECHNIQUE

P.O ODO, S.A UGWU, UDOKA OPATA

Polycarp.odo@unn.edu.ng; aniezichukwu.ugwu@unn.edu.ng; udoka.opata@unn.edu.ng;

DEPARTMENT OF ELECTRONIC ENGINEERING, UNIVERSITY OF NIGERIA, NSUKKA

ABSTRACT

The data sheet provided on pv panels is most often exaggerated by manufacturers in other to lure unsuspecting buyers to patronize their products. For an ordinary pv users, this pose no problem at all as long as current is being generated using the panels. However, for research purpose, this gives inaccurate information thereby rendering the research result null and void. The information provided on the data sheet includes; the open circuit voltage, the short circuit current and the experimental maximum power. These are usually verified using solar simulators which most often does not give accurate information of the data. In this paper, a model is developed using the 1-diode model by iterating the values of both the serial and parallel resistances simultaneously until the maximum operating current is achieved. Using the values of these resistances, the pv data sheets of some standard panels were fairly accurately predicted using the modified diode model.

Keywords: Maximum operating points, 1-diode model, open circuit voltage, short circuit current, maximum power point tracking.

1. INTRODUCTION

The increase in demand for renewable energy sources cannot be over-emphasized. This is because the conventional energy sources are not renewable and may go extinction in the nearest future. Besides, the clamor for greenhouse effect and global warming mitigation has necessitated the rapid advancement in solar technology particularly in the photovoltaic industry. Owing to the resolve by stakeholders in pv industry to achieve higher photon conversion efficiency, there has been a tremendous growth in manufacturing pv panels. From crystalline silicon, polycrystalline silicon, amorphous silicon, multijunction silicon, thin films, organic and dye-sensitized solar cells, to the most recent the organic-inorganic halide perovskite [1] that is produced in laboratory using chemicals. The utmost goal is to have a panel that can convert into electricity most of the incident radiation falling on them.

Any pv panel for research purpose need to be validated in order to ensure that the data provided by the manufacturers are correct to avoid using inaccurate figures for modeling purpose. This is usually done indoors using routine equipment with some calibration errors. The diode models used for pv maximum power point tracking can equally predict nearly accurately the specifications of the panel. Pv panel modeling involves estimating the I-V and P-V curves where one can read the maximum operating points and calculate parameters such as fill factors and module efficiency. This can be done using the electrical equivalents of 1-diode model or the 2-diode model. The single diode model is fairly simple and less accurate than the 2-diode model- which takes longer computation time. The basic circuitry of the diode model consists of photo-generated current source and a single diode in parallel[2]. The 2-diode model has an additional diode[3]. To characterize a panel using the diode model, three parameters are needed viz; open circuit voltage(Voc), short circuit current(Isc) and the diode ideality factor which depends on materials of the pv device. Some authors have argued that for the diode model to have any practical significance, there is need for modification and improvements. The first modification came in the form of one series resistance, R_s [4] otherwise called the R_s – model in literature. This model is the most frequently used in pv module characterization and simulation due to it,s computational efficiency and simplicity[5]. Because of the deterioration in accuracy of this model when subjected to varying temperatures, a further modification came in the form of shunt resistance, otherwise known as the R_P model[6]. The additional parameter take care of leakage current associated with P-N junction of semiconductor diode. Though, this model is of practical importance in pv modeling, it requires high computing time due to increasing complexity in the number of parameters to be evaluated. For the 1-diode model, the R_P –model remains the best for pv simulation.

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Some authors have come up with some interesting techniques on how to handle the additional resistance parameters. For example, [7] included R_s but not R_p for a model of moderate complexity. Other authors neglect both resistances arguing that R_s is small and R_p is large. [8] highlighted the importance of both resistances in pv modeling for accurate computation of simulation parameters. [9] and [3] have proposed using the matching of the experimental maximum power with the simulation power to evaluate the values of R_s and R_p using the 1-diode and 2-diode models respectively. The trouble with that is that the expression is cumbersome and requires too much computational time and large simulink blocks. In this research, a simple technique is proposed using the R_P- model to validate some selected pv panels by incrementing R_s and R_p until maximum current(I_{mp}) on the data sheet is achieved. Using the resistance values at I_{mp}, the pv data sheet is fairly accurately predicted using matlab simulation.

2. MATERIALS AND METHOD

2.1. THE EQUIVALENT CIRCUIT OF THE 1-DIODE MODEL.

The electrical equivalent of the 1- diode model is as represented in Fig 1 below.

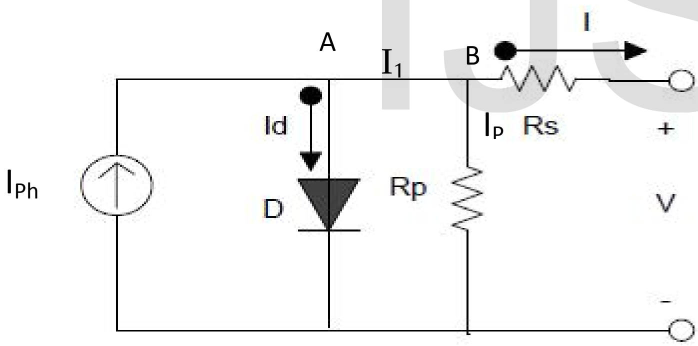

Fig1: One diode model circuit

Node A

By Kirchhoff current law

$I_{pv} = I_I + I_D$ 1

Node B

$I_I = I + I_P$

$I_{pv} = I + I_D + I_P$ 2

LOOP 1

Applying Kirchhoff's voltage law

$V_P - V_D = 0$

$V_P = V_D$ 3

LOOP 2

$V_S + V - V_D = 0$ 4

$V_D = V_S + V$ 5

$V_S = IR_S$ 6

$V_D = V + IR_S = V_P$ 7

$I_P R_P = V + IR_S$ 8

$I_P = \frac{V + IR_S}{R_P}$ 9

I_D is given by the Shockley diode-equation [10].

$$I_D = I_0\left(e\frac{V_D}{AV_T} - 1\right) \quad 10$$

$I_{Ph} = I + I_D + I_P$

$$I = Iph - I_0\left(e\frac{V + IR_S}{AV_T} - 1\right) - \left(\frac{V + IR_S}{R_P}\right) \quad 11$$

I_{Ph} = Photo- generated current

I_0 = diode saturation current

V_D= voltage across the diode

A = emission coefficient, ideality factor, where A= 1 or 2

V_T= Thermal voltage = 25mv at 25^{o}c/298k

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$$V_T = \frac{KT}{q} \qquad 12$$

N_S= no of cells in series

K=Boltzmann constant = 1.38x10^{-23}

T= Cell Temperature in Kelvin

q= charge = 1.6x10^{-19}C

Substituting V_T into the diode model in (11)

$$I = Iph - I_0\left(e\frac{q(V+IR_S)}{(AKT)} - 1\right) - \left(\frac{V+IR_S}{R_P}\right) \quad 13$$

This is the 1-diode equation as given b y[11]

The photon-generated current of the diode is given by [12]

$$Iph = Isc(1+Ki(T-Tref))\frac{G}{Gref} \qquad 14$$

I_{sc}= short circuit current

Ki = short circuit current temp co-efficient of the cell (^oc)

T = working temperature of the cell & in k

T_{ref} = reference temperature of the cell in k = 25^{o}c

G = irradiance on cell surface

G_{ref} = reference Irradiance on the cell surface = 1000w/m^2

The reverse saturation current (I_o) of the diode is given by [13]

$$I_0 = I_{rs}[T/Tref]^3 \exp\left[\left(\frac{qEgap}{AK}\right)\left(\frac{1}{Tref} - \frac{1}{T}\right)\right] \qquad 15$$

Where, E_{gap} =band gap energy of the semiconductor and I_{rs}=diode reverse saturation current given by [14]

$$I_{rs} = \frac{I_{SC}}{\left[\exp\left(\frac{qV_{OC}}{ANKT} - 1\right)\right]} \qquad 16$$

2.2. MODELING OF PV ARRAYS.

Eq.(13) is the 1-diode model of a single cell. For an array with Ns series cells and Np parallel cells, the diode equation is given by [3]

$$I = IphNp - I_0Np\left(e\frac{q(V+IR_S)}{(ANsKT)} - 1\right) - \left(\frac{V+IR_S}{R_P}\right) \quad 17$$

2.3. MODIFICATION OF THE MODEL

Based on the proposition by [3], eq.(15) cannot accurately evaluate the saturation current since it has no term in the current and voltage temperature coefficients. Eq.(18) then aims to match the open circuit voltages of the model with the experimental data for a very large range of temperatures. The Ki and Kv are the current and voltage temperature coefficients respectively introduced in (16) to give (18).

$$Io = \frac{I_{SC} + ki(T-Tref)}{\left[\exp\left(\frac{q(V_{OC}+Kv(T-Tref)}{AN_SKT} - 1\right)\right]} \qquad 18$$

2.4. FURTHER APPROXIMATION OF THE FORMULA

Plotting the P-V and I-V curves require solving (17) for I at(0,Isc,n) and V at (0,Voc,n), assuming Rp is large and Rs is small. This has been effectively deduced by [15] as;

$$V_{OC} = \left(\frac{ANKT}{q}\right)\log\left(\frac{I_{Ph}}{I_O}\right) \qquad 18 \text{ and}$$

$$I_{SC} = \frac{ANKT}{qR_S}\log[1 + M/I_0] \qquad 19$$

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Where M = Io +a, and 0<a<0.01

2.5. QUANTIFYING Rs AND Rp USING THE PROPOSED MODEL

[15] Did not give any detail of how Rs value was determined and arbitrarily assumed a value. This method however seems to determine values of Rs and Rp simultaneously by iterating eq.(17) at the maximum current of the panel assuming Np=1.Starting the iteration at Rs =0 and Rp>>0 using eq.(20) below, their values were obtained at Imp and the result when applied in simulating (17) fairly predicted the pv data sheets accurately

$$\operatorname{Im} p = IphNp - I_0 Np\left(e\frac{q\left(Vmp + IR_S\right)}{\left(ANsKT\right)} - 1\right) - \left(\frac{Vmp + \operatorname{Im} pR_S}{R_p}\right) \quad (20)$$

3. RESULTS AND DISCUSSION

A standard cell, Kyocera KG200GT was simulated using the developed model. The iteration of (17) at maximum current yielded Rs =0.2ohm and Rp=175ohm. This was validated in Fig2 and Fig 3 when a graph of current was plotted against Rs and Rp respectively. The parameters of Kyocera KG200GT are given in Table1 [7] and the simulated parameters in Table2. The short circuit current (Isc) and the open circuit voltage (Voc) almost nearly matched the experimental data as shown in the I-V curves of figure Fig4,and Fig5. The simulation power in Fig6 and Fig7 accurately predicted the experimental power (Pm) as provided by the data sheet.

4. MODEL VALIDATION

The model is validated using I-V and P-V curve of another standard solar cell, **BP Solar MSX-60** in Fig8 and Fig9. The manufacturer datasheet and simulation values of both Kyocera KG200GT and BP solar MSX-60 are compared in Table1 and Table2. The closeness of the values show that the proposed model can be used to characterize pv modules without computing the analytical power equation which is always cumbersome.

5. CONCLUSION

The experimental parameters of both Kyocera KG200GT and BP solar MSX-60 were fairly predicted by the developed model. The dependency of maximum operating points of the PV on irradiance is also affirmed. At high irradiance, current generated increases

Table1: Manufacturer datasheets for the standard cells used

parameter	Kyocera KG200GT	BP Solar MSX-60
Isc	8.21A	3.8A
Voc	32.9v	21.1V
Imp	7.61A	3.5A
Vmp	26.3V	17.1V
Ns	54	36
Pm	200.143w	50.145w

Table2: Simulation datasheets from the proposed model

parameter	Kyocera KG200GT	BP Solar MSX-60
Isc	8.1A	3.9A
Voc	33V	21V
Imp	7.80A	3.45A
Vmp	26V	16.9V
Ns	54	36
Rs	0.2 ohms	0.28 ohms
Rp	175 ohms	186.6 ohms
Pm	200w	50w

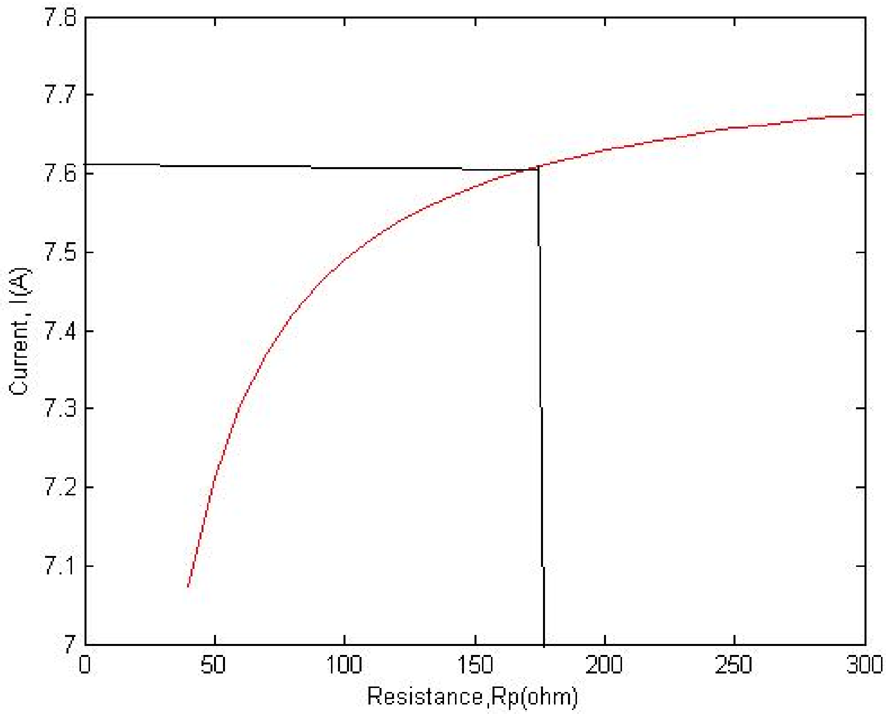

Fig2: Variation of current with parallel resistance (Rp)

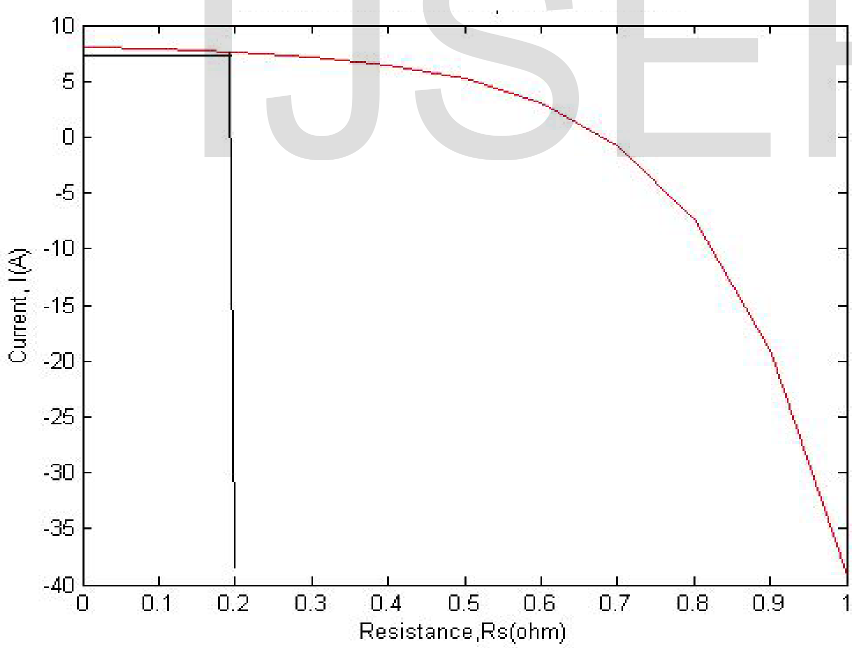

Fig3: Variation of current with serial resistance(Rs)

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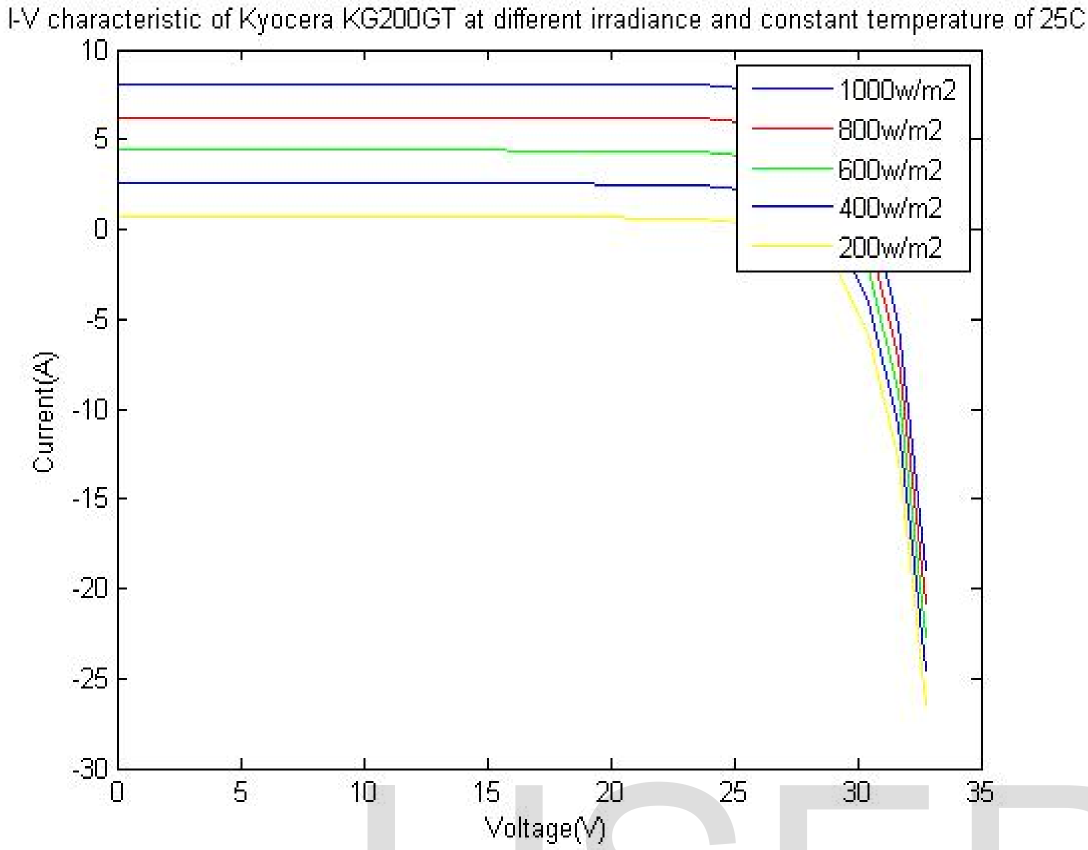

Fig4: I-V curve of Kyocera KG200GT at different irradiance and constant temperature

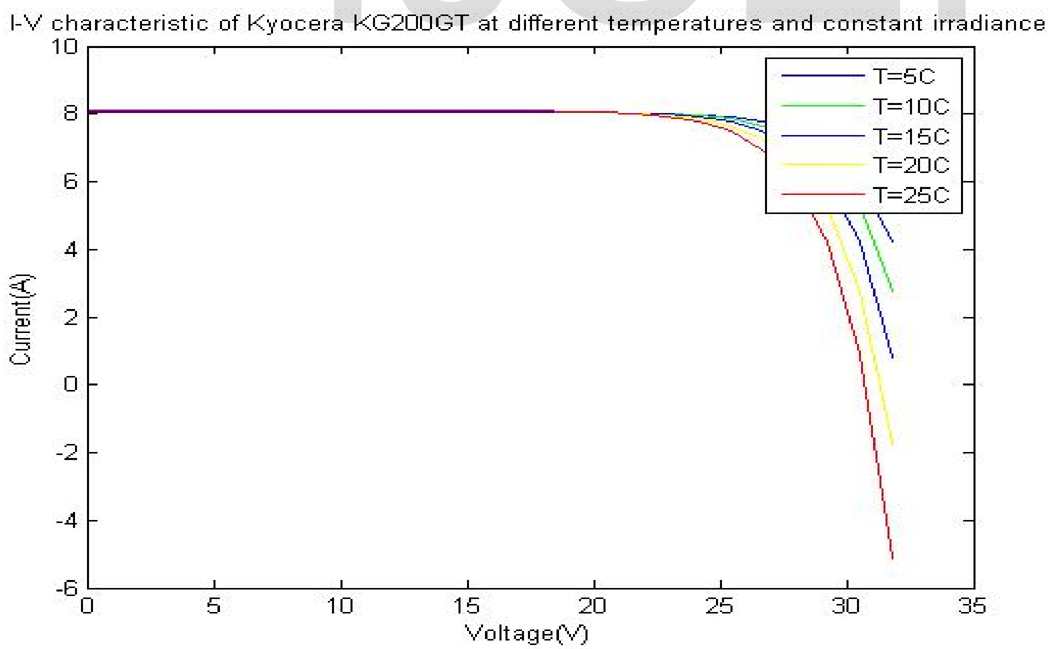

Fig5: I-V curve of Kyocera KG200GT at different temperature and constant irradiance of 1000w/m2

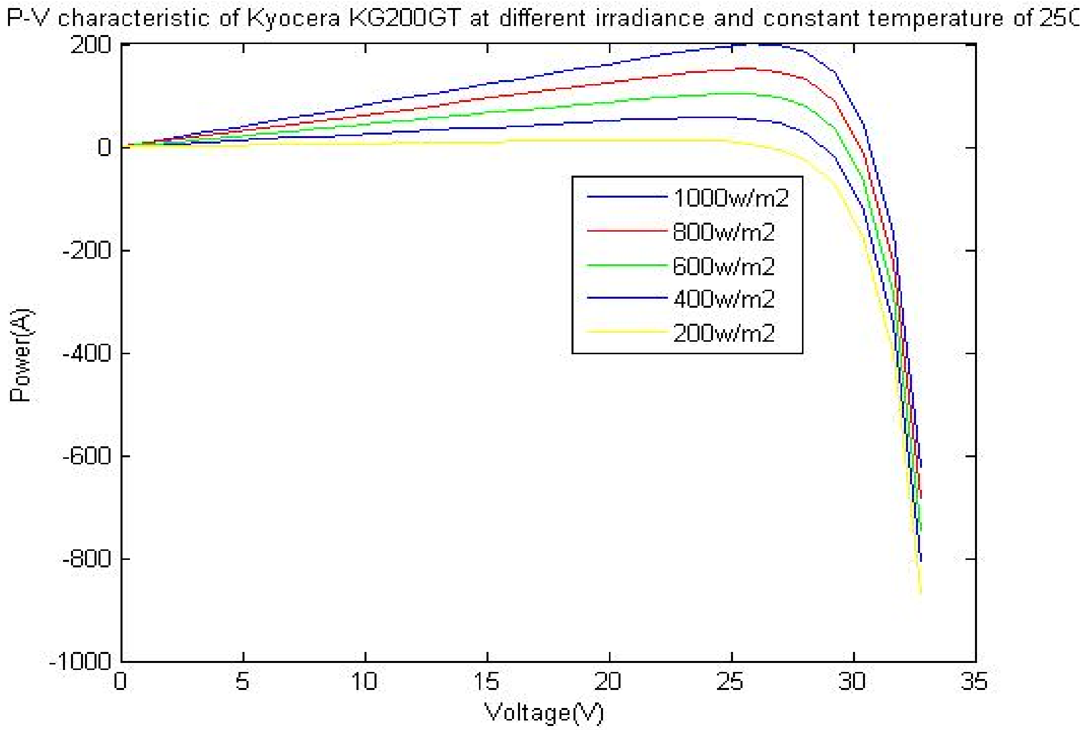

Fig6: P-V curve of Kyocera KG200GT at different irradiance and constant temperature

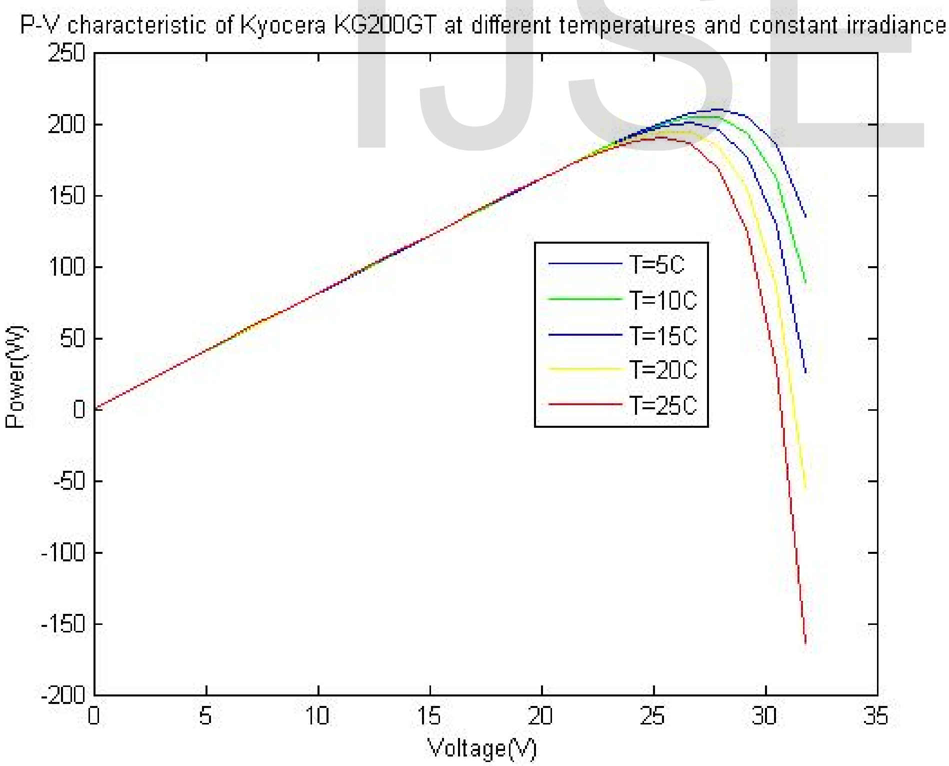

Fig7: P-V curve of Kyocera KG200GT at different temperature and constant irradiance of 1000w/m

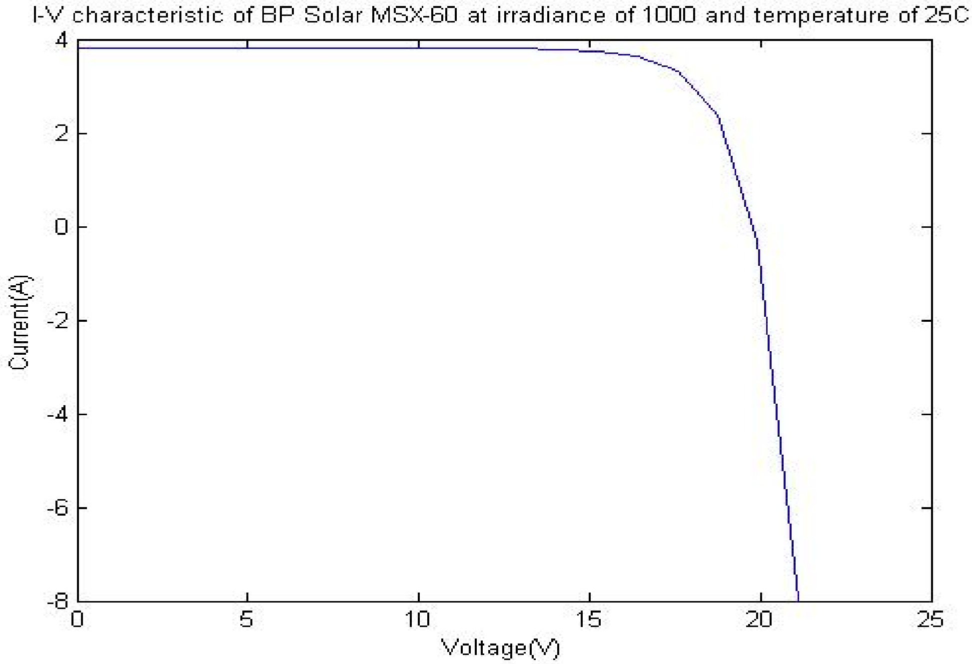

Fig8: I-V curve of BP Solar MSX-60 at irradiance of 1000w/m2 and temperature of 25 degrees

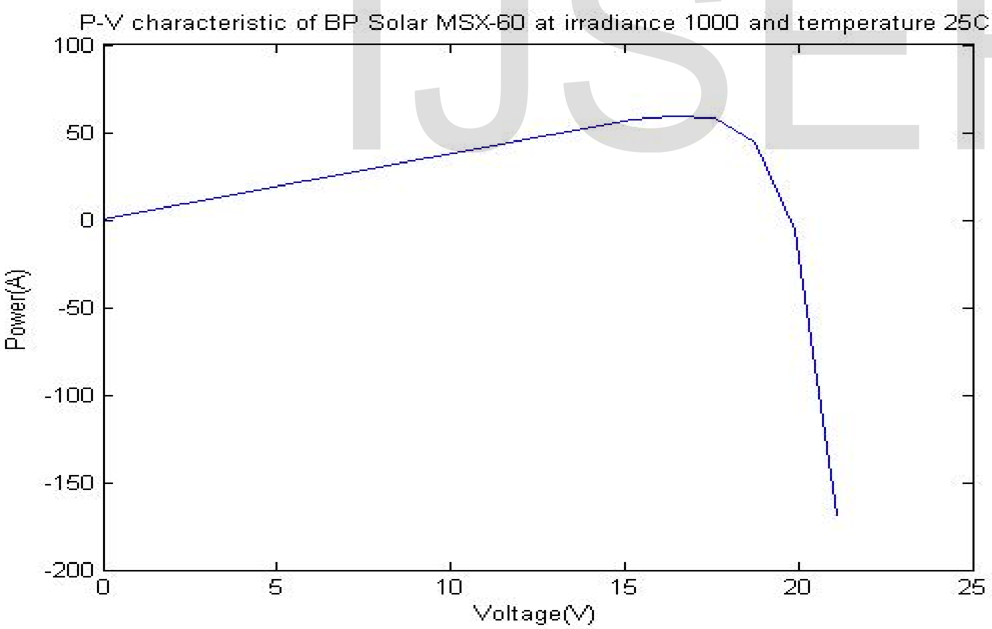

Fig9: P-V curve of BP Solar MSX-60 at irradiance of 1000w/m2 and temperature of 25 degrees

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