Modeling and Simulation of Double Diode Solar Module using MATLAB/Simulink

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Abstract : **:** This article deals with the double diode MATLAB modelling of a photovoltaic module. In this paper, double diode model was developed using the fundamental equations. To validate the simulink/ MATLAB model., developed model results are compared with the experimental data sheet. The developed double diode model is operated at the different operating conditions i.e. at the irradiances 1000W/m^2 and 800 W/m^2; the temperatures 25^0 C and 20^0 C. The required resistances are extracted by using the newton-rapshon method. The simulated results are perfectly coinciding with the experimental values.

IndexTerms **- Solar, Modelling, Experimental, MATLAB, iterative.**

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Introduction: Producing clean and high efficiency solar energy became very important with increasing demand of usage in energy. Over utilization of oil and gas becoming major threat to eco system(1). So renewable energy sources are playing major role in the major energy usage in the world. From pat two decades, solar energy utilization has enhanced by 20% to 30%.

Generally, the photovoltaic modules are made with the silicon material. From last few days, many alternative materials are using in the preparation of solar cells. Solar cells works on the principle of photovoltaic effect. A P-N junction formed in the solar cell, plays major role in producing solar energy. A single solar cell can produce few amount of energy i.e. 1-2 Watts,(2-3), but a combination of cells in series and parallel forms the solar module. Characteristic curves those are I-V and P-V curves are used to study the behaviour of photovoltaic system. To understand the real system, simulated model is very useful. In this work, a double diode MATLAB model is developed and validated using experimental solar data sheet(4-5).

Double diode MATLAB model:

Double diode MATLAB model: Equivalent circuit and corresponding mathematical equations are used to develop the MATLAB/Simulink model. Double diode model is developed using the electrical components those are diode 1 and diode 2, series resistance and parallel resistance. The second diode in the circuit is the representation of the recombination along the depletion region. A two diode model is giving more advantages in computation and accuracy at low irradiance level compared to the single diode(6-8).
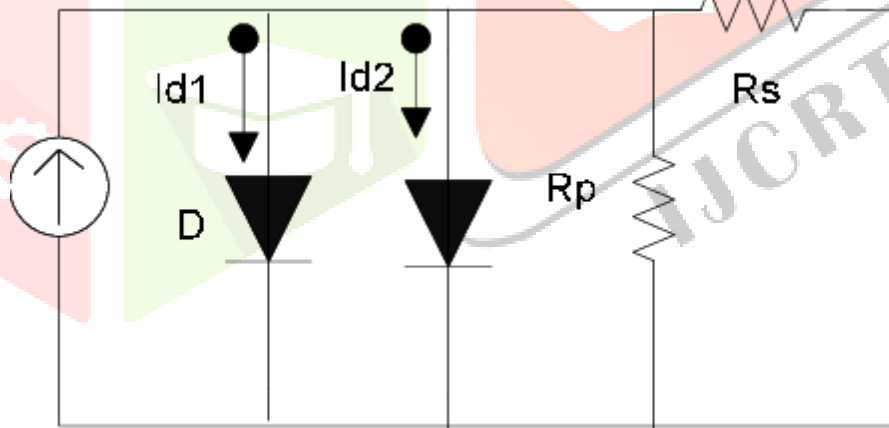

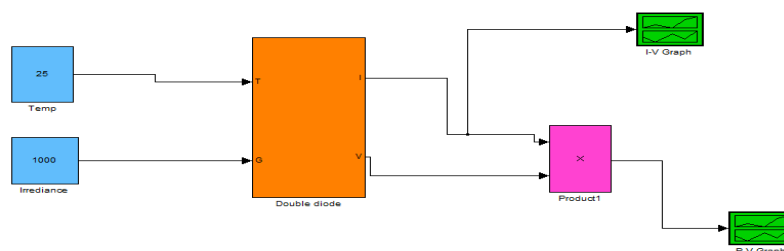**FIG-1: EQUIVALENT CIRCUIT OF DOUBLE DIODE SOLAR CELL**

Simulink model:

Fig-2: MATLAB/Simulink double diode model

Methodology: In a solar cell models, parameters such as V_{mp}, I_{mp}, $V_{OC,}$ I_{SC} are listed in the data sheet

$$I = I_{PV} - I_{d1} - I_{d2} - I_p \qquad \text{Eq.(1)}$$

$$I_{d=} I_o \left[exp\left(\frac{V}{aN_S V_t}\right)\right]$$

$$I = I_{PV} - I_{O\,1}\left[exp\left(\frac{V+IR_S}{a}\right) - 1\right] - I_{O\,2}\left[exp\left(\frac{V+IR_S}{a}\right) - 1\right] - \frac{V+IR_S}{R_P} \qquad \text{Eq.(2)}$$

$$I_{PV} = \frac{G}{G_{ref}}\left(I_{pvn} + K_I.\Delta T\right)$$

$$I_O = \frac{I_{SC,n} + K_i\,\Delta T}{exp\left(\frac{V_{OC,,n} + K_v.\,\Delta T}{\propto t}\right)} \qquad (9\text{-}10)$$

Simulink model of KD 325GX-LFB: MATLAB/Simulink model is developed using the input parameters taken from the data sheet. The developed model is having the input parameters irradiance and temperature .

At 1000W/m^2 and 25^0 C: Solar cell characteristics are studied using the I-V and P-V curves those are said to be characteristic curves. From the P-V curve the parameters maximum power (P$_{MAX}$)and voltage at maximum power (V$_{MP}$)can be calculated. From the I-V graph short circuit current(I$_{SC}$) and open circuit voltage (V$_{OC}$) and Current at the maximum power(I$_{MP}$) also can be calculated. Resistances are very important to achieve the high efficiency those are extracted from the newton-rapshon iterative method in which the parameter can be obtained by the process of iteration . In this case Series resistance(R$_S$) and parallel resistance(R$_p$) are 231.31 ohm and 0.40 ohm

From the results, we can observe that the values of the simulink model for KD-325GXLFB solar module are coinciding with the practical values from the experimental data sheet proving that the MATLAB /simulink model is correct.
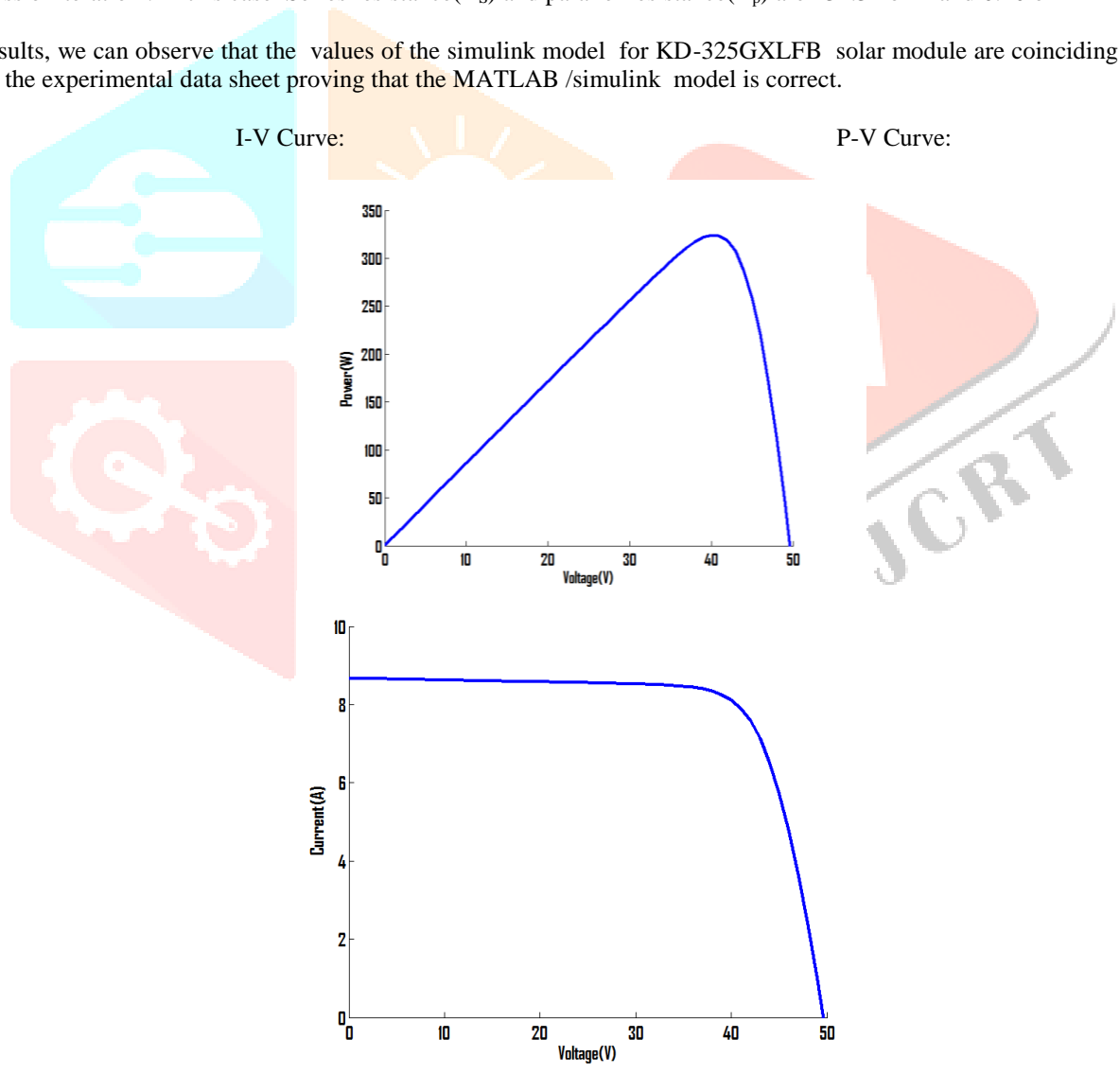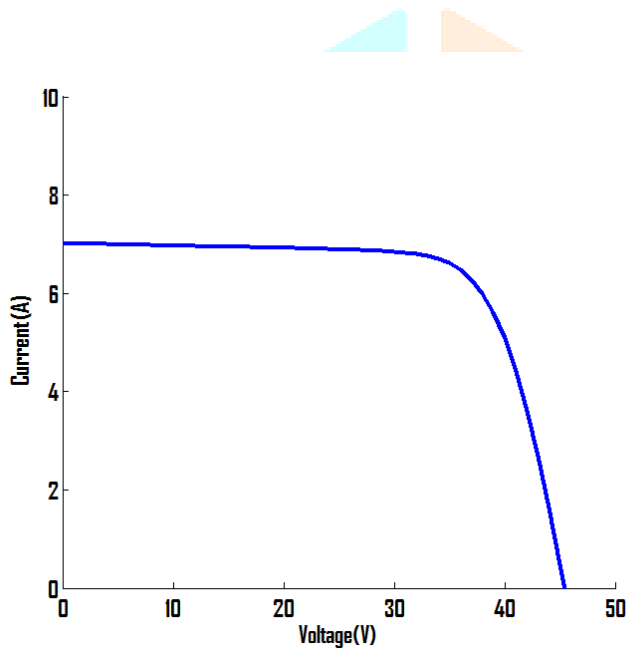
I-V Curve: P-V Curve:
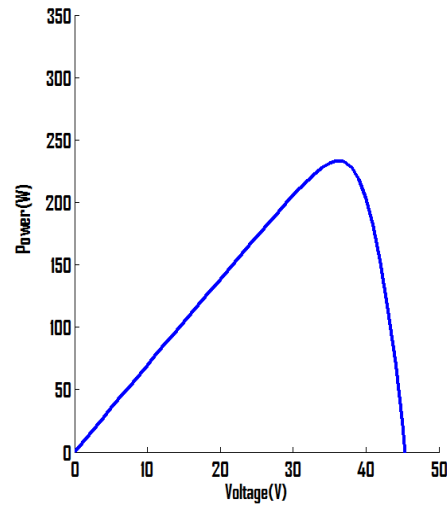

Table-1: Comparison of theoretical and experimental results

S.NO	Parameters	Experimental Results	Simulated results
1	P_{max}	325	324.4
2	V_{mp}	40.3	40
3	I_{mp}	8.07	8.05
4	V_{OC}	49.7	49.7
5	I_{SC}	8.69	8.674

At 800 W/m^2 and 20^0 C: The irradiance of the model is changed to the nominal operating temperature i.e. 800W/m^2 and the values are tabulated by taking the graphs of I-V and P-V. Series resistance(R_S) and parallel resistance(R_p) are 200.88 ohm and 0.52 ohm

P-V Graph: I-V Graph:

S.NO	Parameters	Experimental Results	Simulated results
1	P_{max}	234	233.5
2	V_{mp}	36.2	36
3	I_{mp}	6.47	6.49
4	V_{OC}	45.5	45.5
5	I_{SC}	7.04	7.02

Table:2 Comparision of theoretical and experimental values

From the results in the Table-2 , at normal operating conditions i.e. at the irradiance of 800 W/m^2 and the temperature of 20^0 C. The simulink model results are coinciding with the experimental data sheet values proving that the simulink model is correct.

MATLAB/Simulink model for KD330GX- LFB: Similarly, the simulink model is developed for the KD 330GX-LFB solar module . Required resistance parameters such as series resistance(R_S) and parallel resistance(R_P) are extracted from the same newton-rapshon method. The resistances are 'R_p' and 'R_S' are 203.48 ohm and 0.40 ohm.

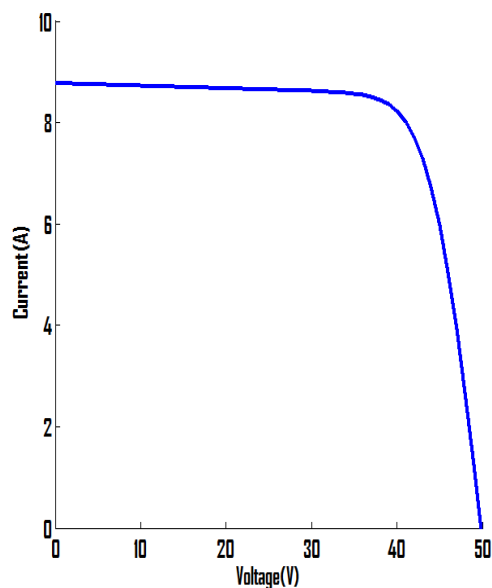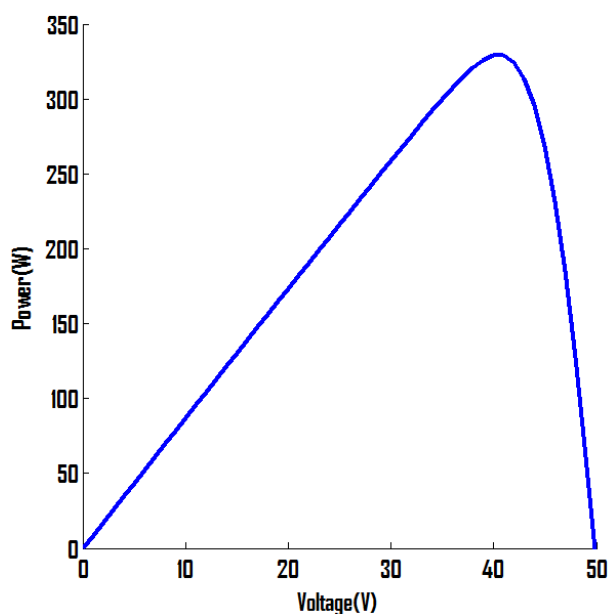P-V Graph: I-V Graph:

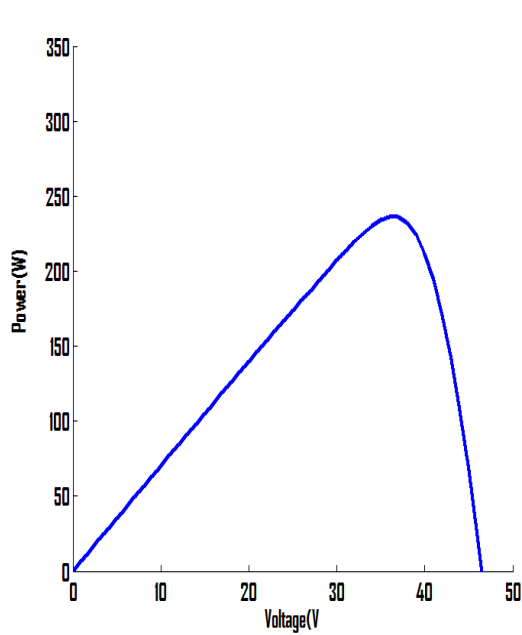Table-3: Comparison of theoretical and experimental results

S.NO	Parameters	Experimental Results	Simulated results
1	P_{max}	330	329.5
2	V_{mp}	40.5	40
3	I_{mp}	8.15	8.22
4	V_{OC}	49.9	49.9
5	I_{SC}	8.79	8.77

The simulation is conducted for the KD330GX-LFB solar module having the input irradiance 1000W/m^2 and the temperature of 25^0C. From the results, it was observed that the simulation values are coinciding with the experimental values from the data sheet.

At 800W/m^2 and 20^0 C:
Similarly, using the same simulink model the simulation is conducted at the nominal operating conditions i.e. at the irradiance of 800W/m^2 and at the temperature of 20^0 C. The required resistances i.e. series resistance(R_S) and parallel resistances(R_P) are extracted using the newton-rapshon method, those values are 0.67 ohm and 176.66 ohm.

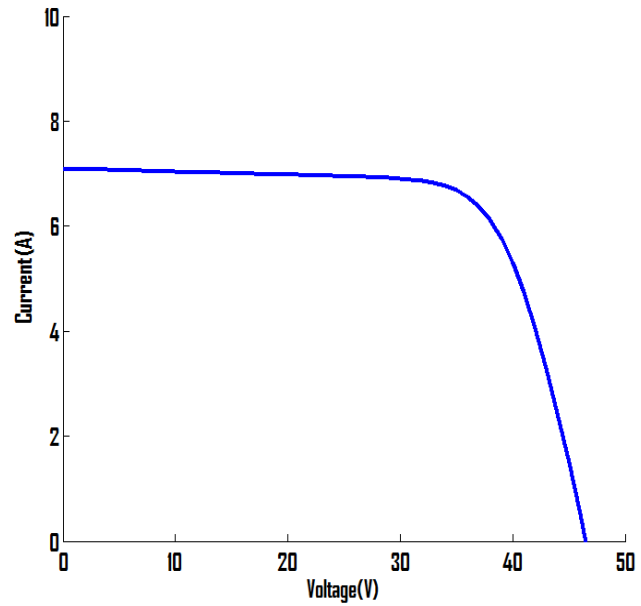At P-V Graph: At I-V Graph:

Table:4 Comparison of theoretical and experimental results

S.NO	Parameters	Experimental Results	Simulated results
1	P_{max}	237	236.2
2	V_{mp}	36.4	36
3	I_{mp}	6.52	6.56
4	V_{OC}	46.6	46.6
5	I_{SC}	7.12	7.093

From the results we can observe that simulink results and the experimental results are coinciding.

Conclusion: From the results, (table 1,2), for KD325GX-LFB, 80 cell solar module at the operating conditions of irradiances 1000W/m^2, 800W/m^2 and at the temperatures 25^0 C , 20^{0}C; the photovoltaic characteristics such as open circuit voltage(V_{OC}), short circuit current(I_{SC}), maximum current at maximum power(I_{mp}), maximum power(P_{max}) are extracted from the I-V and P-V graphs developed by the MATLAB model are coinciding with the experimental results. Similarly for KD330GX-LFB solar module all the photovoltaic parameters(V_{OC}, I_{SC}, V_{mp}, P_{max}) are approximated to the experimental results. This is proving that the developed MATLAB model is accurate for the study of real time solar devices.

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