Analysis of Modelling of Double Diode PV Panel and Effects of Various Parameters and Its Efficiency

Rahul Narang[1], Dr. M. K. Bhaskar[2], Manish Sharma[3], Vinay Sharma[4]

[1, 3]M.E. Scholar
[2]Professor, Department of Electrical Engineering, M.B.M. Engineering College, Jodhpur, Rajasthan, India
[4]Vyas Institute of Engineering College, Jodhpur, Rajasthan, India

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Abstract –*This paper presents P-V characteristics and efficiency of double diode model equivalent circuit for modeling of photovoltaic cell using MATLAB program. The main work of this simulation is to observe effect of variations in solar cell parameters on output power and efficiency. Since simulation with double diode model require extra equations but due to using efficient iterative method it reduced and less equation for faster calculation. This simulation is based on data provided by solar panel manufacturer.*

***Key Words*: P-V Characteristics, Double Diode, Irradiation, Temperature, No. of Cells, Ideality Factor, Parasitic Resistance**

1. INTRODUCTION

Today most of the country use fossil fuel to run vehicles, airplanes, and to power houses and industries but this fossil fuel is limited on earth and will get empty in few decades. [1] To extend this time renewable source of energy is available sun is the great example of renewable source of energy for millions of year as long as the life of sun will give energy. [1][2] Solar gives solar energy in abundant amount of energy in the form of light and various energy, some are harmful like UV some are useful like irradiation and sunlight used by plants and irradiation to heat water, cooking and to generate electricity. [2][3]

Due to blackbody effect almost all material absorbs solar radiation for example a red plate absorbs all visible light 250nm to 2500nm wavelength except 700nm which is red colour's wavelength which is reflected. This absorbed energy heat up the surface, this same pheromone is done with irradiation whose wavelength starts from 700 to make electrical energy with solar cell which captures photons which convert to electrons in junction point and semiconductor will try to make balance between electrons and holes which produce potential across terminals. The energy is very dense in radiation as $1.75W/m^2/nm$ for 500nm wavelength however after $1.5W/m^2/nm$ it starts decreasing near to 0.1 for irradiation. Single layer solar cell is not efficient to collect this amount of densed energy, for higher efficiency multilayer solar panel is used. [4][5][6]

PV technology is getting popular among the world due to it generates energy from free source of energy sun and require less maintenance. Electrical power is generated by a plate of semiconductor its same as other diode with p-n junction where electron-holes pair is generated by collision of sunlight (photons) with atom which release electrons and a hole is left behind this imbalance produces potential across terminals. A single solar cell produce 0.5 to 0.7 V and 0.1 to 0.3A current, which means it requires large array to produce required power this further require large area of land which is an drawback of using solar energy the solution is to increase efficiency of absorption of irradiation, this can be achieve by research in photovoltaic technology which is done by simulation of solar cell. [7]

Researchers use simulation software like matlab and spice for solar cell many pv model is available for an ideal pvcell ideal diode model is used with 3 parameter, single diode model with parasitic resistance with 5 parameters and double diode model with 7-8 parameters and three diode model with 9 parameters.[2][6][7]

In this paper double diode is chosen because this model gives higher accuracy for simulation of solar cell, to reduce simulation time 8 parameter is reduced to seven this result in reduction in no. of equations by the help of efficient iterative method and simulation is done on 7 selected parameter (irradiation, temperature, parasitic resistances, and no. of series and parallel cells and ideality factor) for wide observation on P-V characteristics and their effect on performance & efficiency.

2. Equivalent circuit with double diode model

For mathematical expression of solar cell an equivalent electrical circuit is required as shown in fig 1 which is a double diode model with an current source(Iph) which represent current generated by photons, an ideal diode (D1) in parallel to source whose ideality factor is 1, another diode (D2) in parallel with known ideality factor, series and parallel resistance which represent internal resistance of solar cell , Id1 and Id2 is diode leakage current and I is the output current get by removing all losses from Iph. By efficient iterative method ideality factor, series & parallel resistance and saturation current is obtained. [14] The simulation is based on real model data provided by manufacturer of adani eternal series (300wp) whose specifications are shown in Table 1.

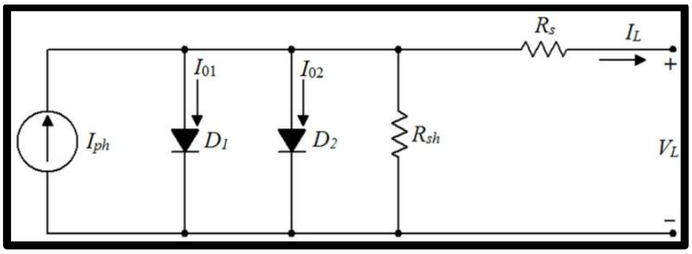

Fig -1: Equivalent Circuit Solar Cell in Double Diode Model

2.1 Mathematical expression

$$I = Iph - Id1 - Id2 - Ish \quad (1)$$

$$Id1 = Io1\left[\exp\left(\frac{V + IRs}{a1 * Vt}\right) - 1\right] \quad (2)$$

$$Id2 = Io2\left[\exp\left(\frac{V + IRs}{a2 * Vt}\right) - 1\right] \quad (3)$$

$$Ish = \frac{V + IRs}{Rp} \quad (4)$$

$$Iph = \left(\frac{G}{Gn}\right)[Iscn + ki * (T - Tn)] \quad (5)$$

$$Io1 = Io2 = \frac{Iscn + Ki * (T - Tn)}{\exp\left(\frac{Vocn + Kv * (T - Tn)}{Vt}\right) - 1} \quad (6)$$

2.2 Nomenclature

Iph is photo generated current

Id1 is Shockley diode equation for diffusion

Id2 is Shockley diode equation for recombination mechanism

Io1 is reverse saturation current for diode D1

Io2 is reverse saturation current for diode D2

Rp is parasitic resistance in parallel

Rs is parasitic resistance in series

Ish is loss due to parasitic resistance

I is total output current

a1 is ideality factor for ideal diode D1

a2 is ideality factor for diode D2

q is electron charge

K is Boltzmann constant

T is surface temperature

G is irradiation

VT is thermal voltage of diode

2.3 Fill Factor (FF)

Voc is the open circuit voltage and Isc is short circuit current which gives maximum I-V curve and maximum power can get by PV module. And the I and p is the actual output current and power of simulation model respectively, fill factor shows the gap between Voc-Isc curve and the actual I-V curve, it is the ratio of maximum power of module and the product of Voc and Isc. This shows the performance of pv module varies from 0 to 1 as this factor close to 1 better the performance , most of the solar module have fill factor above 0.7.[8][9] Expression shown in below equation

$$FF = \frac{Vm * Im}{Voc * Isc} \quad (7)$$

2.4 Efficiency

Efficiency of solar module is get by ratio of maximum input power from sun or product of Vmpp and Impp, where Vmpp is Voltage at maximum power point and Impp is current at maximum power point respectively and the actual output power get from pv module. This shows the performance of PV module and simulation model at different conditions of Parameter. [10]In this paper efficiency is observed at different levels of parameters (Irradiation, temperature, series resistance, parallel resistance, no or cells in series & parallel and ideality factor)

$$EF = \frac{Voc * Isc * FF}{Pmax} \quad (8)$$

3. Simulation with double diode model

To observe the effect of changes in solar cell parameters with the help of simulation software matlab, this simulation is based upon double diode model which have 8 Parameters but due to efficiency iterative method it is reduced to 7 parameter which results in reduction in no. Of equations which reduce simulation time. Double diode model is selected for this simulation because it gives better accuracy as compared other low parameter models. [11][12][13]

This simulation gives P-V characteristics and efficiency of model at different conditions of Parameters as discussed below. The fixed parameter are taken from solar panel model adani eternal series (300wp) datasheet, specifications are shown in table 1

Table-1: Solar panel model datasheet

Parameter	Values
Pmax	300w
Open circuit voltage (Voc)	39.53V
Short circuit current (Isc)	10.01A
Temperature coefficient for Voc	-0.31%/°C
Temperature coefficient for Isc	0.068%/°C
Reference temperature	25°C

4. Irradiation (G)

In solar cell simulation irradiation varied from 200W/m^2 to 1000W/m^2 to observe its effect over output P-V characteristics. From the observation it is seen that at low IR concentration about 200W/m^2 output power is 57W and as it reaches to 1000W/m^2 it gives 290W output power all variations at 25°c, so as high as the irradiation raises the output power will also rises. [14][15] this demonstrated in fig (2)

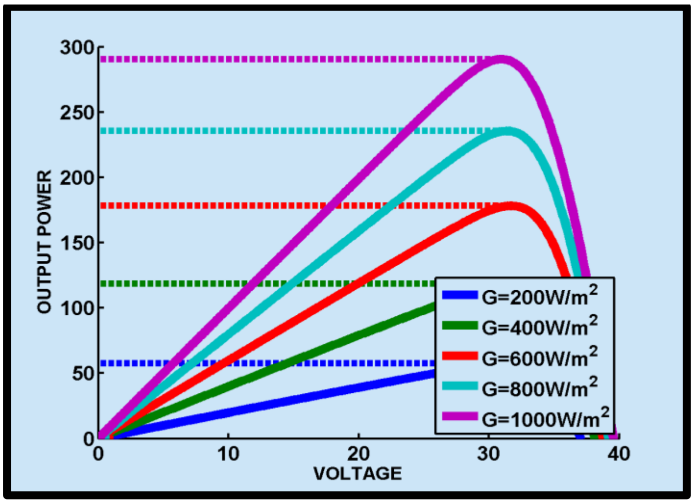

Fig -2: P-V Characteristics for Irradiation

Efficiency at 200W/m^2 is low as19% but as soon as this irradiation increases to 1000W/m^2 efficiency improved to 96.8% which shows the efficiency or performance is highly effected by irradiation , the full variation from 200 to 1000W/m^2 is can be seen in fig(3)

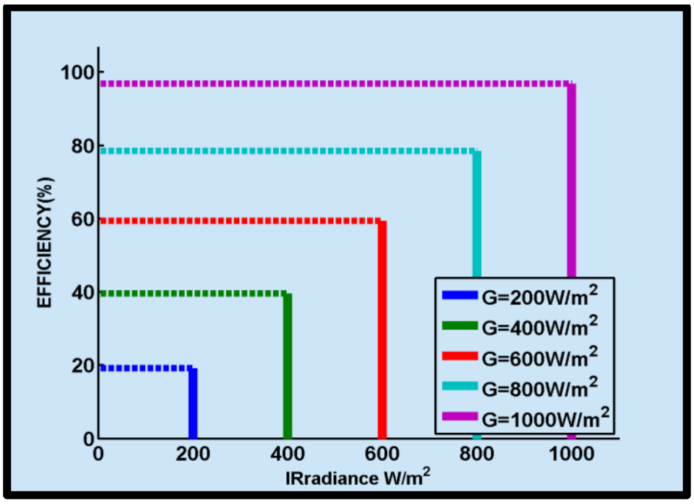

Fig -3: Efficiency for Irradiation

5. Temperature (T)

To see the effect of temperature on solar cell output temperature is varied from 15°C to 55°C at 1000W/m^2 irradiation and not varying other parameters. At 15°C simulation model gives 292W as the temperature rises to 55°C it decreases to 286W , this decrement in power is due to as the temperature rises current slightly increased but voltage decreased drastically which results in decrement in output power[16][15]. This clearly can be seen from fig (4).

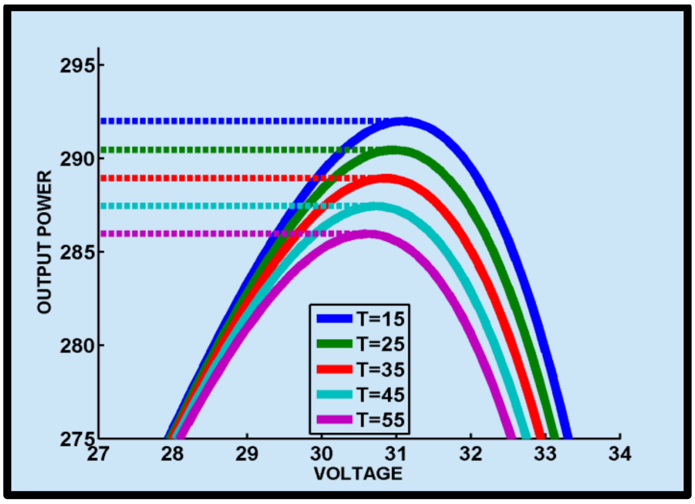

Fig -4: P-V Characteristics for Temperature

Efficiency at 15°C and 292W is 97% and at 55°C, 286W efficiency is 95% which shown at low temperature areas solar cell will give better performance and at high temperature areas like countries comes under equator solar cell gives low performance and degrade faster. Effect of temperature on Efficiency is shown in figure (5)

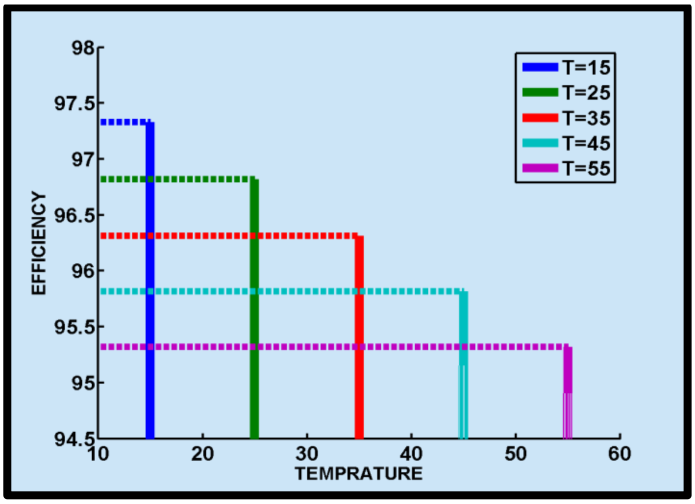

Fig -5: Efficiency for Temperature

5. Ideality factor (a1, a2)

In mathematical expression diode equation without ideality factor is an ideal diode equation; to make it act like an real diode it must follow recombination mechanism in which recombination is different at different location in junction point. To deviate diode equation from ideality it requires ideality factor represented as a2 in equation (3), where as equation (2) is an ideal diode equation in which value of a1 is 1. As this factor rises the diffusion and recombination rises for diode D1 and D2 respectively. Which rises output power slightly after ideality factor 1.2 and become constant near 2 [18] [19] [20]

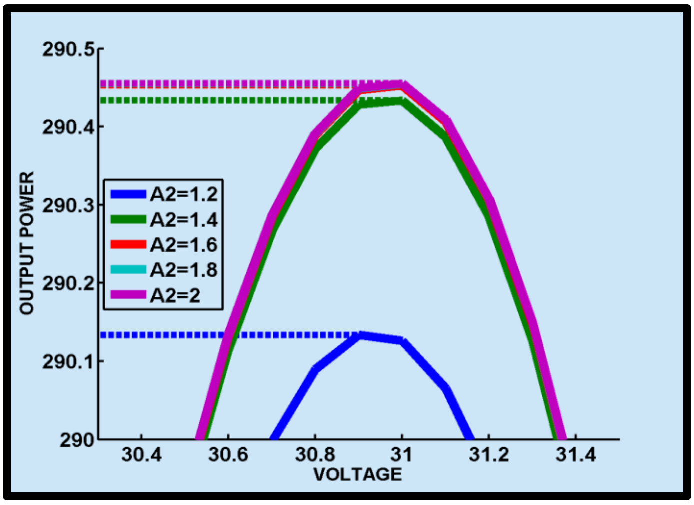

Fig -6: P-V Characteristics of Ideality Factor

Efficiency of solar cell by variations in ideality factor is seen in figure (7) which shows that at after ideality factor 1.2 efficiency become constant.

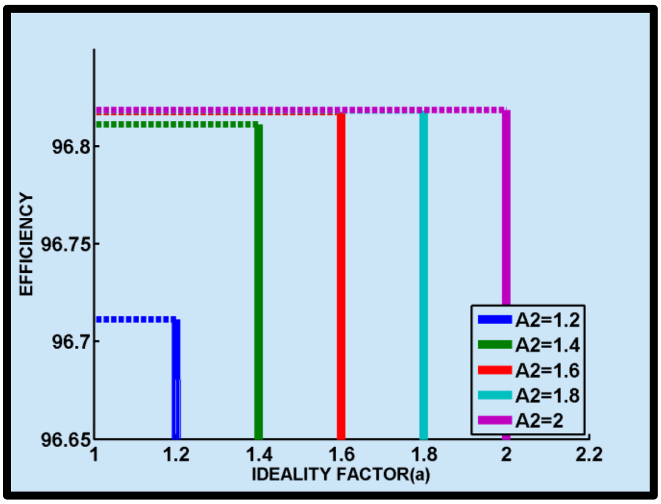

Fig -7: Efficiency for Ideality Factor

6. Series connected cells (Ns)

Cells in series add up the voltage , every solar cell act like an battery in series , this forms an series string of cells to form an module and module act like an large single cell whose voltage and current is higher and for powering house or industry an array of modules is formed in a grid. As the no. of series cells increased the open circuit voltage Voc and Vmpp will increase and the current will remains same results in increase in peak power. As seen from figure (8)At 40 series cells output power is 194.5W and as it rises to 60 cells output power is 290.45W.[20]

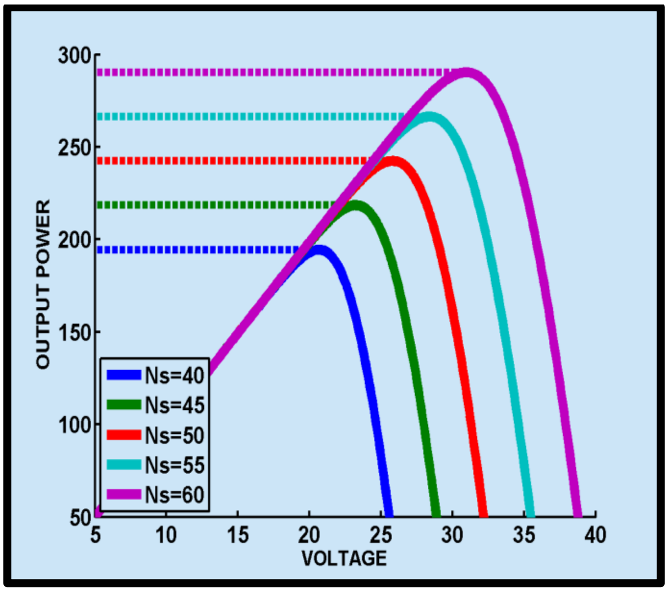

Fig -8: P-V Characteristics for Ns

Efficiency rises as the no. Of series cell rises because it is clear from P-V characteristics power riser with no. Of cells so efficiency also rises, at 40 series cells 64.8% and at 60 cells it rises to 96.8%

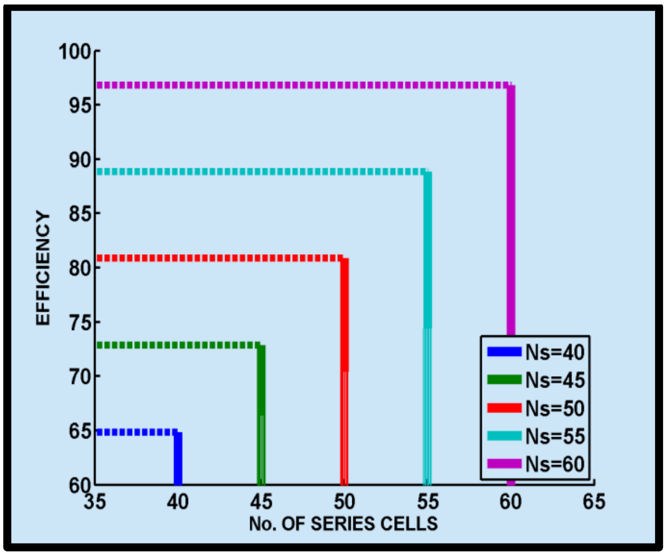

Fig -9: Efficiency for Ns

7. Parallel connected cells (Np)

As the no. Of parallel cell added existing cell then the current will rise and the voltage will remain same as previous this results in rise in Isc, Impp and output power. Parallel connection is based on required load, no matter how parallel connection is made as cell to cell, string to string or panel to panel output will same. As seen from figure(10) at single string of cells output power is 290.45W and as 3 string of cell is connect in parallel output power will become 876.6W

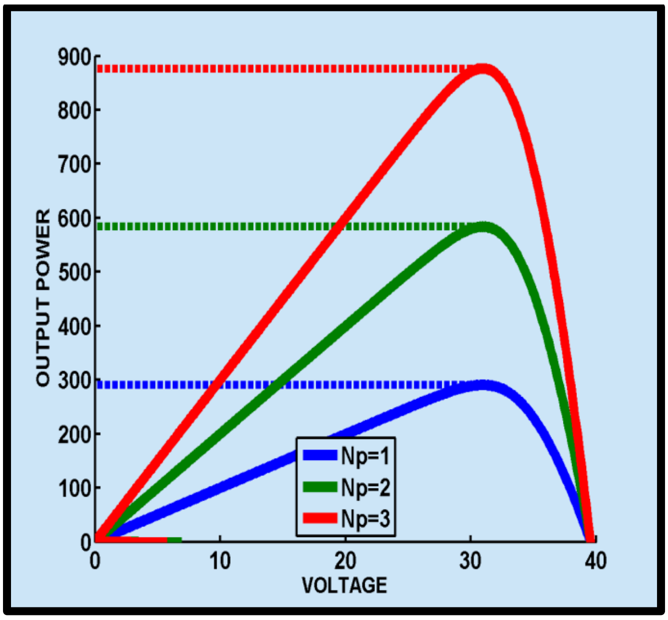

Fig -10: P-V Characteristics for Np

As the no. Of parallel connection increase output current increases and power also increases which results rise in efficiency, as seen in figure (11)

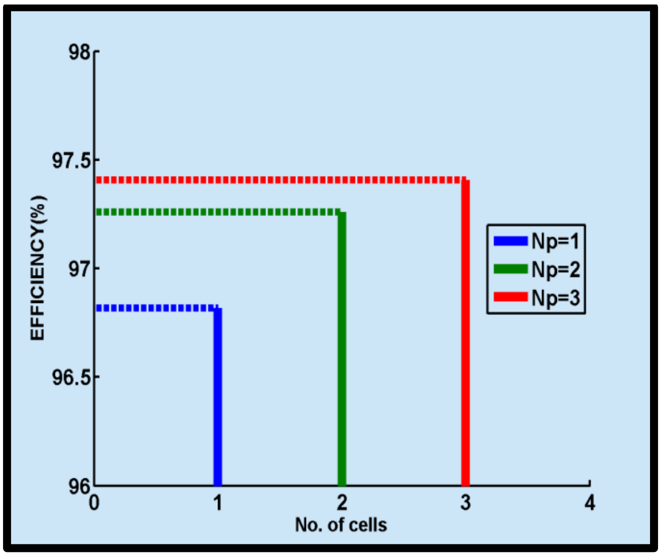

Fig -11: Efficiency for Np

8. Shunt Resistance (Rp)

Shunt or parallel resistance is an component of internal resistance based on impurities in diode or diode temperature, as this resistance rises higher the output power will get, As the double diode gives better accuracy and stability not vary much increment is seen in power, at 355 ohm output power is 290.45W and as it rises to 755 ohm output power is at 291.8W [16] [17] as shown in figure (12)

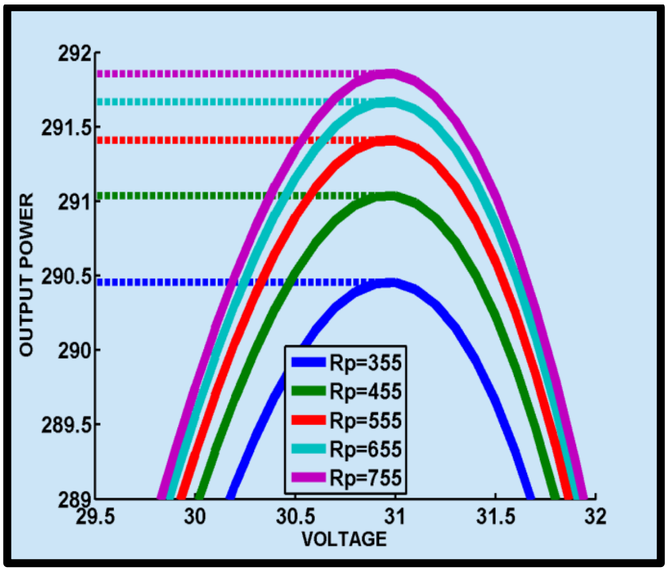

Fig -12: P-V Characteristics for Rsh

Efficiency is low at low shunt resistance due to Ish rises and small amount of power is dissipated through it as the shunt resistance raises this loss become smaller and better output power is obtained. It is clear that output power is not much affected by shunt resistance.

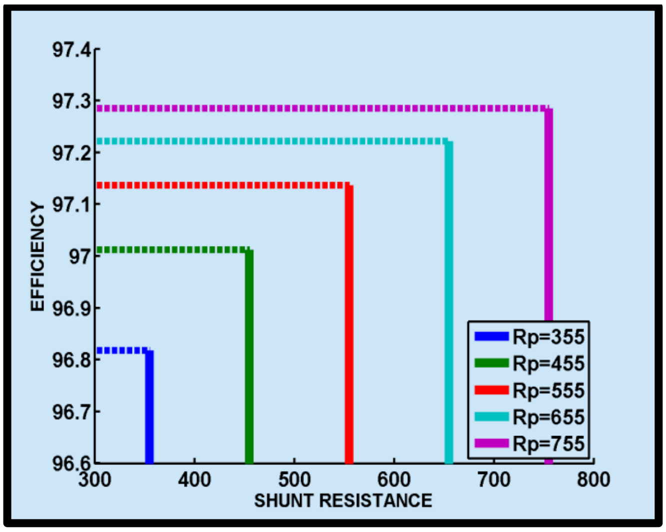

Fig -13: P-V Characteristics for Rp

9. Series Resistance (Rs)

Series resistance is also a part of internal resistance between p-n junction and output terminal, as this resistance getting higher due to external and internal disturbance the output current and output power also get lower simultaneously like as at 0.44 ohm output is 290.45W and as it get higher to 0.84 ohm it gives 255.73W which shows any small changes in series resistance output power will affected so much as changes can be seen from figure (14)

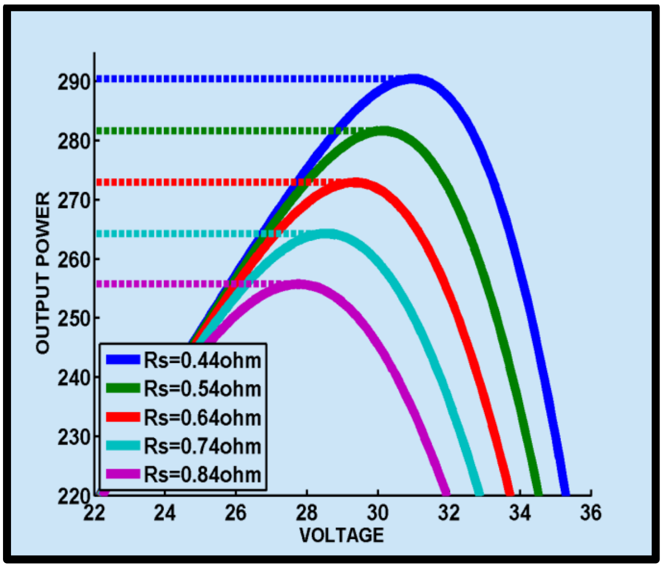

Fig -14: P-V Characteristics for Rs

Efficiency of solar cell by variation in series resistance is vary affected by it like as at 0.44 ohm efficiency is 96.8% but as it rise to 0.84 ohm efficiency decreased to 85.24% which clearly shows that performance of solar cell is vary affected by series resistance.

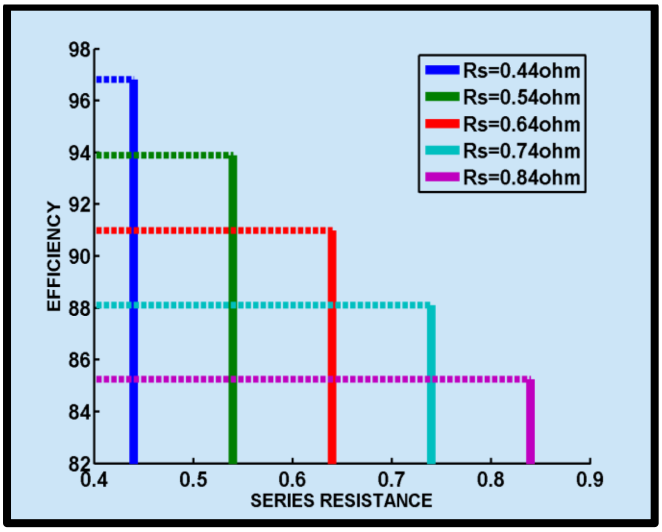

Fig -15: Efficiency for Rs

10. CONCLUSIONS

This paper presents the effect of different parameters (G, T, Ns, Np, Rs, Rp, a) on double diode simulation model with the use of efficient iterative method, comparison of different value is get by P-V characteristics and there efficiency. all the parameters set to constant while simulating one parameter.

On Changing irradiation (G) it is seen that as the irradiation raises the output power and efficiency also rises.

On Changing temperature (T) it is seen that as the temperature decrease the output power and efficiency rises or visa-versa.

On Changing ideality factor (a2) it is seen that as the ideality factor raises the output power also rises slightly while keeping other parameter constant.

On Changing no. of series cells (Ns) it is seen that as the no. of series cells raises the output power and efficiency rises because voltage rises.

On Changing no. of parallel cells (Np) it is seen that as the no. of parallel cells raises the output power and efficiency rises because current rises.

On Changing series resistance (Rs) it is seen that as the series resistance rises the output power and efficiency decreases while keeping other parameter constant.

On Changing shunt resistance (Rp) it is seen that as the shunt resistance rises the output power and efficiency rises to a constant value while keeping other parameter constant.

The main aim of this paper is to show the effects of these parameter on output power and efficiency in double diode model as discussed above it is seen that some parameters are responsible for decrease in power and efficiency such as temperature (T), ideality factor (a2) and series resistance (Rs) while some are responsible for increase in power and efficiency these parameters are no. of cells (Ns, Np), shunt resistance (Rp) and irradiance (G).

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