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Effects of Internal Resistance on the photovoltaic parameters of Solar Cells

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Abstract

Solar cells are promising devices for clean electric generation and have attracted intensive research. Like all other electrical power generators, solar cells possess internal series resistance(Rs) which affects significantly their power conversion efficiency(PCE). Moreover the simulation and design of solar cell systems also require an accurate knowledge of the series resistance and extracting the series resistance(Rs) , shunt resistance(Rsh) for solar cells is therefore of vital importance. Rs effects on the efficiency, I_{SC}, fill factor(FF).The internal series resistance(Rs) in the equivalent circuit model of the solar cell causes output voltage to reduce as the output current to increase and the shunt resistance(Rsh) causes internal power losses by diverting some of the created current away from the output path. With the aim of increasing conversion efficiencies the series internal resistance (Rs) is 0 ohm(short circuit) and shunt resistance(Rsh) of infinity(open circuit).This paper describes the optimized series& shunt resistance by matlab simulation.

Keywords: *Photovoltaic cell, Solar cell model, Matlab simulation, Fill factor, Maximum power point.*

1. Introduction

The research for the renewable energy has become an important topic in the 21^{st} century with the problem of energy crisis becoming more and more aggravated, resulting in increased exploitation and search for new energy resources such as wind, water, geothermal, and solar energy around the world [1]. Due to its inexhaustible and environmentally friendly energy, the research in solar energy has become an increasingly important topic in recent years [2]. Photovoltaic (PV) Solar Cells have been used for many decades. Today, with the focus on greener sources of power, Solar cell has become an important source of power for a wide range of applications. Besides assisting in the reduction of the emission of greenhouse gases, they add the much- needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels. Photovoltaic (PV) generation has many advantages such as cleanness maintenance-free, inexhaustible and noiselessness [3].

An accurate knowledge of solar cell parameters from experimental data is of vital importance for the design of solar cells and for the estimates of their performance. Thus, different solar cell models have been developing to describe their electrical behavior, but the electrical equivalent circuit is a convenient and common way in most simulation studies. The five parameters of interest in the equivalent circuit are the photo-current (I_{PV}), series resistance (R_S), diode saturation current (I_0), parallel resistance (R_{SH}) and the ideality factor (A). The current-voltage relationship of a solar cell is described by a mathematical equation that is both implicit and nonlinear, therefore; the evaluation of these parameters has been the subject of investigation of several authors. While some authors use numerical analysis methods to solve the implicit nonlinear equation of I-V relation [4-6], others use analytical methods with a series of simplifications and approximations [7-9].

In this work, we elaborate a MATLAB script file program, which uses to compute the five parameters of the single diode model of illuminated solar cells. The results obtained by simulation show the effect of internal resistances on the photovoltaic performances has been investigated and discussed. The consistency between the data and obtained the parameters given by the manufacturer, namely: short circuit current (I_{SC}), open circuit voltage (V_{OC}) and maximum power point (P_{mpp}).

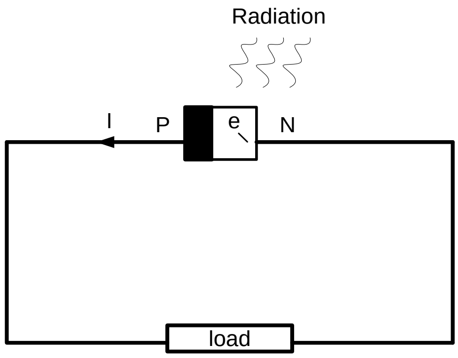

Fig. 1: Photocurrent generation principle.

2. Solar Cell Model

Figure 1 shows the p-n junction solar cells with photocurrent generation. Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor (usually silicon) [2].

A solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel [2, 10]. Considering only a single solar cell; it can be modeled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell [2,3,10]. Two diode models are also available but only single diode model is considered here in Fig. 2. It includes a current source, diode, a series resistance and a shunt resistance [5, 6].

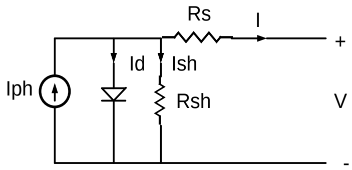

Fig. 2: solar cell equivalent circuit.

In view of that current to the load can be given as:

$$I = I_{ph} - I_o\left(\exp\left(\frac{q(V+IR_s)}{kT}\right)-1\right)-\frac{V+IR_s}{R_{sh}} \quad (1)$$

In this equation, Iph is the Photo current, Io is the reverse saturation current of the diode, k is the Boltzmann constant, T is junction temperature, N is the ideality factor of the diode, q is the electron charge, v is the voltage across the diode, R_s & R_{sh} series and shunt resistance of the cell respectively. Based on the eq. (1) the I-V & P-V curves of the solar cell are obtained by matlab simulation.

3. Shunt Resistance Effect

The shunt resistance of any PV cell should be large enough for higher output power and fill factor. In fact, for a low shunt resistor, the PV cell current collapses more, higher power loss and lower fill factor, from eq. (2) it is shown by matlab simulation as varying shunt resistance [11, 12].

$$I = I_{ph} - I_o\left(\exp\left(\frac{q(V)}{nkT}\right)-1\right)-\frac{V}{R_{sh}} \quad \textbf{(2)}$$

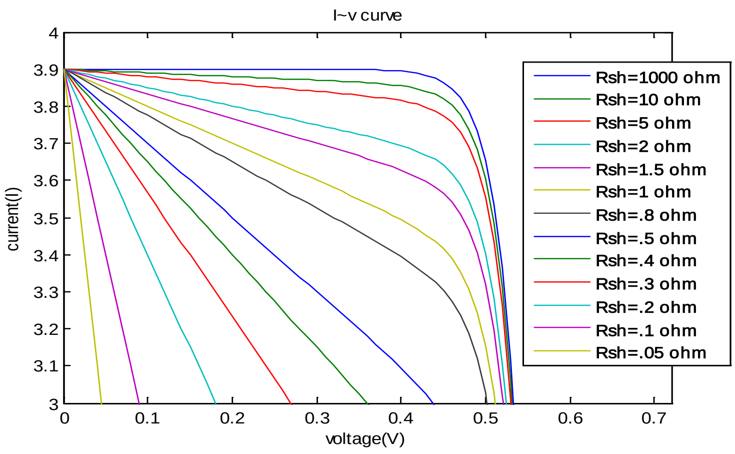

Fig. 3: I-V curves of at varying R_{sh}.

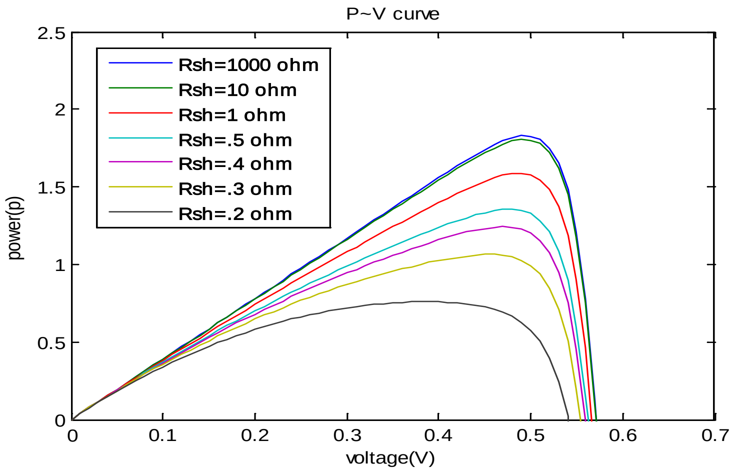

Fig. 4: P-V curves of at varying R_{sh}.

From Fig. 3 & Fig. 4 it is decided that the optimized shunt resistance is 1000 ohm for the solar cells.

4. Series Resistance Effect

With the increasing of the series resistance collapses the PV cell voltage, causes the higher power loss, lower fill factor and the cell efficiency. From the eq. (1) it is shown [10] that with the increasing the series resistance the above parameters are decreasing which is obtained in Fig. 5.

$$V = IR_s + \frac{kT}{q} log \frac{I + I_0 + I_L}{I_0} \qquad (3)$$

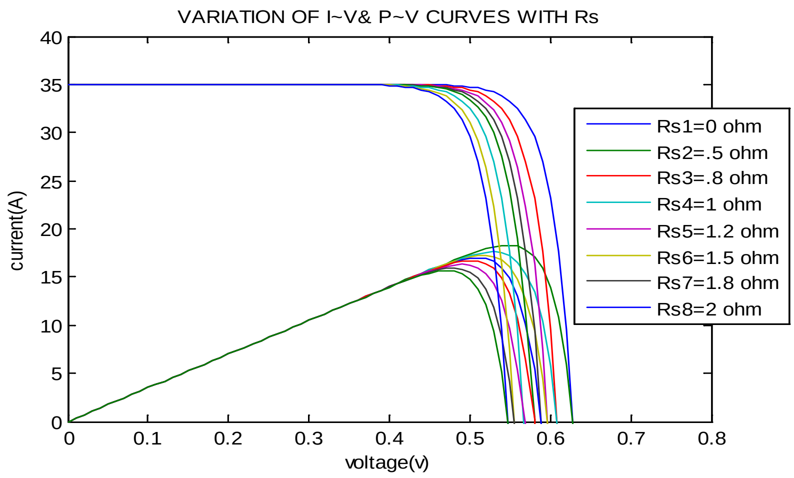

Fig. 5: I-V&P-V curves at varying Rs.

From the eq. (3) by varying load current I we can be obtained the **I-V&P-V** curves of solar cells at varying series resistance.

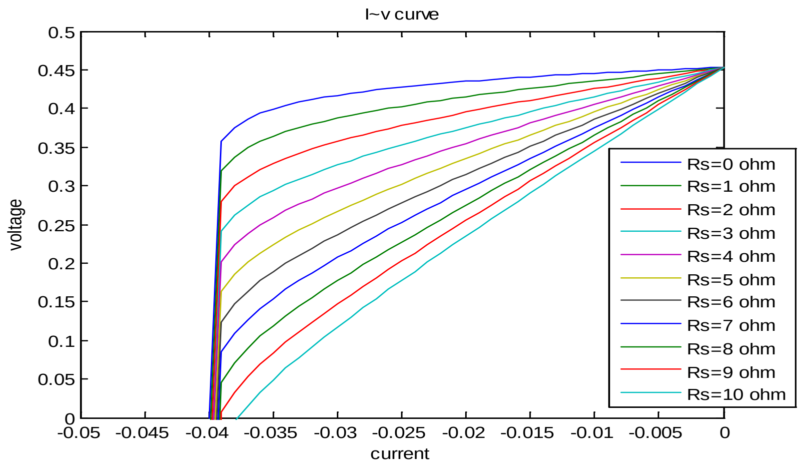

Fig. 6: V-I curves of at varying Rs.

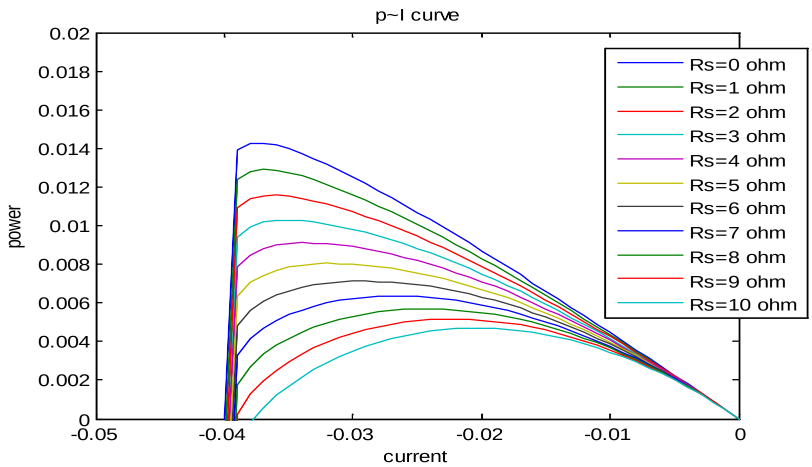

Fig. 7: V-P curves of at varying Rs.

From the Fig. 6, 7, and 8 the optimized series resistance is 1milli ohm by matlab simulation.

5. Coincide Optimized R_s& R_{sh}

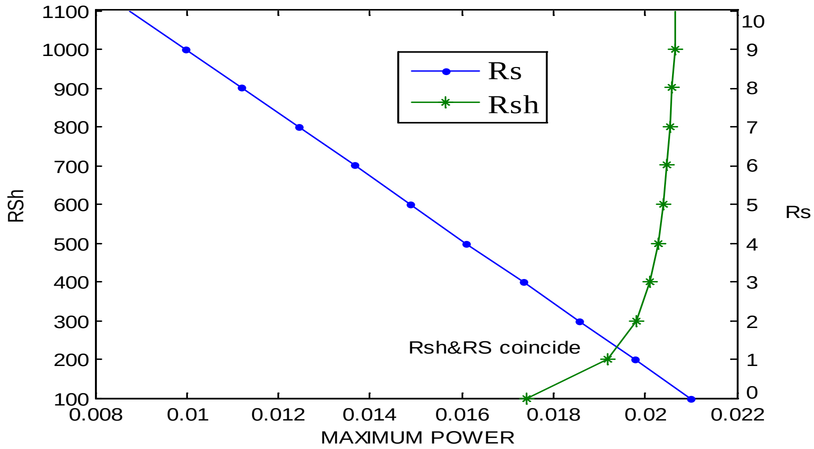

Fig. 8: optimized resistance at varied Pmax.

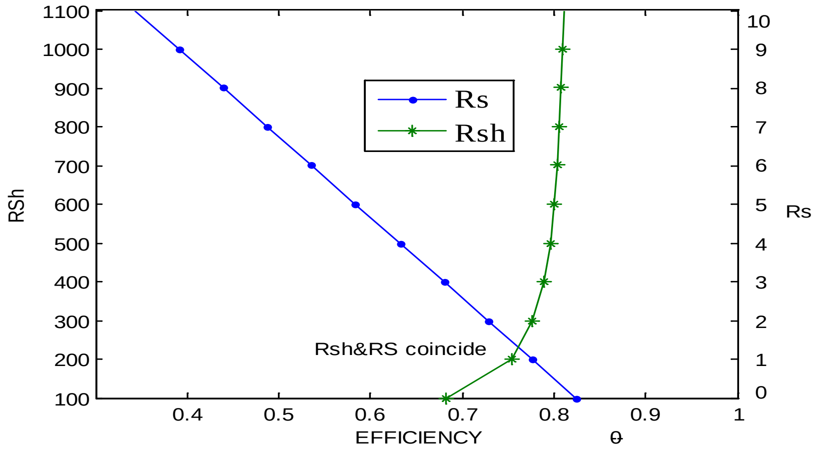

Fig. 9: optimized resistance at varied efficiency.

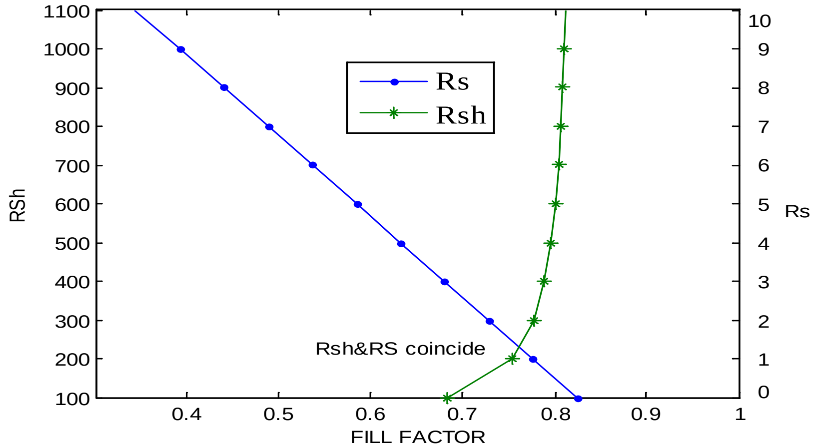

Fig. 10: Optimized resistance at varied fill factor.

From the Fig. 8,9,10 it is shown that with the increasing of series resistance fill factor, maximum power, efficiency decreases and with the increasing of shunt resistance those parameters increases and the optimized coincide series and shunt resistance is R_S=1.2 ohm& R_{sh}=240 ohm. Then optimized curves for the solar cell is obtained by matlab simulation.

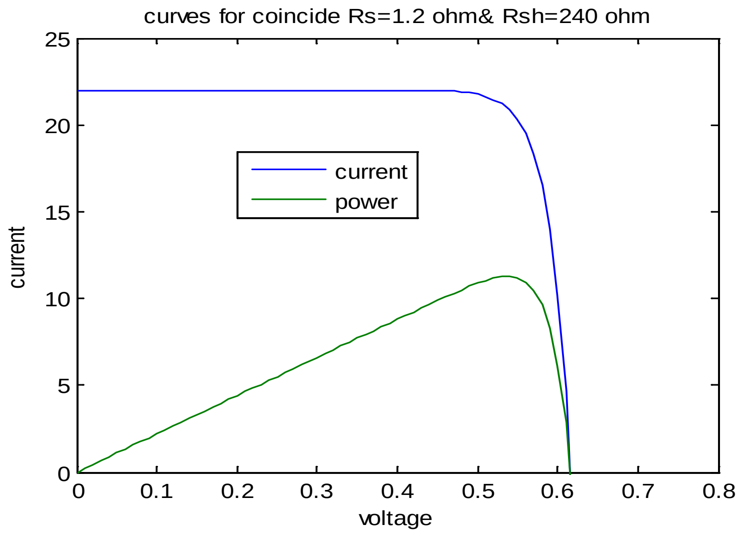

Fig11: I-V&P-V curves for optimized solar cell.

6. Conclusion

The effects of internal resistance of PV cells were investigated by using Matlab simulation program. The simulation of ideal photovoltaic solar cell shows how it is possible to increase the efficiency of solar cell in theory and electrical load will affect the performance of solar cell. It also shows how internal design of solar cell can affect the efficiency of solar cell, such as the internal series resistance& shunt resistance. To experimental characterization of the PV cells is a time consuming and costly task, so to overcome this problem Matlab simulation techniques are used to simulate the behavior of PV cells under different conditions. The fill factor mainly decreases with the value of series and shunt resistances, which in turns reduces the efficiency of PV cells. So the performance of PV cells is maximized by optimizing the value of series and shunt resistances. The optimized value of series and shunt resistances are 1.2 and 240 ohm, respectively.

7. References

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APPENDIX

Table 1. Solar cells parameters

NAME	SYMBOL	VALUE	UNIT
Reverse saturation	Io	$1x10^{-9}$	A
Electronic charge	q	$1.6x10^{-19}$	C
Series resistance	R_s	.001	Ω
Boltzmann constant	K	$1.3x10^{-23}$	J/K
Photo current	I_{ph}	4	A
Shunt resistance	R_{sh}	1000	Ω
Temperature	T	300	K
Voltage	v	0:0.01:0.6	volt

Table 2. Variation of FF & P_{max} with Rs

SERIS RESISTANCE	MAXIMUM POWER	FILL FACTOR
0 ohm	0.021	0.8274
1 ohm	0.0198	0.775
2 ohm	0.0186	0.7237
3 ohm	0.01733	0.6738
4 ohm	0.0161	0.6251
5 ohm	0.0149	0.5777
6 ohm	0.0137	0.5315
7 ohm	0.0124	0.4867
8 ohm	0.0112	0.443
9 ohm	0.00998	0.4006
10ohm	0.00875	0.3595

Table 3. Variation of FF & P_{max} with Rs

SHUNT RESISTANCE	MAXIMUM POWER	FILL FACTOR
100 ohm	0.0174	0.7065
200 ohm	0.0192	0.7669
300 ohm	0.0198	0.7871
400 ohm	0.020	0.7972
500 ohm	0.0203	0.8032
600 ohm	0.0204	0.8072
700 ohm	0.0205	0.8101
800 ohm	0.02055	0.8123
900 ohm	0.0206	0.814
1000 ohm	0.02064	0.8153
1100 ohm	0.02069	0.824