SELECTION OF SOLAR CELL ARRANGEMENTS FOR STREET LIGHTENING

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ABSTRACT

One of the primary need for development of country and mankind is consumption of energy in different forms. The most useful form of energy is the electrical energy. Development of power from renewable energy sources especially solar energy is one of the best method to achieve. Solar energy plays a vital role in feeding the needs of remote areas and one such basic requirement is street lightening. The paper focuses on simulation of two different models of solar cell and best model in terms of high efficiency is proposed for a standalone solar powered street lightening whereby no power is taken from grid.

Keywords: Fill Factor, Maximum Power Point, Simulink Models, Solar Cell

I. INTRODUCTION

Renewable energy sources are gaining more attention from last some decades and the research is still on its way. The energy consumption is increasing because of technological advancements and population growth. Renewable sources are the solution to match the requirements and to overcome the climate change problems due to fossil fuels [1]. The renewable energy sources are clean, abundant and environmental friendly. Solar energy, wind energy, geothermal energy, tidal energy, hydrogen energy and biomass are the renewable energy sources which are becoming popular by their advancements. Solar energy is one of the most adopted renewable energy source because of its reliability and availability. The sunlight is converted into electrical energy (DC) using photo-voltaic (PV) cells where photovoltaic effect takes place.

PV cells are made of semiconductor materials (P type and N type). If the energy of photon is more than the energy band gap then the electrons are emitted and flow of these electrons takes place through closed circuit. A number of PV modules are arranged in series and parallel to meet the energy requirements. Solar panels may be grid connected or off grid. Capacity of solar panels ranges from watts to megawatts. Stand-alone solar panels are mainly small scale systems used by individuals [2]. A solar cell has low voltage therefore more cells are connected in series to get sufficient amount of voltage. The efficiency of solar panels is dependent upon direct solar radiation and it can be achieved by adopting maximum power point tracking (MPPT) [3].

II. PV CELL MODELING

A PV array consists of several PV cells connected in series and parallel. It is a combination of various PV modules. Series connections results in increase in voltage whereas the current remains same and parallel connections results in increase in current whereas the voltage remains same in the array. A solar cell can be modeled by a current source and a diode connected parallel to it. It has series and parallel resistances [4]. Series resistance is due to blockings in the path of flow of electrons from n type junction to type p junction and parallel resistance is due to the leakage current.

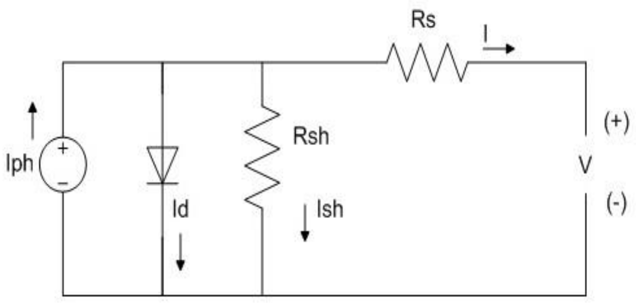

Fig. 1. Basic Model of PV Cell

Output current (I) from the PV array is given by equation (1)

$I = I_{SC} - I_d$ (1)

Where,

I_{SC} is the short-circuit current and is equal to photon generated current whereas I_d is current through diode. The diode current is given by equation (2)

$$I_d = I_O(e^{\frac{qV_d}{kT}} - 1) \quad (2)$$

Where,

I_O is the reverse saturation current of diode (A),

q is the charge of electron ($1.602*10^{-19}$ C),

V_d is the voltage across diode (V),

k is the Boltzmann's constant ($1.381*10^{-23}$ J/K),

T is the junction temperature in Kelvin (K)

From above equations (1) & (2) we get equation (3)

$$I = I_{SC} - I_O(e^{\frac{qV_d}{kT}} - 1) \quad (3)$$

For a constant temperature the reverse saturation current of diode (I_O) is constant.

After solving,

$$I_{SC} = I_O(e^{\frac{qV_d}{kT}} - 1) \quad (4)$$

The solar cells can be connected by increasing the number of cells in series or parallel based on the load requirement.

The specifications of PV Cell are as follows:

Energy band gap = 1.11 eV

Measurement temperature = 25 ^{0}C

Short circuit current (I_{SC}) = 7.34 A

Open circuit voltage (V_{OC}) = 0.6 V

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Irradiation = 1000 W/m^2

Quality factor = 1.5

III. SIMULATION OF SOLAR CELLS

Solar cells can be modeled in various combinations i.e. series and parallel combinations depending upon the currents and voltage desired. Different models of solar cells were tested and observed in Matlab/Simulink. The results are shown for 36 numbers of solar cells.

3.1. Case 1: It comprises of all the 36 solar cells connected in series. In this the current remains same but the voltage gets multiplied.

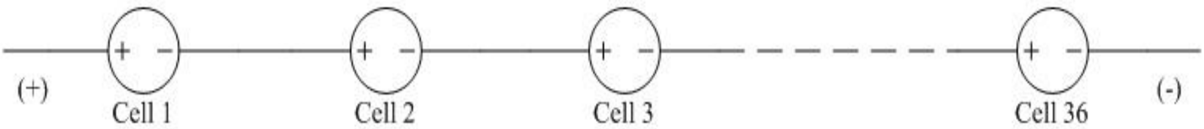

Fig.2. Connection for Cells in Series Combination

3.2. Case 2: It comprises of all the 36 solar cells connected in parallel. In this the voltage remains same but the current gets multiplied.

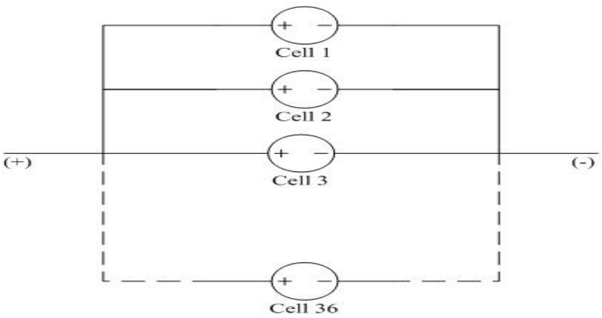

Fig.3. Connection for Cells in Parallel Combination

IV. RESULTS

Simulink model was tested for the irradiation of 1000 W/m^2 and ideality factor (n = 1.5). The I-V curves for all models are shown in Fig. 4.

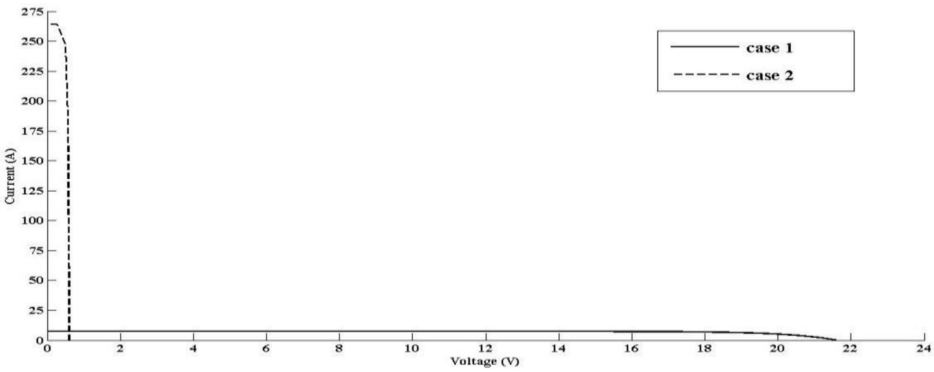

Fig.4. I-V Curves for Different Solar Cell Models

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The voltage is maximum and current is minimum for case 1 and the voltage is minimum and current is maximum for case 2. The P-V curves for all the models are shown in Fig. 5.

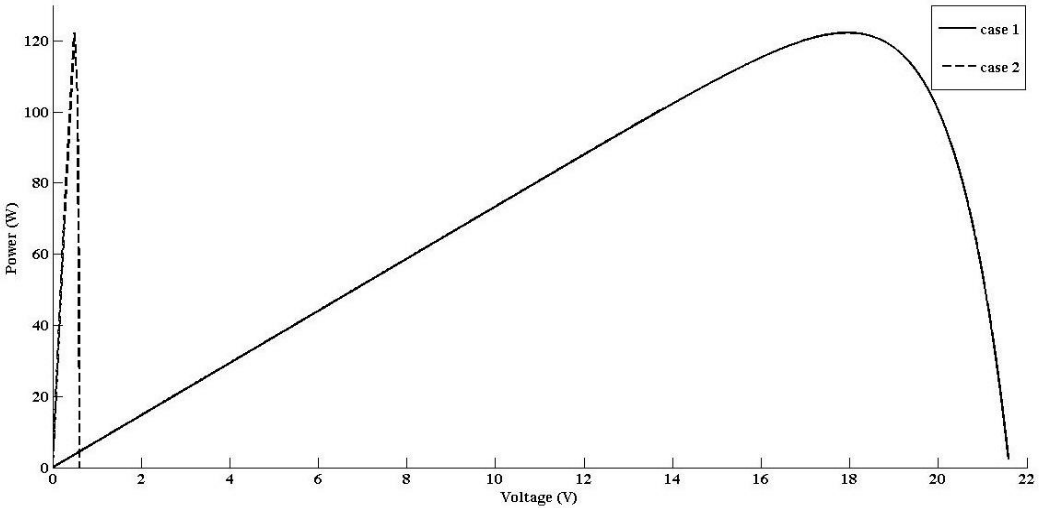

Fig.5. P-V Curves for Different Solar Cell Models

The maximum power is almost same for all the models but the value of voltages at which the maximum power is obtained, is different for different cases.

The fill factor of the solar power system is calculated by equation (5)

$$FF = \frac{P_{MPP}}{(V_{OC} \times I_{SC})} = \frac{(V_{MPP} \times I_{MPP})}{(V_{OC} \times I_{SC})} \qquad (5)$$

Where,

I_{SC} = Short circuit current (A)

V_{OC} = Open circuit voltage (V)

MPP = Maximum power point

I_{MPP} = Current at MPP (A)

V_{MPP} = Voltage at MPP (V)

P_{MPP} = Power at MPP (W)

FF = Fill Factor

Table1. Fill Factor for Different Cell Arrangements

Case	Case 1	Case 2
I_{SC} (A)	7.36	264.96
V_{OC} (V)	21.6	0.6
P_{MPP} (W)	122.5	122.5
FF (%)	77.056	77.056

The scope results of current, voltage and power for case 1 are shown in Fig. 6.

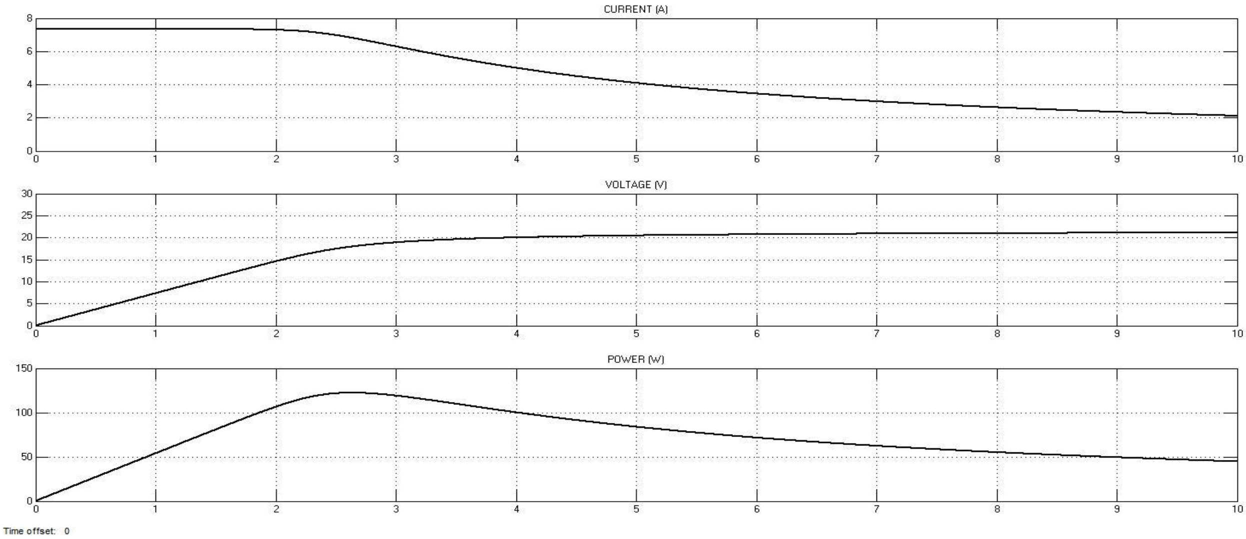

Fig.6. Scope Results Of Current, Voltage And Power For Series Combination Connection

V. CONCLUSION

The behavior of the models is analyzed using 36 solar cells. These cells are arranged in different combinations and their fill factors are obtained. The following observations can be made from the analysis of different solar cell arrangements:

1. The maximum power is same for both cases but voltage and current values differ from each other.
2. The value of fill factor is same for both the cases.
3. Value of current is very high for second case thus it leads to higher electrical losses.
4. The value of voltage in first case is very high compared to second case thus first case is preferable over second case.

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