ANALYSIS OF MATHEMATICAL MODEL OF PV MODULE USING MATLAB/SIMULINK ENVIRONMENT: REVIEW

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***Abstract*— Energy is required for large number of purposes. Traditional energy is used from coal, natural gas, oil and nuclear energy. But they are exhaustible and polluting. Conventional energy sources are unable to meet the increasing demand for energy worldwide. So, alternative energy sources like sunlight, wind and biomass come into picture. In that context, photovoltaic energy is a source of interesting energy; it is renewable, in exhaustible and non-polluting, and it is used as energy sources in various applications. This paper deals with the working of the PV cell. As well as the mathematically model of PV cell is also done. This paper also presents the design of the DC-DC Boost converter and PV module connected to the Boost converter. The models are simulated using MATLAB software.**

***IndexTerms*— Solar radiation, PV Cell, PV module, MATLAB/SIMULINK characteristic**

I. INTRODUCTION

The development of new energy sources is continuously enhanced because of the critical situation of the chemical industrial fuels such as oil, gas and others. Thus, the renewable energy sources have become a more important contributor to the total energy consumed in the world. In fact, the demand for solar energy has increased by 20% to 25% over the past 20 years. The market for PV systems is growing worldwide. Solar cells convert solar energy into electrical energy. This phenomenon occurs in materials which have the property of capture photon and emit electrons. The main material used in the photovoltaic industry is silicon. For the better understanding of the PV module the mathematical model is continuously updated. A photovoltaic (PV) system directly converts sunlight into electricity. The basic device of a PV system is the PV cell. Cells may be grouped to form panels or arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors. More sophisticated applications require electronic converters to process the electricity from the PV device. These converters may be used to regulate the voltage and current at the load, to control the power flow in grid-connected systems. The PV systems have the advantage of being maintenance and pollution-free but their installation cost is high and, in most applications; they require a power conditioner (DC/DC or DC/AC converter) for load interface. Since PV modules still have relatively low conversion efficiency. The overall system cost can be reduced using high efficiency power conditioners which, are designed to extract the maximum possible power from the PV module. The PV generators exhibit non-linear I-V characteristics. On the other hand, the optimum operating point changes with the solar irradiation, and cell temperature.
Photovoltaic (PV) is the name of a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon commonly studied in physics, photochemistry and electrochemistry. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. The process is both physical and chemical in nature, as the first step involves the photoelectric effect from which a second electrochemical process take place involving crystallized atoms being ionized in a series, generating an electric current.

II. PV CELL

PHOTOVOLTAIC CELL PRINCIPLE

With no pollutant emission, Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. Figure shows the photocurrent generation principle of PV cells. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one.

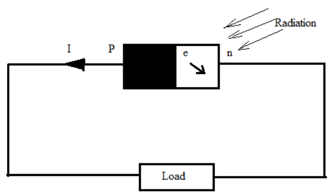

Fig 1: Photocurrent generation principle.

Typically, a PV cell generates a voltage around 0.5 to 0.8 volts depending on the semiconductor and the built-up technology. This voltage is low enough as it cannot be of use. Therefore, to get benefit from this technology, tens of PV cells (involving 36 to 72 cells) are connected in series to form a PV module. These modules can be interconnected in series and/or parallel to form a PV panel. In case these modules are connected in series, their voltages are added with the same current. Nevertheless, when they are connected in parallel, their currents are added while the voltage is the same.

MODEL OF PV CELL / MODULE

A PV module consists of number of solar cells connected in series and parallel as per the requirement. When solar light falls on PV cell, light energy is converted to electrical energy without any moving parts. The transmitted light is absorbed within the semiconductor, by using this light energy to excite the free electrons from the low energy status to an unoccupied higher energy level. These excess electron hole pairs contribute to the flow of current.

A photovoltaic cell/module is mathematically modeled using single diode equivalent circuit. The equivalent circuit of the general model which consists of a photon current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the flow of current is shown in Fig.

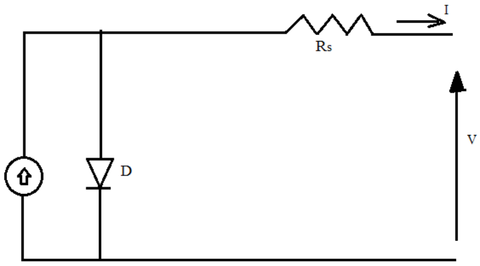

Fig 2: Solar cell model using single diode

The light generated current depends both on irradiance and temperature. It is measured at some reference conditions. Thus,

$$I_{ph} = \{I_{sc} + K_i * (T - 25)\} * \lambda \quad \dots\dots\dots\dots\dots (1)$$

According to Kirchhoff's current law, output current of an ideal cell is given by,

$$I_{cell} = I_{ph} - I_d \quad \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

The net cell output current (I_{cell}) is difference of the light generated current (I_{ph}) and the diode current (Id) which is expressed by Shockley diode equation.

$$I_d = I_s \left(e^{\frac{qv}{NKT}} - 1\right) \quad \dots\dots\dots\dots\dots\dots\dots (3)$$

For practical PV cell,

$$I_{cell} = I_{ph} - I_d - I_{sh} \quad \dots\dots\dots\dots\dots\dots (4)$$

Table 1 Parameter specification

Parameter	Specification
Power	250W
Identity constant	1.2
Energy Bandgap (Eg)	1.2
Temperature	25˚C
Shortcurcuit current temperature co-efficent	0.05
Irradiation	1000
Boltzmann's constant(K)	1.38×10^{-23} J/K
Charge of electron(q)	1.6×10^{-19} C/K
No. of series cell	60

$$I_{sh} = \frac{(V + I_{cell}R_s)}{R_{sh}} \quad \dots\dots\dots\dots\dots\dots\dots\dots (5)$$

$$I_{ph} = I_r * \frac{I_{sc}}{1000} \quad \dots\dots\dots\dots\dots (6)$$

The ideality constant is responsible for the various mechanisms for moving carriers across the junction. The parameter *N* is equal to 1 if the mobility process is purely diffusion and *N* is equal to 2 if it is primarily recombination in the depletion region. In this work *N* is taken as 1.2 and assumed to be related only to the material of the solar cell and independent of solar irradiation. A series resistance *Rs* is more dominant when the device operates in the voltage source region and depends on the contact resistance of the metal base with the *p* semiconductor layer, the resistance of the *p-n* bodies, the contact resistance of the *n*-layer with the top metal grid and the resistance of the metal grid. Shunt resistance representing the reverse leakage current of the diode. Rsh has stronger influence on the current source region of operation. To find value of reverse saturation current Is , considering open circuit condition Icell =0, and at short circuit condition Icell =Isc hence short circuit current *Isc* is equal to the light generated current Iph and is given by;

$$I_s = \frac{I_{sc}}{e^{\frac{V_{oc}}{NKT}} - 1} \quad \dots\dots\dots\dots\dots (7)$$

Series resistance (*Rs*) and shunt resistance (*Rsh*) minimum and maximum limits are calculated using

$$R_s < \frac{0.1 * V_{cc}}{I_{sc}} \quad \dots\dots\dots\dots\dots (8)$$

$$R_{sh} > \frac{10 * V_{cc}}{I_{sc}} \dots\dots\dots\dots\dots (9)$$

The PV module is typically composed of a number of PV cells in series. The generalized equation for a PV module connecting *Ns* number of cells in series can be written as,

$$V_t = \frac{NKT}{q} \quad \dots\dots\dots\dots\dots (10)$$

$$P = V * I \quad \dots\dots\dots\dots\dots (11)$$

Efficiency is the ratio between the maximum power and the incident light power. The efficiency of the module is given by

$$\eta = \frac{P_m}{EA_c} \quad \dots\dots\dots\dots\dots (12)$$

Fill factor is the ratio of the maximum power that can be delivered to the load and the product of Isc and V_{OC}

$$\text{Fill Factor (FF)} = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}}$$

Where;

Iph	=	light generated photon current
Is	=	cell saturation of dark current
T	=	Cell temperature in Celsius
K	=	Boltzmann's constant, 1.38 * 10-19 J/K
q	=	Charge of electron, 1.6 * 10-23 C
Ki	=	Short circuit current temperature coefficient at Isc
λ	=	Solar irradiation in Watts/m2
Isc	=	Short circuit current at 25º C
Eg	=	Band gap energy for silicon
A	=	Ideality factor Tnom Reference temperature in Celsius
Is	=	Cell saturation current at Tnom
Rsh	=	Shunt resistance in Ω
Rs	=	Series resistance in Ω

III. I-V AND P-V CHARACTERISTIC OF PV CELL

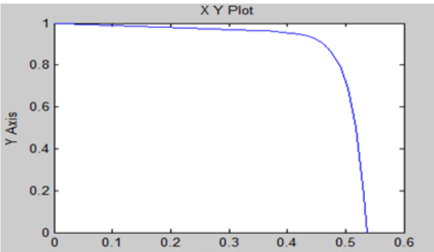

Fig 3: I-V characteristic of PV Cell

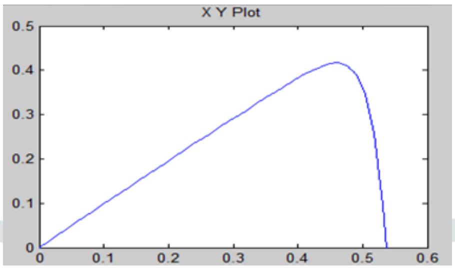

Fig: 4: P-V characteristic of PV Cell

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I-V AND P-V CHARACTERISTIC OF PV MODUL

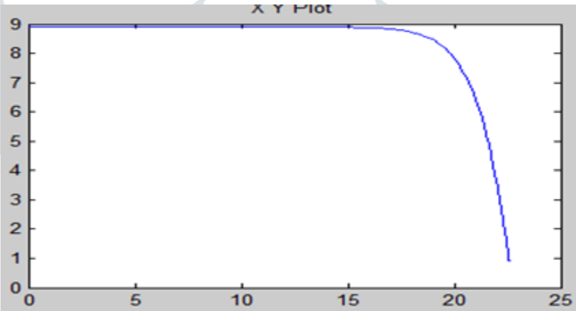

Fig 5: I-V characteristic of PV Module

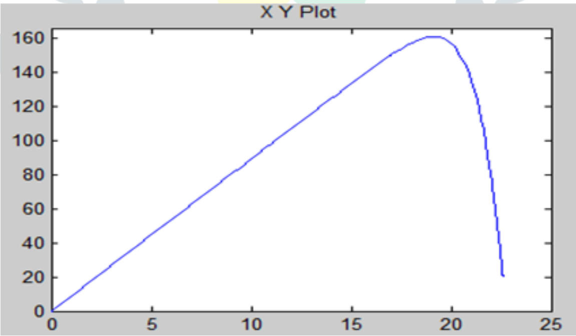

Fig 6: P-V characteristic of PV Module

IV. CONCLUSIONS

The model is shown above of PV cell, by using this cell we get around 0.5 volt. But such type of voltage is not enough for any use. That means this voltage is useless or meaning less. To get higher amount of voltage numbers of PV cells are connected in series or parallel. By connecting, 36 cells in series we get around 750 voltage. To boost up this voltage, converter is connected with this model in series. These both together are connected with the grid.

V. FUTURE WORK

For the future work this model will connect to the DC bus. Now this bus has different types of loads like AC or DC loads. Now to convert this voltage, converter and inverter are used. This whole system is connected to the grid. In this scenario, it is necessary to regulate the grid voltage and to control the load sharing between different sources. So, to regulate this voltage and load sharing between different sources voltage droop method is implemented. The main objective of this method is to regulate the grid voltage and load sharing between different sources. In this method, proportional and proportional-integral controllers are used to regulate the dc voltage of dc microgrid. The droop controller emulates an impedance behavior reducing the converter output voltage with the increase of the supplied current. This strategy promotes the current sharing between paralleled converters connected in dc microgrid without the need of a central control. A low-pass filter is used to reduce harmonic frequencies and fast oscillations of the dc bus voltage.

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