Efficient design of Integrated Grid Photovoltaic Module Solar Terminal for improved performance at different temperature conditions

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ABSTRACT* - In this paper a photovoltaic technology was studied for power injection in grid This model is based on mathematical equations and is described through an equivalent circuit including a photocurrent source, a diode, a series resistor and a shunt resistor.. This paper presents a statistical analysis on the effects of grid-connected photovoltaic (PV) systems in a solar system under different weather conditions .Initially data of a real life power plant having 24V, 230W Power PV module has been compared and analyzed with that of Mat-lab program output for identical module and it has been find out that a variation in temperature affects the parameters values as well as the performance of the solar module.. A grid connected PV system is modeled and simulated using Mat-lab/Simulink software to study the effect of this technology on the system under different levels of solar irradiation. The simulation results showed better performance by specifying variations in parameters such as voltage flicker, power factor.

KEYWORDS*- PV, Photovoltaic models, Photovoltaic power systems, solar radiation, maximum power point.*

I. INTRODUCTION

The word "photovoltaic" made up of two terms – "photo" means light and "voltaic" means voltage. A photovoltaic system is defined as a system which uses one or more solar panels to convert solar energy into electricity. It contains multiple components, including the Photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output .

(A) Photovoltaic Cell

Photovoltaic cell also known as solar cell is an electrical device used to capture radiation of sun and convert sunlight into electricity directly. The solar cells are made up of silicon. PV panel generates electricity under the phenomenon of photoelectric effect. It generates electricity using the semiconductor materials such as silicon by the photovoltaic effect. Basically it is a form of photoelectric cell and its electrical characteristics like current, voltage, or resistance vary when it is exposed to light. When light is incident upon it ,it can generate and support an electric current without being attached to any external voltage source, but it must have an external load for power consumption .[1][4]

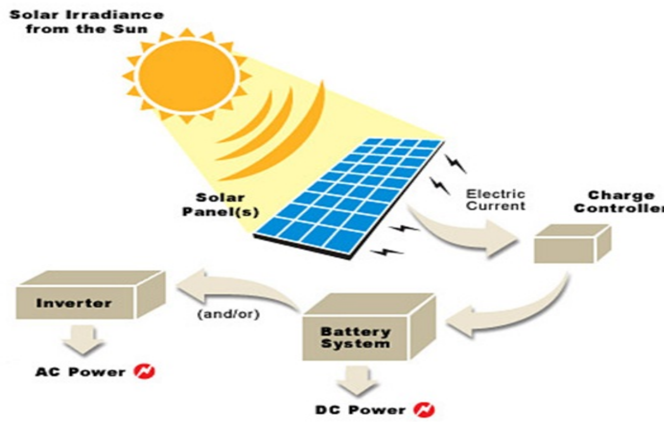

Figure.1 Photovoltaic cell

The operation of a photovoltaic (PV) cell is given as under:

1. The absorption of light by solar cell after it is exposed to sun generates electron-hole pairs.

2. The opposite charge carriers are being separated. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.

3. An array of solar cells converts solar energy into a usable amount OF DIRECT CURRENT (DC) electricity.

(B)Photovoltaic Effect:

When sunlight or irradiance hits the surface of solar PV cell, an electrical field is generated inside the cell. The generated electric field separates positive and negative charge carriers in an absorbing material (joining p-type and n-type). In the occurrence of an electric field, these charges can generate a current that can be used in an external circuit.[4]

The amount of generated current depends on the intensity of the incident radiation exposed on the semi-conductor. The more electrons can be unleashed from the surface as higher the level of light intensity and the more current is generated .

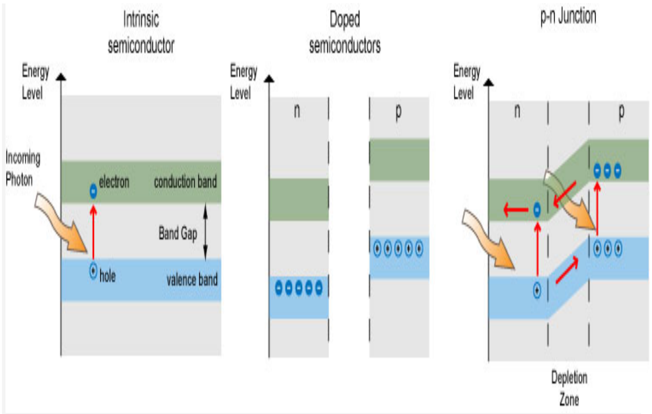

Figure 2.Structure of Solar power system

The solar cell works in three steps:

1. Sunlight in the form of photons hit the solar panel and is absorbed by semiconducting materials, such as silicon.
2. Negative charge i.e. electrons are excited from their current molecular/atomic orbital. Electron once excited can either dissipate the energy and return to its orbital or travel through the cell until it reaches an electrode. To cancel the potential Current starts flowing through the material and this electricity is captured in the external circuit through load. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
3. The electricity generated by a single solar cell is not sufficient so an array of solar cells is used that converts solar energy into a usable amount of direct current (DC) electricity. This electricity can then be used to power a load. A PV cell can either be circular or square in construction.[2][3]

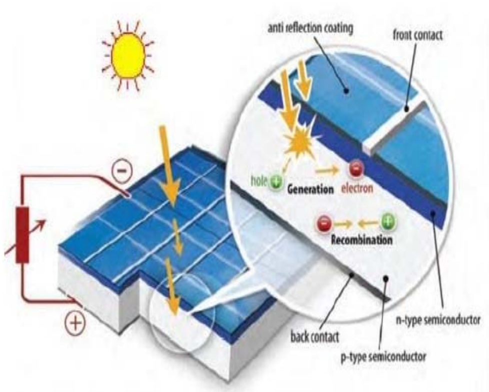

Figure3.Basic Structure of PV Cell

II. PHOTOVOLTAIC MODULE &ARRAY

An output voltage generated by a single PV cell is less than 1V, about 0.6V for crystalline silicon (Si) cells, thus a number of PV cells are connected in series to archive a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Silicon cells have either 36 or 72 series-connected cells. A photovoltaic module comprised of a number of interconnected solar cells encapsulated into a single unit. A solar panel is a lay down of solar photovoltaic modules electrically connected and assembled on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. To generate and supply electricity in commercial and residential applications the solar panel can be used as a component of a larger photovoltaic system. Solar modules use light energy in the form of photons from the sun to generate electricity through the effect. Electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability Voltage provided by a 36-cell module is suitable for charging a 12V battery, and similarly voltage provided by a 72-cell module is appropriate for a 24V battery [4].

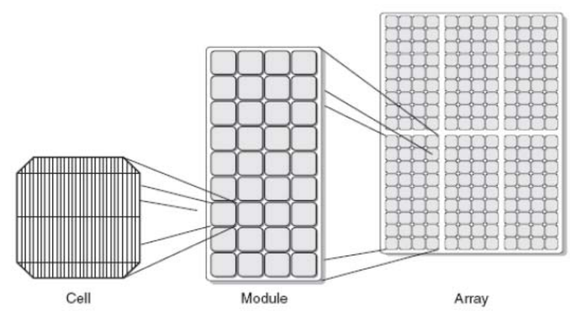

Figure4. Photovoltaic array

Due to the power that one module can produce is not sufficient to meet the requirements of home or business so Photovoltaic Array is being used. A photovoltaic array also known as a solar array comprises of multiple photovoltaic modules generally referred as solar panels, to convert solar radiation (sunlight) into usable direct current (DC) electricity. A Photovoltaic array consists of number of solar cells wired in series and in parallel connections. A photovoltaic system used in residential, commercial, or industries to supply energy normally contains an array of photovoltaic (PV) modules because energy produced by single solar unit is not enough to meet the requirements. The electricity produced by solar cells is Direct Current so one or more DC to alternating current (AC) power converters also known as inverters are used. A number of other components like racking system that supports the solar modules, electrical wiring and interconnections, and mounting for other components are being used .

A small PV system is capable to produce sufficient AC electricity to power a single home, or even an isolated device in the form of AC or DC electric. For example, military and civilian Earth observation satellites, street lights, construction and traffic signs, electric cars, solar-powered tents and electric aircraft may contain integrated photovoltaic systems to provide a primary or auxiliary power source in the form of AC or DC power depending on the design and power demands. Large grid-connected photovoltaic power systems are capable of providing an energy supply for multiple consumers .

III. MATHEMATICAL INTERPRETATION OF PV CELL

A photovoltaic module made up of a number of interconnected solar cells assembled into a single unit. In order to forecast the power extracted from the solar modules and the module current-voltage (I-V) characteristics, it is significant to model the solar cell. Once the I-V characteristics of a single solar cell are determined using the model, one must then develop that model to determine the behavior of a PV array or module. A Photovoltaic array consists of many solar cells wired in series and in paralleled. A solar cell model is shown in Fig.9. when the radiation and temperature changes the model takes into consideration the variation of the photoelectric current and also takes into account the variation of the diode saturation current when the temperature changes. In this, generated photoelectric current is represented by the current generator I_L while the diode and the resistance Rs, which takes into account the internal electrical losses, model the photovoltaic module .[4][10]

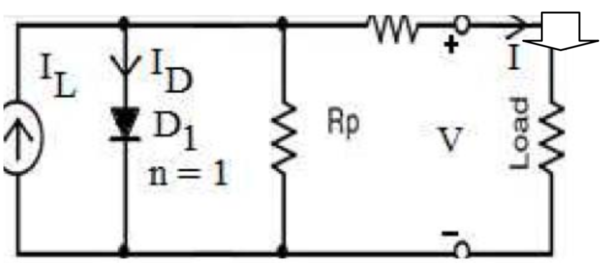

Figure5. Equivalent circuit of photoelectric module

- I = output current (ampere)
- I_L = photo-generated current (ampere)
- I_D = diode current (ampere)
- I_{SH} = shunt current (ampere).

By applying the Kirchhoff law to the node of the circuit reported in Fig. 1, the current 'I' produced by the photovoltaic module is obtained as:

$$I = I_L - I_D - I_{SH} \quad (1)$$

The I_D diode current is given the Shockley diode equation is:

$$I_D = I_0 \left\{ \exp\left[\frac{qV_j}{nkT}\right] - 1 \right\} \quad (2)$$

Where

- I_0 = reverse saturation current (ampere)
- n = diode ideality factor (1 for an ideal diode)
- q = elementary charge , (1.602*10-19C)
- k = Boltzmann's constant, (1.381*10-23K)
- T = absolute temperature

By substituting (2) in (1), the following equation is obtained, which represents the I-V module characteristics curve under generic radiation and temperature conditions.

$$I = I_L - I_0 \{\exp [qV_j/nkT] - 1\} \quad (3)$$

At 25°C,

$$kT/q \approx 0.0259 \text{volt.}$$

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_j}{R_{SH}} \quad (4)$$

Where R_{SH} = shunt resistance (Ω). The current through these elements is governed by the voltage across them:

$$V_j = V + IR_S \quad (5)$$

Where

- V_j = voltage across both diode and resistor R_{SH} (volt)
- V = voltage across the output terminals (volt)
- I = output current (ampere)
- R_S = series resistance (Ω)

Substituting these into the first equation produces the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I = I_L - I_0 \left\{ \exp\left[\frac{q(V + IR_S)}{nkT}\right] - 1 \right\} - \frac{V + IR_S}{R_{SH}}. \quad (5)$$

The model proposed in equation (3) describes the working of a photovoltaic module under the hypothesis of knowing the values of n, Vj, Io and IL.

$$I = I_{0,Ref}\left(\frac{Tc}{Ta,Ref}\right)^{3}\exp\left[\left(\frac{qEg}{Kv}\right)\left(\frac{1}{Ta,Ref} - \frac{1}{Tc}\right)\right] \quad (6)$$

$$I = \left(\frac{G}{GRef}\right)[I,Ref + \mu Isc(Tc - TRef)] \quad (7)$$

IV. RESULTS AND DISCUSSION

The simulink modal implemented for single phase power grid connected PV system with MPPT working at different temperature conditions .Here the solar cell is represented by a block includes the controlled current source with resistance in series. The MPPT and gating signal generator are shown in a single unit called 'MPPT '. The 'I Generator' is basically the photo –generated current that is given as input to the single diode model of the cell. Other elements of the model constitute the boost converter. This boost converter with inductance of 0.01H and capacitance of 2e-3F is used to step up the voltage to the required value. The gating signal to the boost converter is generated by comparing the signal generated by the MPPT algorithm to a repeating sequence operating at a high frequency. Universal bridge with PWM is regarded as the dc–ac power conversion circuit to meet the requirement of grid connection. Discrete PWM generator is used to generate pulses for carrier based PWM control.

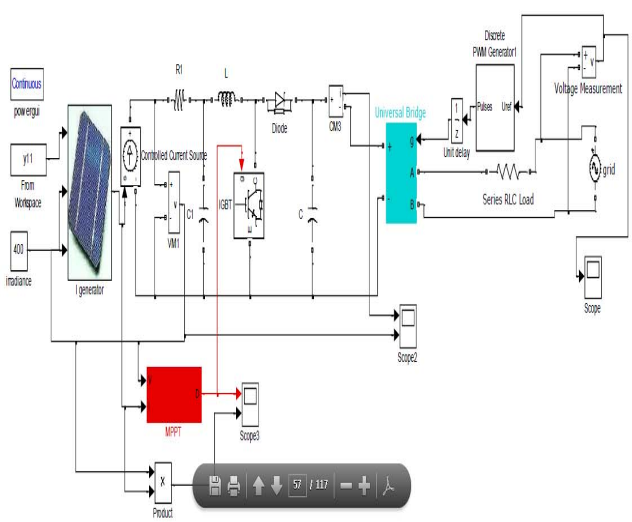

Fig 6 Simulink model PV

The simulations were carried out in Simulink and the various voltages, currents and power plots were obtained.

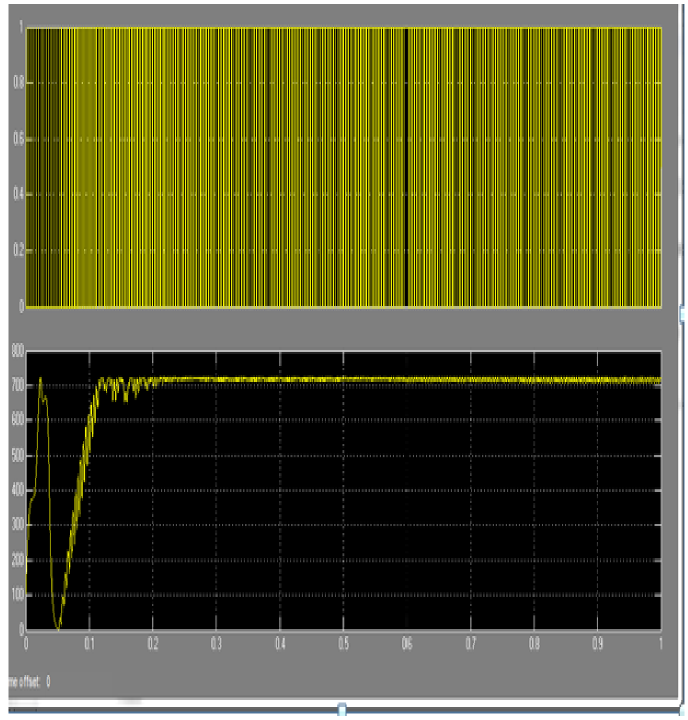

Fig 6.1 Duty cycle for converter & power output of PV

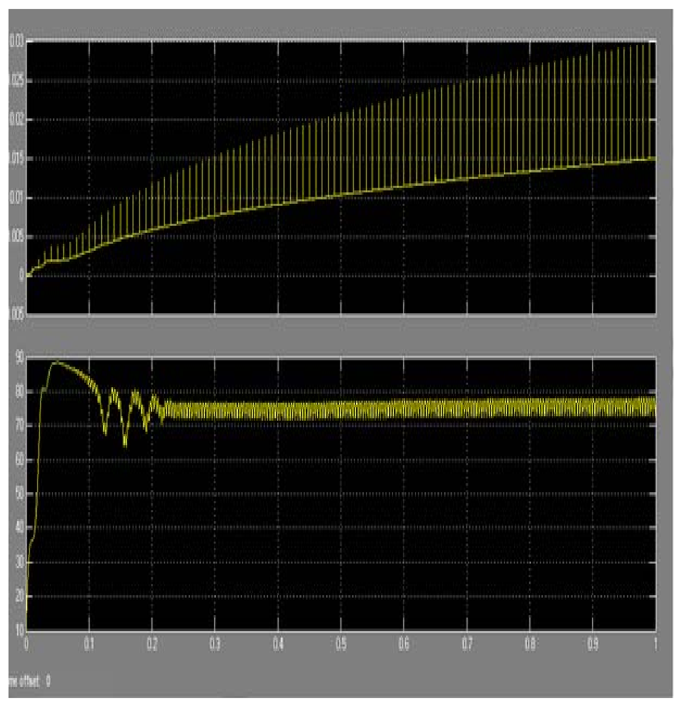

Fig 6.2 Current output of converter & voltage output of PV

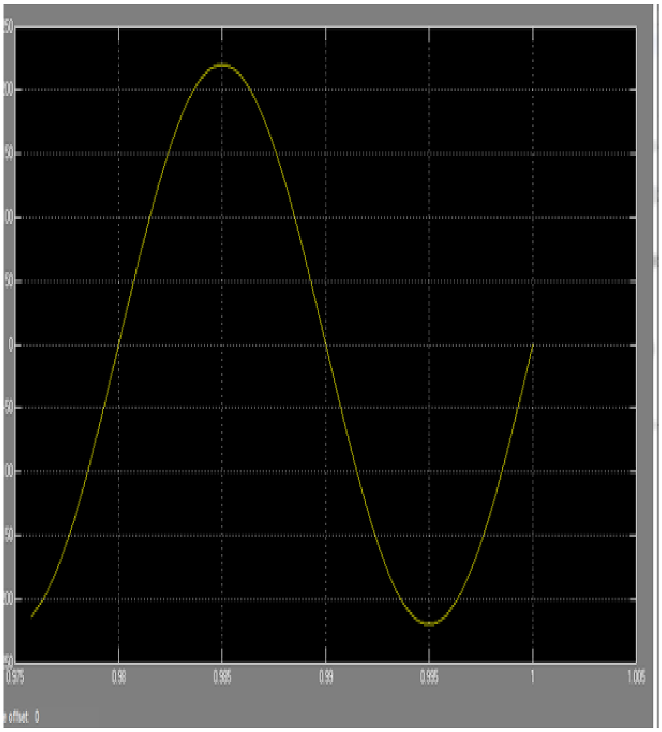

Fig.6.3 Voltage output at the point of coupling of grid and PV inverter

From the fig 6.1 we can see that a fixed duty cycle has been obtained for the gating signal of boost converter by using the MPPT thereby even the system is operating at different temperature conditions, the power output of pv is almost constant and it is around 700 watt . Fig 6.2 shows the almost constant output voltage of pv that is around 77v. The given pv cell Voc (open circuit voltage) was 66 v and Vm (measuring voltage) was 54.2 V It also shows the current variation of boost converter.From the fig.6.3, we can see that even in different temperature conditions of the system, at the point of coupling of PV inverter and grid, the output of the inverter of pv system is in synchronous with that of output of ac grid given as 220 V,50 Hz frequency

CONCLUSION

In this paper modeling for power grid connected PV system has been done and simulations were implemented. For this simulink modal, a PV cell was designed based on the characteristics equations of mathematical model of pv cell. As the output of pv cell is very low, a boost converter has been added to the system. The frequency of operation was set by using a repeating sequence generator. This generator was utilized for generating the pulse signal that was compared with the signal generated from the MPPT unit to give out the gating signal to the switch of boost converter. The output of converter was converted to ac by inverter and a series load was used with the inverter thereby making the output of pv system synchronized with that of ac grid. To take into account the different temperature conditions for this model, the MATLAB CODE has been written. Various simulation output were obtained and it has been find out that there is a small loss of power from the solar panel side to the boost converter output side. This can attributed to the switching losses and the losses in the inductor and capacitor of the boost Converter.

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