

# SIMULATION OF GRID CONNECTED PHOTOVOLTAIC POWER GENERATION BASED ON PSCAD/EMTDC

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**Abstract:** This paper is about the investigation of a simulation model grid-connected photovoltaic power generation based on PSCAD/EMTDC software. MPPT (maximum power point tracking) implemented by Incremental conductance algorithm to track the maximum power point. A simulation model of PV array model is developed. DC-DC Boost converter is employed to increase the maximum power and controlled by MPPT strategy. A Voltage Source Converter (VSC) is employed to transform the direct current to alternating current. The output of the VSC is supplied to the grid. The simulation results show the quick variations in the maximum power with the strength of the solar irradiation.

**IndexTerms** -PV Array, MPPT (Maximum Power Point Tracking), DC-DC Converter, Voltage source converter (VSC), Power Systems Computer Aided Design (PSCAD).

## I. INTRODUCTION

The raise in the world residents and industrial movements happens to consume more energy. Most of the polluted gasses are ejected to the environment due to the utilization of the fossil fuels for fulfillment of load requirement. Nowadays renewable energy generation became an attractive power sources but most of the people use the PV generation because of their cleanness and high capability [1]. As the significant nature of photovoltaic cells, the optimization design of the total arrangement is very important in the photovoltaic power generation system.

The fabrication process of solar PV is simple. It does not need any moving parts. Due to the rigid nature of Photovoltaic's have the long lifespan. To expand PV system electrical output, the operator just adds extra photovoltaic elements and because of these economies of scale is essential for companies as prices reduce by raising output. Photovoltaic's' study and improvement will proceed great investment in new elements, cell patterns, and novel methods of solar stock and goods improvement. It is tomorrow wherever the garments you use and your mode of moving can create energy that is reliable and secure.

The potential of solar power in the Southwest United States is similar in range to the hydropower resource of the Northwest. A barrens area 10 miles by 15 miles could produce 20,000 megawatts of energy, while the electricity demands of the whole United States could probably meet with a photovoltaic arrangement within a region 100 miles on a side. Analyzing solar power, or solar thermal could limit the sun's radiation to give domestically safe, large-scale and environmentally favorable electricity.

The PV module produces the volatile power for a constant input condition of cell temperature and solar radiation level. In addition, the PV module output power is taken as a function of electrical variables such as current and voltage. At a specific level of isolation, temperature and load maximum power from the PV module is required. Therefore, a maximum power point tracker (MPPT) is used for continuous maximum power [2]. A boost converter is an electronic device that can increase the output of the PV array and change the raw electric output power to usable power.

In this paper, solar PV generator connected through the boost converter produces the maximum power with the help of MPPT strategy. There commended model was simulated with the various irradiations through PSCAD/EMTDC software and results are plotted.

2. Block diagram Representation

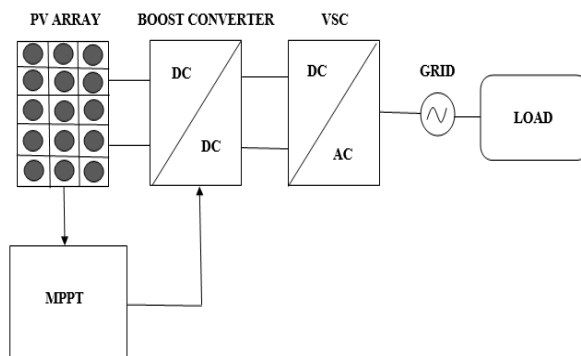


Fig 1: Block Diagram Representation of the system

3. Modeling of the system

3.1 Designing of PV array:

PV array is the combination of cells connected in series and parallel. Fig2 shows the simple equivalent circuit of the PV cell [3].

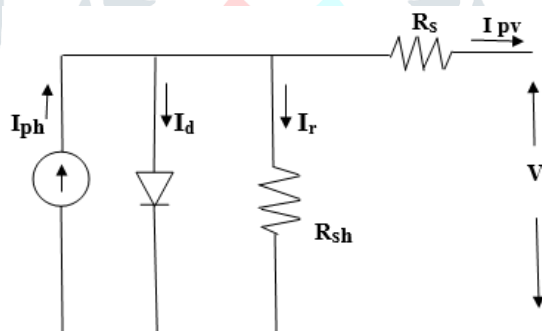


Fig 2: Equivalent circuit of PV cell

Current flowing through the PV cell can be represented by the equation

$$I_{pv} = I_{ph} - I_D = I_{ph} - I_0 \left( \exp \left( \frac{q(V + R_s I)}{mKT} \right) - 1 \right)$$

The photo current of the solar array is depending on the irradiation and temperature. As we discussed PV array is the combination of series, parallel cells then the above equation can be changed as

$$I_{pv} = N_p I_{ph} - N_p I_0 \left( \exp \left( \frac{q \left( V_{pv} + R_s I_{pv} \frac{N_s}{N_p} \right)}{mKT} \right) - 1 \right)$$

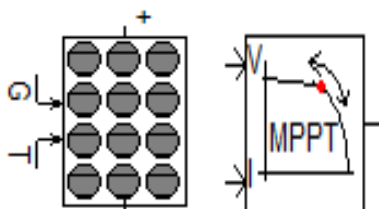
Where:

$V_{pv}$  and  $I_{pv}$  are the voltage and current of the array respectively;

$N_p$ = No of cells connected in parallel;

$N_s$ =No of cells connected in series.

In PSCAD/EMTDC software PV array model is directly available in master library. Users have to give the values of irradiation and temperature. According to power and voltage requirements the combination of the series, parallel cells of the photovoltaic module can be defined.



**Fig 3: PSCAD library models of PV array and MPPT**

Fig 4 represents PV array connected to resistance, to exhibit the characteristics of the PV array. There is a change in the current and terminal voltage of the PV array with the variation of the irradiation.

No of modules connected in series per array	22
No of module strings connected in parallel per array	250
No of cell strings connected in parallel	1
No of cells connected in parallel module	36
Reference irradiation	1000
Reference temperature	25

**Table 1: Reference values for PV array**

V-I and P-V characteristics can be obtained and shown in fig 5 V-I characteristics are obtained by plotting the voltage in the x-axis- V characteristics are obtained by plotting the current in the y-axis.

Effective area per cell	0.01
Series resistance per cell	0.02
Shunt resistance per cell	1000
Diode factor	1.5
Band gap energy	1.103
Saturation current at reference conditions per cell	1e-12[kA]
Short circuit current at reference condition per cell	0.0025[kA]
Temperature coefficient of photo current	0.001

**Table 2: Reference values for PV cell**

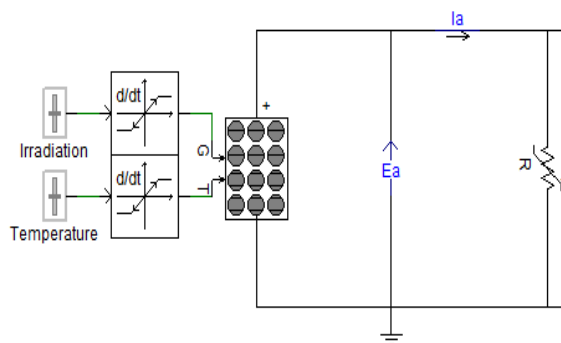


Fig 4: PV array connected to resistance

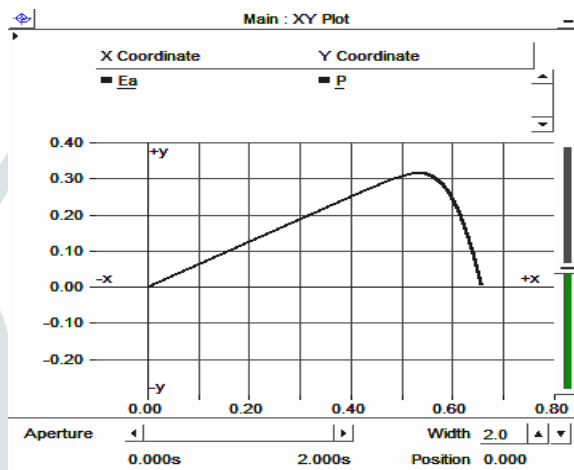


Fig 5(a): P-V characteristics of PV array at  $1000 \text{ w/m}^2$

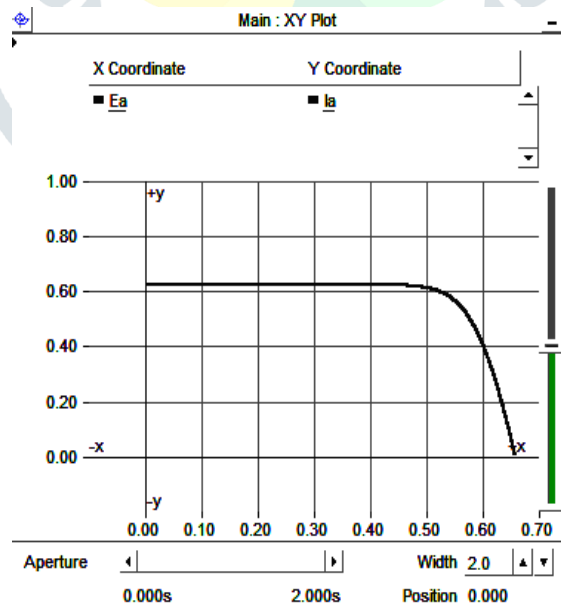


Fig 5(b): V-I characteristics of PV array at  $1000 \text{ w/m}^2$

Irradiation	At 1000 w/m <sup>2</sup>	At 800 w/m <sup>2</sup>	At 500w/m <sup>2</sup>
Voltage(kV)	0.659	0.652	0.63
Current(kA)	0.62	0.50	0.31
Power (MW)	0.31	0.25	0.15

**Table 3: Irradiation table for different values**

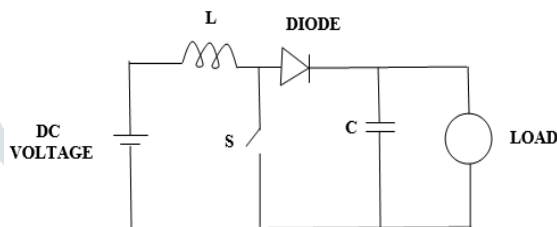
With decrease of irradiation value, all the factors such as voltage, current and power decreases and vice versa.

**3.2 Boost Converter;**

Boost converter is the main scheme in solar power design. DC-DC boost converter operates some significant role as given below [4]

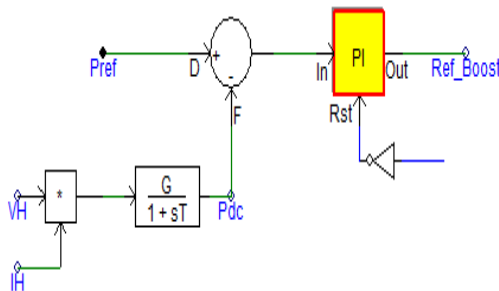
1. To change the variable input dc voltage into fixed output dc voltage.
2. To decrease the quantity of voltage ripple in the output voltage.
3. To control and sustain the dc output voltage opposes the changes in load and line.
4. To discrete the input source and the load.

The dc link voltage and the inverter output can be change by varying the input constraints. The voltage across the dc link should remain constant for having controlled arrangement and better result at output side. The input side can be regulatory scheme is done by PI controller in input side by modify the value of controller to maintain the dc link constant throughout the process.



**Fig 6: Basic Diagram of DC-DC Boost converter**

When the voltage at the input side is not sufficient then the value of output voltage is increased to the certain required level. For this purpose, boost converters are used having converter has an inductor, a switch (usually IGBT or MOSFET), diode and a capacitor. Low pass filter connected at the input side of the boost converter. Boost converter can be controlled by MPPT strategy.



**Fig 7: Power Conversion Diagram of Boost converter**

In fig 7 the reference power is matched with the DC link power (P<sub>dc</sub>) and the fault signal is communicated to a PI controller to determine the boost converter duty cycle. PI controller coefficients and its output boundaries altered by managing control panel.

From high currents, the boost converter can be protected by adjusting the reference power to maximum power. If the reference power is less than maximum power, then switch is in ON position and enables the boost and fed to PI controller.

### 3.3 Maximum Power Point Tracking

MPPT have so many techniques, among all P&O (perturb & Observe), and INC (incremental conductance method) are mostly used techniques. In PSCAD software only these two techniques are available. P&O technique can be failed under rapid changing atmospheric conditions due to this Incremental conductance method is chosen. Flow chart for (incremental conductance algorithm is given below [5].

The incremental conductance procedure [6] is based on the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by

$$dP/dV = 0 \quad \text{At MPP}$$

$$dP/dV > 0 \quad \text{Left of MPP}$$

$$dP/dV < 0 \quad \text{Right of MPP}$$

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + \frac{VdI}{dV} = \sim I + V \frac{\Delta I}{\Delta V}$$

Then the above equations are written by

$$\Delta I/\Delta V = -I/V \quad \text{At MPP}$$

$$\Delta I/\Delta V = -I/V \quad \text{Left of MPP}$$

$$\Delta I/\Delta V = -I/V \quad \text{Right of MPP}$$

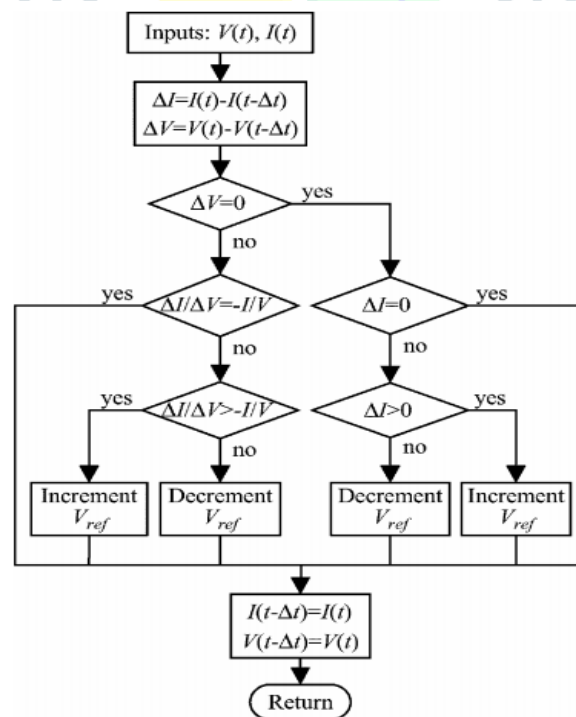


Fig 8: MPPT Incremental Conductance Algorithm

The Maximum Power Point can track by compare the instantaneous conductance ( $I/V$ ) to the incremental conductance ( $\Delta I/\Delta V$ ) as given in the flowchart in Fig. 8.  $V_{ref}$  is the reference voltage of PV array. At the MPP,  $V_{ref}$  equals to  $V_{MPP}$ . Once the MPP is attain, the process of the PV array is continuing at this point if not a change in  $\Delta I$  is noted, representing a modification in atmospheric circumstances and the Maximum Power Point. The algorithm decrements or increments  $V_{ref}$  to track the new MPP. In PSCAD software maximum power point tracking component is directly available so easily connected to the main system. The controlling loop for maximum MPPT is given below.

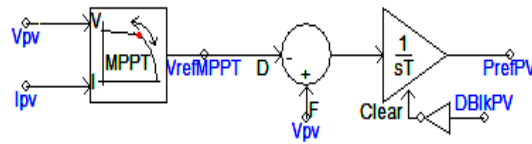


Fig 9: MPPT controlling loop

### 3.4 Voltage Source Converter;

In a Voltage Source Converter direct current flows in one or two ways of direction but converter valves have bidirectional, so the dc voltage does not change. Generally, the asymmetrical turn off devices used in the voltage source converter such as IGBT, GTO, and IGCT etc. [7].

Voltage sourced converters in which the dc voltage always has one polarity, and the power reversal takes place through reversal of dc current polarity. IGBT has a parallel reverse diode built in as part of a fully integrated device perfectly suitable for voltage source converter. Voltage source converter consider as 6-pulse IGBT based VSC.

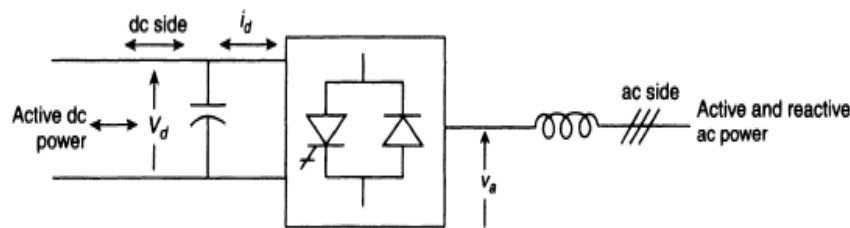


Fig 10: Basic voltage source converter diagram

The basic operation of a voltage-sourced converter is as shown in Fig 10. The internal topology of converter valves is represented as a box with a valve representation inside. On the dc side, voltage is unipolar and is supported by a capacitor. These capacitors huge enough to at least handle a continued charge/discharge current that accompanies the switching progression of the converter valves and shifts in phase angle of the switching without significant change in the dc voltage. For the purpose of discussion, the dc capacitor voltage will be assumed as stable. It is also shown on the dc side that the de current can flow in either direction and that it can exchange power with the connected de system in either direction. Shown on the ac side is the generated ac voltage connected to the ac system via an inductor [8].

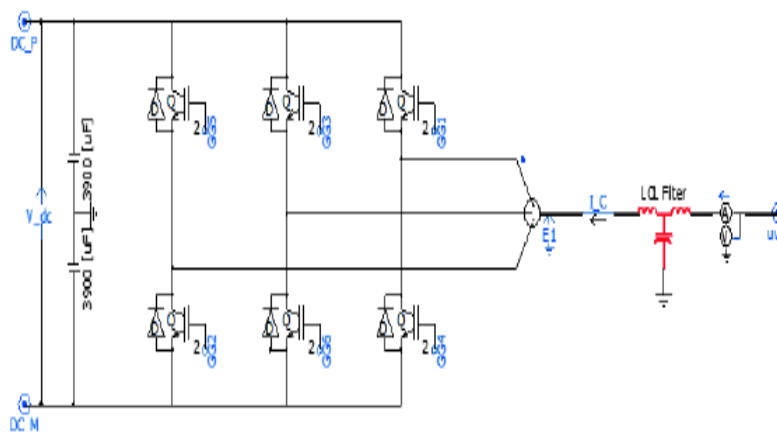
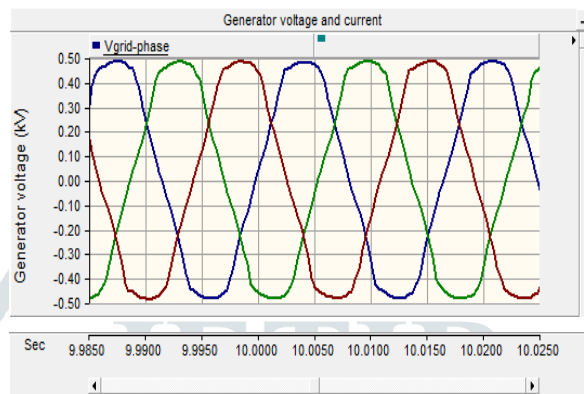


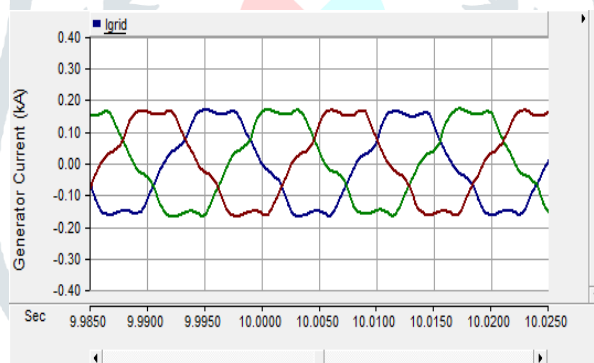
Fig 11: 6-pulse IGBT based VSC implemented by PSCAD

Being an ac voltage source with low internal impedance, a series inductive interface with the ac system (usually through a series inductor and/or a transformer) is essential to ensure that the de capacitor is not short-circuited and discharged rapidly into a capacitive load such as a transmission line. Also, an ac filter may be necessary (not shown) following the series inductive interface to limit the consequent current harmonics entering the system side. Basically, a voltage-sourced converter generates ac voltage from a de voltage. It is, for historical reasons, often referred to as an inverter, even though it has the capability to transfer power in either direction. With a voltage-sourced converter, the magnitude, the phase angle and the frequency of the output voltage can be controlled.

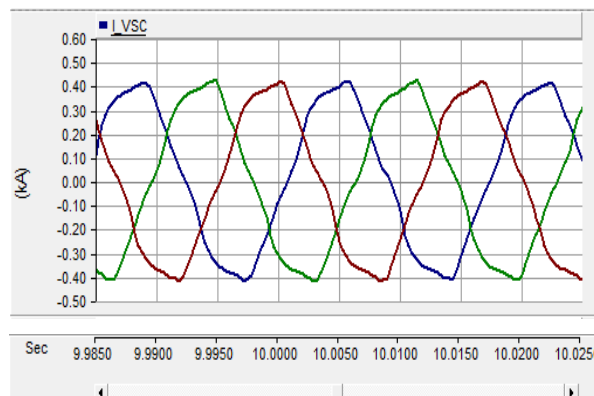
**4. Simulation Results:**



**Fig 12: Grid voltage wave form**



**Fig 13: Grid current**



**Fig 14: Current at VSC**



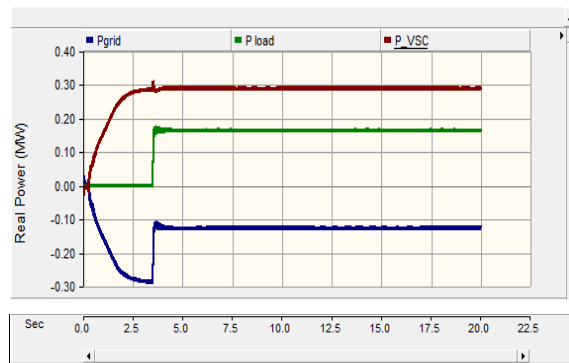


Fig 15: Active Power at grid, load and VSC respectively

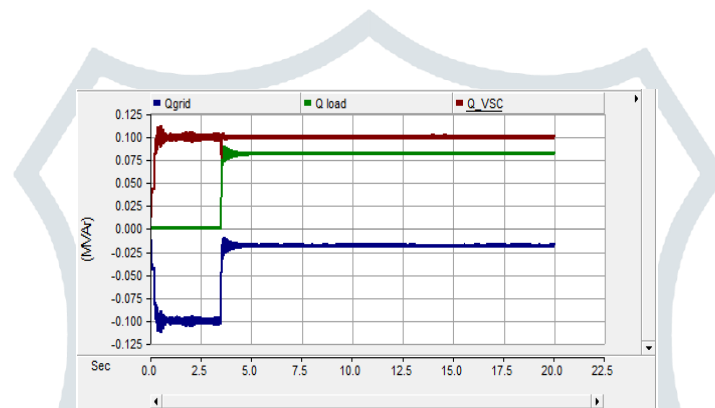


Fig 16: Reactive Power at grid, load and VSC respectively

## 5. Conclusion:

Simulation of a grid-connected PV array model has been made by using the PSCAD software. The photovoltaic array simulation model simulated the P-V characteristics and I-V characteristics of PV array under various strengths of solar radiation and different ambient temperatures and resultant graphs are plotted. The MPPT model makes the output power of the photovoltaic array becomes to the maximum point in a small period. The improvement in PV power because of an irradiation growth on the PV array, the boost converter increases its duty cycle so that extra current is extracted from the PV array so dc link voltage increases. To keep the dc voltage level at the dc link, VSC draws numerous currents from the dc link. Since controlling the dc link voltage is matching the power reference from the MPPT. Hence, the single-phase PV grid-connected generation systems installed in this paper provides the framework for the wide analysis light to the PV grid-connected generation systems.

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