MAT JOURNALS
Journal of Power Electronics and Devices
Volume 4 Issue 2

Simulation of Grid Connected Solar Power System and Harmonic Reduction

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Abstract
The use alternative sources of Power Generation is the need of today. In general, the renewable energy resources are pollution free (Such as Wind, Hydro, Solar), easily constructible, and require less maintenance as compared to conventional energy sources (Such as Natural gas and oil). Most effective method for generation of Power, among renewable energy sources, is photovoltaic system (using solar cell). Solar Photovoltaic System is easy to install, clean and light. Once installed, it has no recurring expenditure except the battery. This Paper deals with connecting solar system with 3 phase grid system. Thereby reducing the need of battery. MPPT technique is used to extract the maximum power obtained from the sun radiation and transfer it to grid. Three phase inverter is also used to convert DC, of boost converter, into AC, which is fed into grid. Further, harmonic is also reduced from the grid by using filters.

Keywords: *Renewable energy, PV modules, Photovoltaic system, boost converter, voltage source Inverter, MPPT control, Grid.*

INTRODUCTION
At present, the demand of Power is rising day by day due to enlarged population and fossil fuel supply viz. petroleum, Coal, and natural gas are going to exhaust, in a few years. The rate of electrical energy consumption is increasing and fuel supply is depleting leading to energy scarcity. Therefore it is power crisis. Consequently renewable and alternative resources of energy need to be developed to fulfil the requirement of electrical energy. Energy abundance and the sustainability thus grid connected photovoltaic system is widely used, although solar energy is available abundantly and free of cost, the cost of the photovoltaic cells is very high. Hence the initial investment on solar energy will be very high.

The photovoltaic (PV) energy effect can be considered an essential sustainable resource because of solar radiant The basic element of a PV system is the solar cell which converts the solar irradiance into direct current. Grid interconnection of PV system requires an efficient converter to converter the low DC voltage into AC.

PV panels is used either on grid-line or off-grid line. PV panels supply local loads in off-grid line. In on-grid connected applications, the PV system delivers power to local loads as well as to utility grid.

Here, the PV system is entitled "**grid-connected PV system**."

SIMULATION WORK ON GRID CONNECTED PV SYSTEM

A. Elements Included in a System of Photovoltaic Conversion-

The basic diagram of grid connected solar power system with harmonic compensation is shown below.

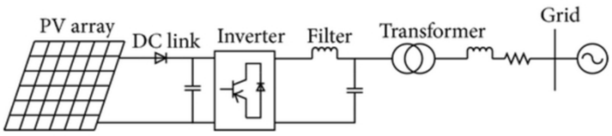

Fig.1 *Basic Diagram of Grid Connected Solar System*

The main elements that can be included in this system are PV array, DC to DC converters, Inverter for DC to AC conversion, transformer, filters for harmonic compensation and utility grid[2]. It is an arrangement used in PV standby power supply units, its called grid connected system with filters.

(i)) PV modules

A solar PV cell is a constant current source and consists of a diode with a parallel resistance (R_P) and series resistance (R_S) as shown in fig. The solar output current is a function of radiations

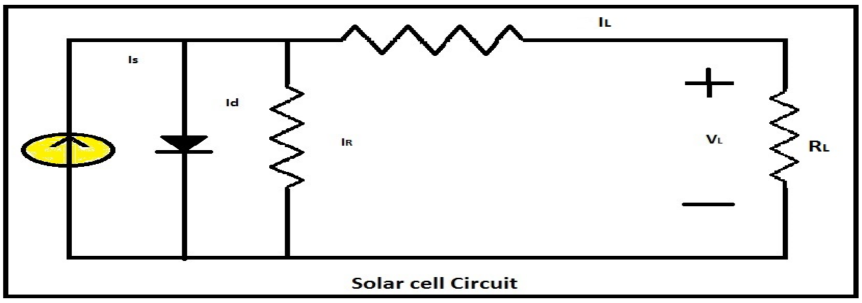

Fig.2 *PV Cell Circuit Diagram*

A backward current is a current to flow in a P-N junction when there is no radiations (S) from the sun. This is also called a dark current (I_O). The current I_S is produced by the solar cell. When there are radiations, a load current will flow in the external circuit (I_L) and shall be measured. The resistor, R_L is a load connected to the cell, and the voltage (V_L) is the open circuit voltage when no load is linked across the circuit. The current I_S is the maximum current that will generate at a specific solar radiation (S) and I_{SC} is a short- circuit current that is generated by shorted terminals. The current I_L is the load current for a meticulous load and solar irradiation (S). Solar cell block model presentation with power output is shown in Fig. 3.

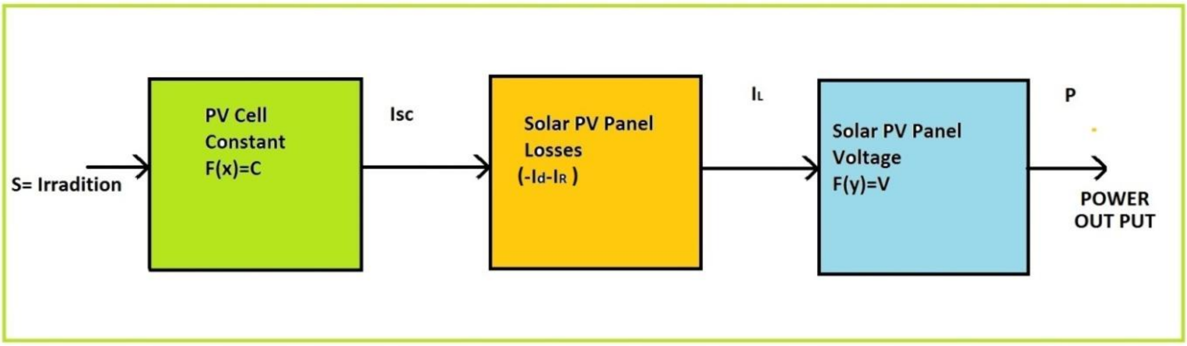

Fig. 3 *Solar Cell - Block Diagram*

(ii) PV ARRAY

Here, 12 KW PV array uses 330 sun power modules (SPR-305E-WHT-D). The array consist of 8 strings of 5 series connected modules connected in parallel (8*5*305.2 = 12.208KW)

The manufacturer specification for one module are:

Number of series connected cells: 96

Open- circuit voltage: Voc = 64.2

Short-circuit current: Isc = 5.96 A

Voltage and current at maximum power: Vmp = 54.7 V, Imp = 5.58A

The PV array block allow us to plot I-V and P-V characteristic for one module and whole array.

The PV array block has two input that allow us to vary sun-irradiance and temperature.

(iii) DC-DC boost converter(Chopper)

The function of boost converter is to convert low level of DC voltage to high level of DC voltage. This is too called "step-up converter". A power supply includes a boost converter has been presented in **Fig 4**. The energy flow is controlled by a switch S. while switch (*S*) is ON, a current erected on the inductor (L_S), in the meantime the diode *D* is in the reverse overcrowding mode since the ON-state of *S* denotes a zero voltage crosswise it. When *S* is OFF, the power accumulated in the inductor charges to the capacitor *Cs*, every one the way through the diode *D*. The inductor current will be proscribed to pursue a preferred wave shape. In power factor adjustment circuit, the inductor current is usually controlled to pursue the rectified voltage, and the current and voltage will be in phase in ac side.

Fig 4 illustrates a power supply by means of a boost converter circuit and its input voltage and current. The current is considered just about sinusoidal with roughly unseen high frequency by switching ripples. The dimension of the boost converter becomes fewer than either passive filter, but the presentation will be to a great extent better. It becomes very hard to put up for sale power supplies through dynamic power factor improvement since predictable high cost and smaller trustworthiness associated to added equipment.

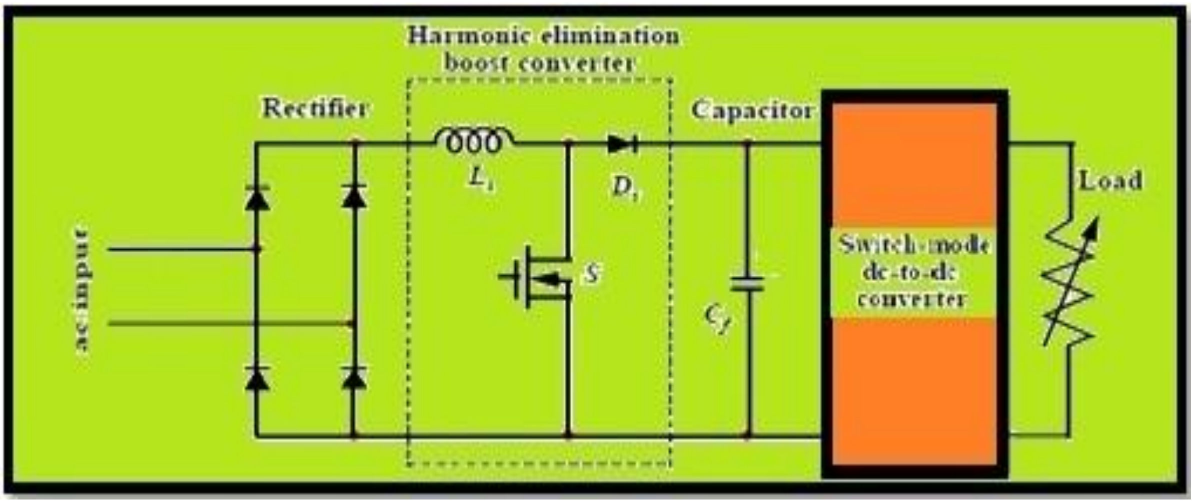

Fig. 4 *Boost Converter Diagram*

PV array is to be controlled to via regulating the duty cycle (D), the solar panel is to be restricted to function at the greatest power point. The control scheme has two levels. The output voltage of PV system is regulated by reference V_{Ref} . This is computed by means of MPPT algorithm and will produce the control signal for the boost up circuit.

(iv) MPPT Algorithm technique

The objective of a MPPT technique is to track the *Vmpp* at the every value of the irradiance and the so the maximum power output *Pmpp* can be injected into a power system grid. There are several temperature MPPT techniques available to achieve this namely, perturb and observe technique, incremental conductance method, partial short circuit current or open circuit voltage etc. The technique used here is incremental conductance method.

The schematic block diagram of MPPT based PV system is shown below

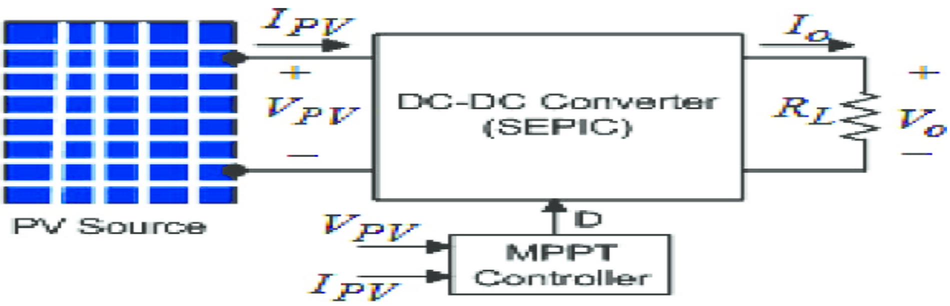

Fig. 6 *MPPT Connections*

The incremental conductance procedure continuously monitors the conductance value in order to achieve the MPP. It can be said that on *MPP*, rate of change of solar PV power P_{PV} with respect to the PV voltage I_{PV} is zero,

$$\frac{d\,(P_{pv})}{d_{PV}} = 0$$

The rate of change of PV power by way of PV voltage can be represented as;

$$P_{pv} = V_{pv} \times I_{pv}$$

$$\frac{d\,(P_{pv})}{d_{PV}} = I_{pv} + V_{pv}\frac{d}{dV_{pv}}(I_{pv})$$

Hence the following expression can be written in the three regions of the PV characteristics. At *the MPP*, the following expression is true.

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} = -\frac{I_{pv}}{V_{pv}}$$

The left region of *MPP* when the PV power raises with the boost in PV voltage, the following expression is true.

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} > -\frac{I_{pv}}{V_{pv}}$$

The right side of *MPP* when the PV power decreases with the increase in PV voltage, the following expression is true.

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} < -\frac{I_{pv}}{V_{pv}}$$

Thus comparing the instantaneous conductance value, a reference voltage can be set for a PV in order to achieve *PMPP* using the expressions. The fractional open circuit voltage method makes use of the fact that the highest power point voltage (V_{mpp}) and open- circuit voltage (V_{oc}) have a linear relationship amongst them. The PV short circuit current *ISC* and current (*IMPP*) also have a linear correlation.

VMPP = K1.VOC

IMPP = K2.ISC

The constants of proportionality *K*1 and *K*2 in above equation can be computed by an empirical determination of the V_{OC} and V_{MPP} at different temperature and irradiance values. Once these proportionality constants are calculated, during the operation of a PV, *VOC* can be measured by momentarily shutting down the power converter. Thus by using the values of *VOC* (or *ISC*) and *K*1 (or *K*2) the MPP values of *VMPP* (or *IMPP*) can be computed.

Flow chart of INC method is shown below

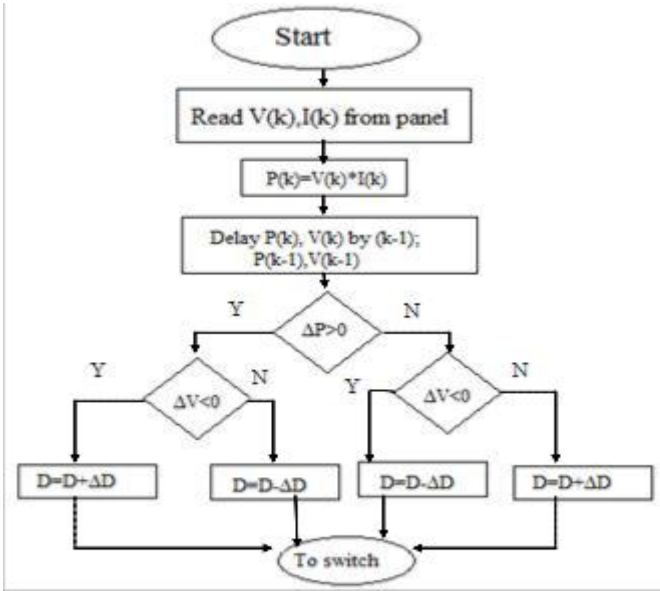

Fig. 7 *Flow Chart of INC method*

(v) Transformer
Here, we are using step up transformer to boost our voltage according to grid requirement. The transformer will boost 260 volt coming from inverter to 25KV.

RESULTS AND DISCUSSION

The output of PV module which is dc is given to a boost converter to raise the voltage level to 500 V. The switches that are used in boost converter is switched at a frequency of 5KHz. The output voltage of boost converter changes if the output of PV module changed (As by changing irridance and temp. Here, we have kept our PV module at irridance of 1000 W/m2 and temp. At 25 degree Celsius.) The output of boost converter which comes out as 500 V is given as input to Inverter which convert it into AC and is fed in to grid via transmission line, transformer and filter. Filter are used to remove harmonic present in the waveform that was coming from inverter side.

Matlab Simulation model of above is as shown below

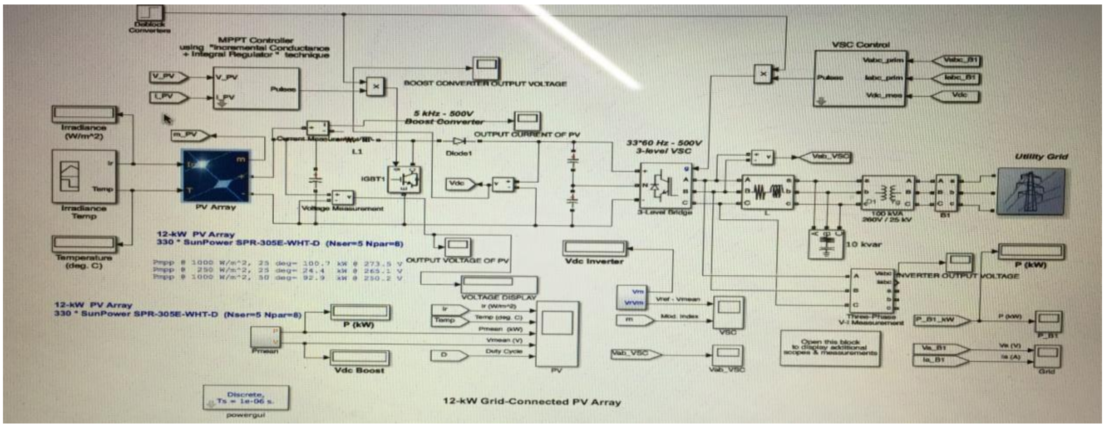

Fig. 8 *MATLAB Simulation*

Based on the simulation of above, following results are obtained
Output voltage of PV module is shown below

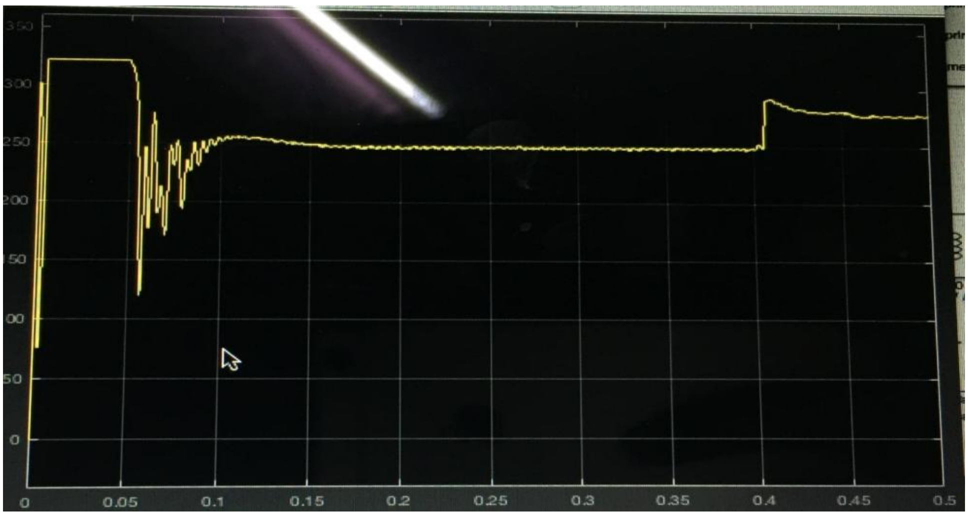

Fig. 9 *Output Voltage of PV Module*

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From above simulation result we can conclude that voltage get settle down after t = 0.5 sec and its value is = 255.3 Volt

Ouput current of PV module is shown below-

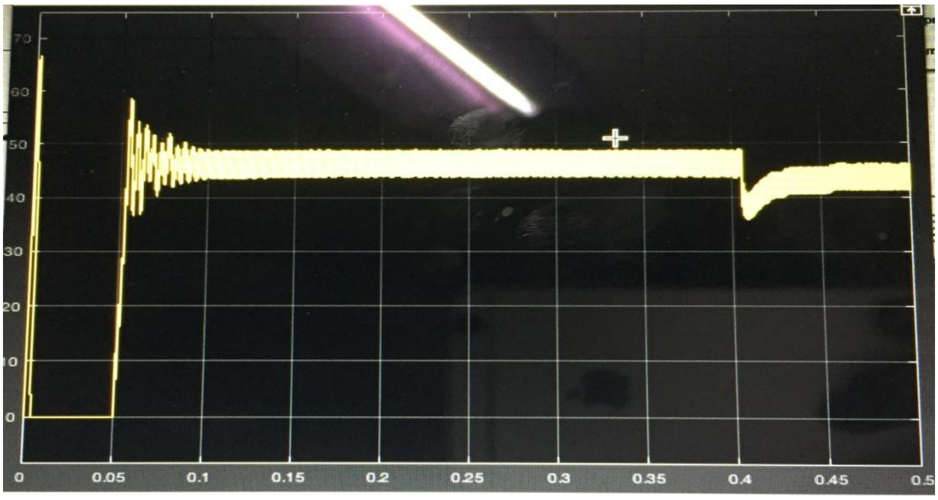

Fig. 10 *Output Current of PV Module*

From above simulation result we can conclude that current get settle down after t = 1.5 sec and its value is = 40.78A

Pmean, Vmean and duty cycle waveform is shown below-

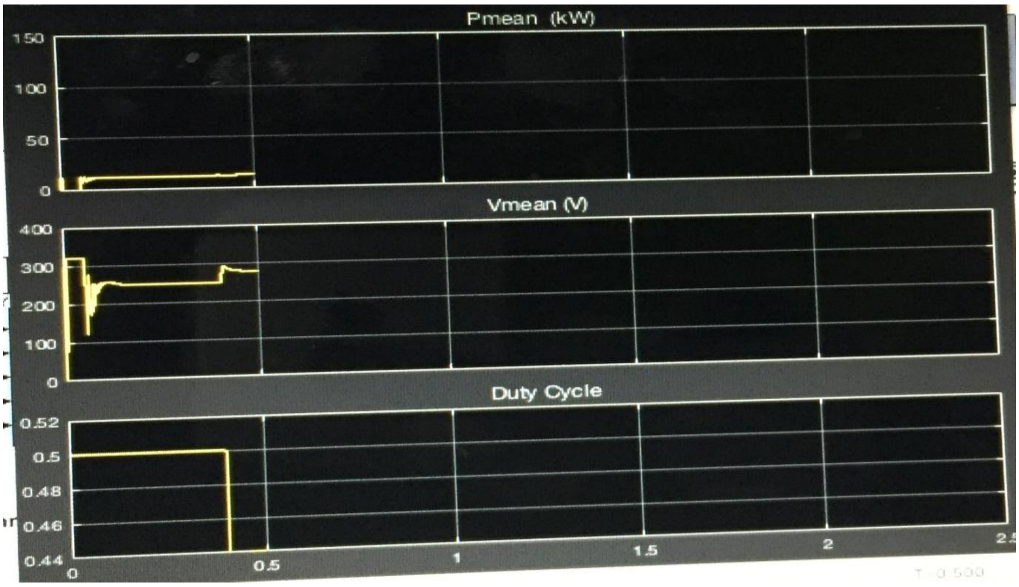

Fig.11 *Pmean, Vmean and Duty Cycle Waveform*

In this the simulation result is obtained for mean power, mean voltage of PV array and duty cycle of boost converter.

From above mean power of Pv array comes out to be 11.22 KW, and Vdc boost settle down to 255.3 V.

Boost converter output voltage is shown below

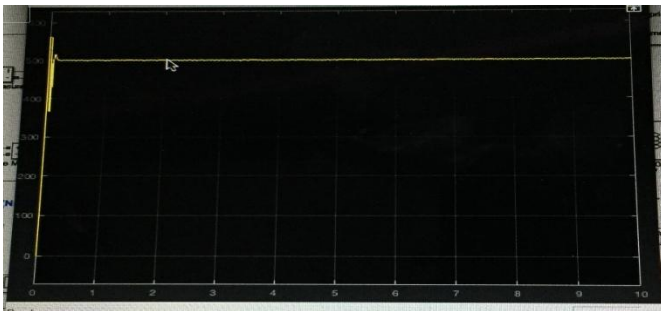

Fig.12 *Boost Converter Output Voltage*

The output voltage of boost converter coming out to 500 Volt.
The voltage waveform of VSC is shown below-

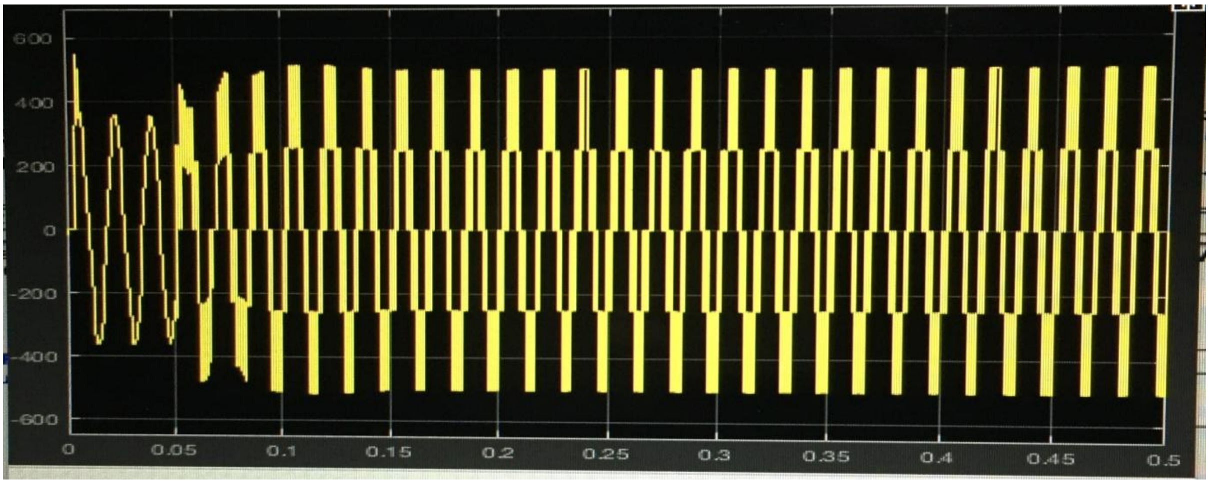

Fig.13 *VSC Output Voltage Waveform*

The output voltage source converter is coming out to 500 Volt.
Inverter output voltage is shown below-

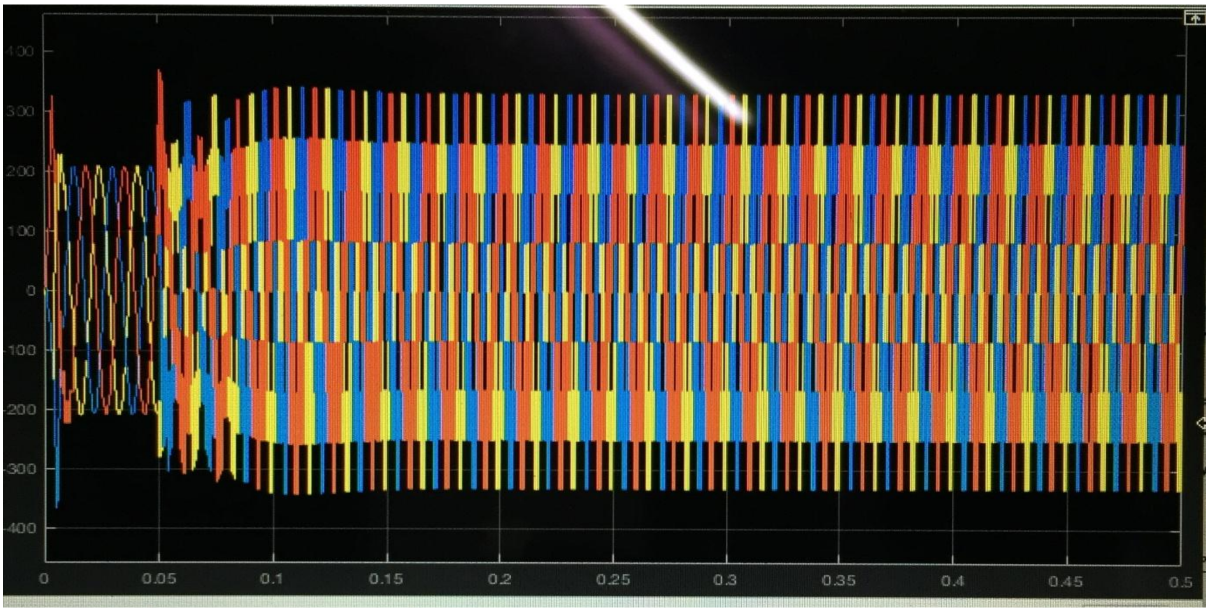

Fig 14 *Inverter Output Voltage Waveform*

From above inverter ourput voltage measured between two phase is coming out as 259.6V. Grid voltage (Va) and current flowing through one phase (Ia) is shown below

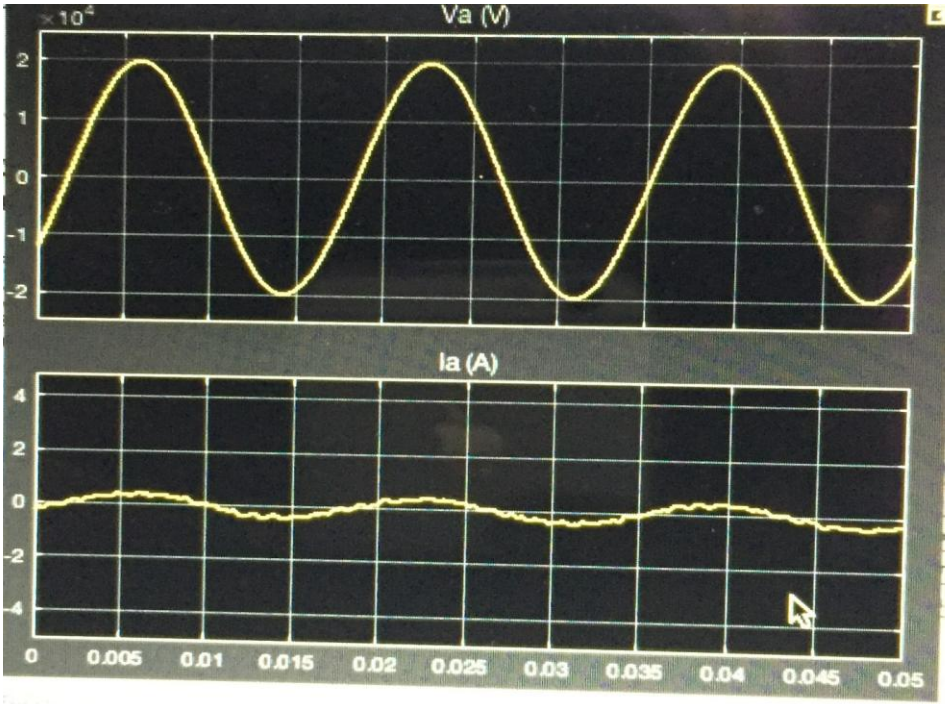

Fig.15 *Grid Voltage and current waveform*

From figure it is cleared that the voltage is approaching pure sinusoidal waveform that is less content of harmonic is present.

CONCLUSION

The result shows that the incremental conductance based MPPT system requires less time (0.7 ms) to attain the maximum power. Thus the incremental conductance MPPT system is better in response and doesn't depend on knowing any parameter of PV panel. From the Simulation results we have also found that incremental conductance algorithms gives better power output and higher efficiency under normal and varying conditions. Simulation results confirm that the presented method can effectively improve the dynamic performance and steady state performance simultaneously.

Whenever excess amount of energy is required solar power plant can be connected to grid. It results in overall increase in plant capacity thus increase both load factor and diversity factor of the system. By using MPPT control technique, always maximum power is taken from the PV array to result in increase of overall power of the system.

REFERENCES

1. A. Chatterjee, A. Keyhani, and D. Kapoor, "Identification of Photovoltaic Source Models," Energy Conversion, IEEE Transactions on, vol. PP, pp. 1-7, 2011.Aalborg University, Denmark, 2012.accessed on November 10, 2012.
2. A. Khalifa and E. El-Saadany,"Control of three-phase grid-connected photovoltaic arrays with open loop maximum power point tracking," Proceedings of IEEE Power and

Energy Society General Meeting, pp. 1–8, 2011.
3. A. Mansoor, et al, "Predicting the net harmonic currents produced by large numbers of distributed single-phase computer loads," Conference Record: IEEE PES Winter Power Conference, Jan. 1995, #95 WM 260-0 PWRD.
4. A. Yazdani and R. Iravani, "Voltage-sourced converters in power systems," John Wiley and Sons, 2010.
5. A.K.Zairian, M. Karimi Ghartemani."On the equivalence of three independently developed phase-locked loops," IEEE Trans. on Automation Control, Vol. 50, No.12, pp. 2021-2027, 2005.
6. A. Ellis, R. Nelson, E. VonEngeln, R. Walling, J. MacDowell, L. Casey, E. Seymour, W. Peter, C. Barker, B. Kirby, and J. Williams, "Review of existing reactive power requirements for variable generation," IEEE Power and Energy Society General Meeting, 2012, San Diego, USA, pp. 1–7, Jul. 2012.
7. A. Hoke, R. Butler, J. Ham brick and B. Kropotkin, "Steady-State Analysis of Maximum Photovoltaic Penetration Levels on Typical Distribution Feeders," IEEE Transactions on Sustainable Energy, vol. 4, no. 2, pp. 350 - 357, 2012.
8. A. B. Gregene, H. R. Camenzind. "Frequency-selective integrated circuits using phase-lock techniques". IEEE Journal of Solid-State Circuits, Vol.4, No.4, pp. 216-225, 1969.
9. B. Lindgren, "A Power Converter for Photovoltaic Applications," Licentiate of Engineering Degree, Department of Electric Power Engineering, Chalmers University of Technology Goteborg, Sweden, 2000.
10. 10) B.Verhoeven, "Utility aspects of grid connected photovoltaic power systems," International Energy Agency Implementing Agreement on Photovoltaic Power Systems, Report IEA PVPS T5-01, 1998.
11. BP Solar, PV System Specification-Solar Skin PV Norway Trondheim, Doc . 100686 50 rev, 2. BP Solar Limited, March 2000.
12. C.R. Nave, "The P-N Junction," Physics World, 2012. http://hyperphysics.phy-astr.gsu.edu/hbase/solids/pnjun.html#c3.[Accessed 20 September 2014].
13. C.Wang, "Modelling and Control of Hybrid Wind/Photovoltaic/Fuel cell Distributed Generation Systems," PhD Dissertation, Montana State University, Bozeman, 2006.
14. C.S.T. Huan-Liang Tsai, and Yi-Jie Su, "Development of Generalized Photovoltaic Model Using MATLAB/SIMULINK," In the World Congress on Engineering and Computer Science 2008, San Francisco, USA, 2008.
15. Clean Energy Council, Tech Info Energy Efficient and Renewable EnergyBulletin.September2006.UpdatedNovember2009.http://www.solaraccreditation.com.au/installerr sources'/tech info.html. accessed on November 10,2012
16. D. C. Martins, "Analysis of a three-phase grid-connected PV power system using a modified dual-stage inverter," International Scholarly Research Notices (ISRN) Re-newable Energy, vol. 2013, pp. 1–18, 2013.

17. D. E. Rice, “Adjustable speed drive and power rectifier harmonic—their effect on power systems components,” IEEE Trans. on Ind. Appl., Vol. IA-22, No. 1, Jan./Feb. 1986, 161.