Modelling and Simulation of PV Array for Maximum Load Demand at J.C.O.E.T and Grid Interconnection

Prasad K. Dighde[1], Shweta V. Behere[2], Ashwajeet M. Chakranarayan[3] , Shital R. Thakare[4], Shubham G. Bardhiya[5], Dipali N. Tayade[6]

[1-6]Student, Dept. of Electrical Engineering, J.C.O.E.T, MS, India

---***---

Abstract - *This paper presents the modelling and simulation of PV array for maximum load demand at JCOET and grid interconnection. The simulations are carried out for 100 KW PV system using Maximum Power Point Tracking (MPPT) algorithm for capturing the maximum possible power under varying solar irradiance and temperature conditions on MATLAB/Simulink platform. The generated power will be utilized by J.C.O.E.T. & extra power will be transferred to the Grid. The MPPT algorithm (Incremental Conductance) is incorporated in the control strategies employed in the DC-DC boost converter connected between the PV array and the inverter. The simulation results of output power for varying solar irradiance and temperature conditions have been proposed.*

***Key Words*: Grid connected PV system, DC- DC Boost Converter, MPPT techniques, PV array model, Three Phase Three-Level Inverter.**

1. INTRODUCTION

The increasing demand for energy particularly in developing countries like India and China and depletion of fossil fuel reserves has pushed all countries to finding alternative sources of energy. Though we are having many alternative sources of energy, solar PV and wind are the widely used energy resources [1]. A PV system consists of many components such as PV modules, mounting structure and electrical connections and means of regulating and modifying the electrical output. As we know solar cells, when exposed to solar radiation, produce DC power which has to be converted to AC power using power electronics-based converters along with control equipments [3].

Most of the PV inverters are voltage-source inverters as they are simple, have both voltage and current loops with good stability, very fast response. These are easy to implement and have inherent ability to control both voltage and current.

The modeling and simulation of 100 kWp Photovoltaic Power System for maximum load demand at Jagadambha college of engineering and technology. This grid-connected PV system consists of PV arrays can be installed on the roof-top terraces of two of the buildings in the college. Maximum Power Point Tracker (MPPT) for capturing the maximum possible power under varying solar irradiance conditions in MATLAB/Simulink platform uses Incremental Conductance

(IncCond) algorithm which is incorporated in the control strategies employed in the DC-DC boost converter connected between the PV array and the inverter [2]-[6]. The simulation results of output power and other parameters for varying solar irradiance are observed .

2. DC-DC CONVERTER

Fig. 1 below shows a step up or Pulse Width Modulated(PWM) boost converter. It consists of an input dc voltage source Vg, controlled switch S, diode D, boost inductor L, filter capacitor C and the Load resistance R.When the switch is ON, the current in the inductor increases linearly and the diode is in OFF state .When the switch is OFF the energy stored in the inductor will be released through diode to the RC circuit [4].

Fig. 2 above shows the inductor current waveform and Fig. 3 shows the inductor voltage waveform.

From the inductor voltage balance equation we have

$$V_g = (DT_s) + (V_s - V_0)(1 - D)T_s = 0 \qquad (1)$$

$$V_0 = \frac{V_g}{(1-D)} \qquad (2)$$

Conversion ratio

$$M = \frac{V_0}{V_g} = \frac{1}{(1-D)} \qquad (3)$$
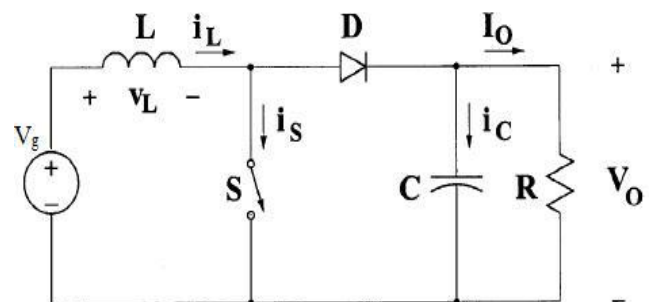

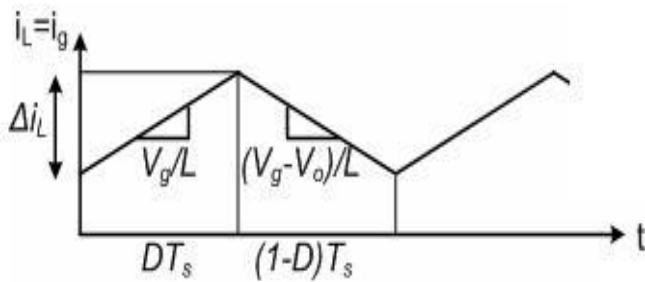**Fig -1**: Circuit diagram or boost converter

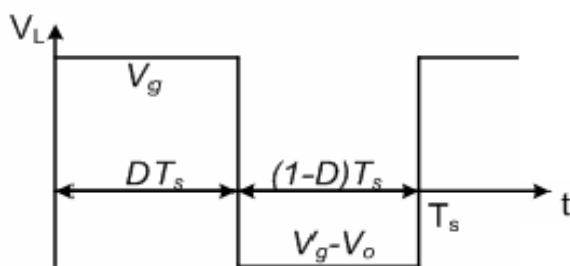**Fig -2**: Inductor current waveform

Fig -3: Inductor voltage waveform

3. MAXIMUM POWER POINT TRACKING

Many algorithms have been reported in the literature to capture the maximum power from the PV system. There are two methods, namely the Perturb and Observe and Incremental Conductance methods, of which Incremental Conductance who have good speed of convergence and less complexity, is employed in our simulation.

3.1 Incremental Conductance Method (IncCond)

Normally any conventional MPPT has two independent control loops for the control of maximum power. The first loop contains the algorithm and second contains the Proportional-Integral (PI) controller. This method uses Incremental conductance to generate the error signal which will be zero at maximum power. Most of the time this error will not be zero therefore it is the function of the second control loop to make this error zero. Due to nonlinear characteristics of the PV output and the unpredictable behavior of weather PI controllers do not perform well.

4. INVERTER CONTROL

4.1 Three-Phase Three- Level Inverter

Here we are using three-phase three-level inverter as it provides industrial applications by adjustable frequency power. The DC supply for the inverter is taken from the large capacitor connected at the input terminal to suppress the

Therefore Incremental Conductance method, which exerts direct control, is preferred in this paper. Here the duty cycle is directly adjusted from the algorithm. For compensating the lack of PI we are allowing a marginal error of 0.002. This size of permissible error determines the sensitivity of the system. The condition for maximum power capture is $(dI/dV = -I/V)$. The flow chart for the Incremental Conductance method with direct control has been shown in Fig. 4. According to the MPPT algorithm duty cycle is calculated and used as the desired duty cycle for the next step.
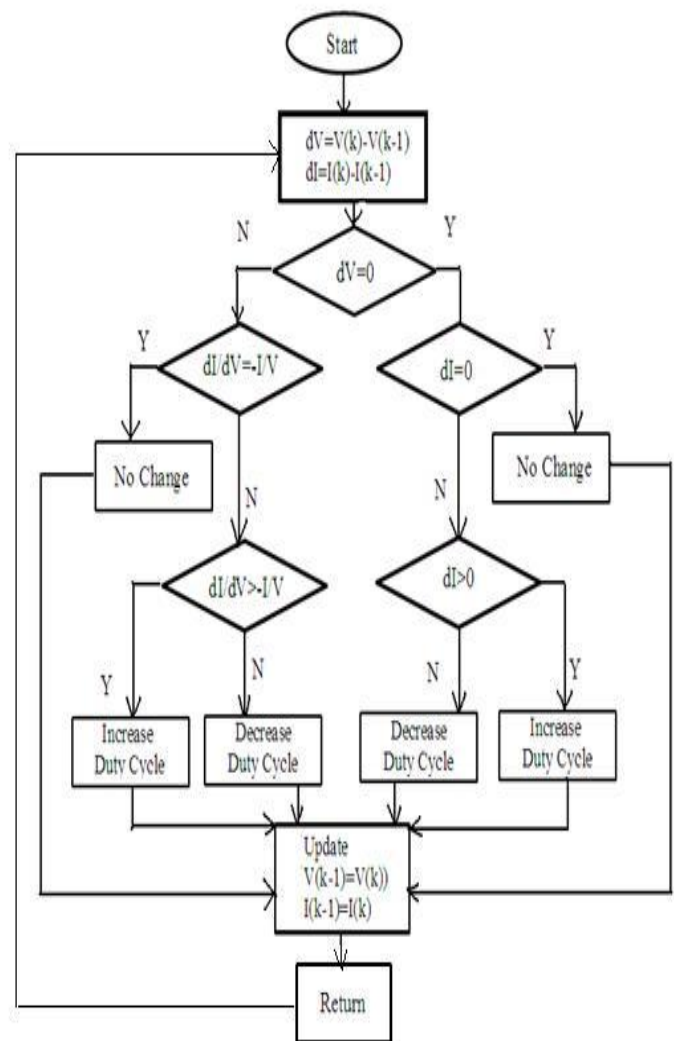

Fig -4: Flow chart for Incremental Conductance method with direct control

harmonic feedback to the source and to make the DC input constant. The inverter is neutral point clamped (NPC) to have higher voltage and to reduce the current ripples in the waveform by increasing the number of steps[4].

The elementary concept of three level inverter to achieve a higher power is to use a series of power semiconductor switches with several lower voltage dc source to perform the

power conversion by synthesizing a staircase voltage waveform [7]. In order to create a smoother stepped output waveform, more than two voltage levels are combined together and the output waveform obtained in this case has lower dv/dt and also lower harmonic distortions [8].

4.2 Voltage Source Converter Control

The three-phase voltage source converter regulates the DC bus voltage to 500 Volts by keeping the power factor at unity. Here the control system uses two control loops: an external loop for regulating the DC link voltage to +/- 250 Volts and an internal loop for regulating the grid side active current component (I_d) and reactive current component (I_q). The control system uses a sampling period of 100µs for the voltage and current controllers.

4.3 Control of Grid Side Controller

The major functions of the grid side controller are:

- Grid synchronization
- Ensure acceptable power quality at the grid interface unit
- Control of reactive power transfer between the grid and converter

- Control of active power injected into the grid and to maintain constant DC link voltage

Here the control strategy involves two cascaded loops: The first is a fast internal current loop for maintaining sinusoidal currents and to protect against over currents and the second is an external voltages loop for balancing the power flow in the system[4].

5. SIMULATION MODEL

Fig. 5 shows the simulation models for Incremental Conductance method. This model is almost same as of P&O method except for the techniques implemented on the Boost converter for MPPT. Here the PV array delivers power output as per the varying solar irradiance conditions. The boost converter steps up the PV voltage for all varying irradiance conditions to 500V. The switching of duty cycle will be controlled by the MPPT methods used. Inverter converts 500V DC to the grid voltage level and maintaining unity power factor. A 10 kvar capacitor bank is also used to filter the harmonics produced by the inverter. A 33 kVA three phase transformer is used to connect the local distribution system to the utility grid.
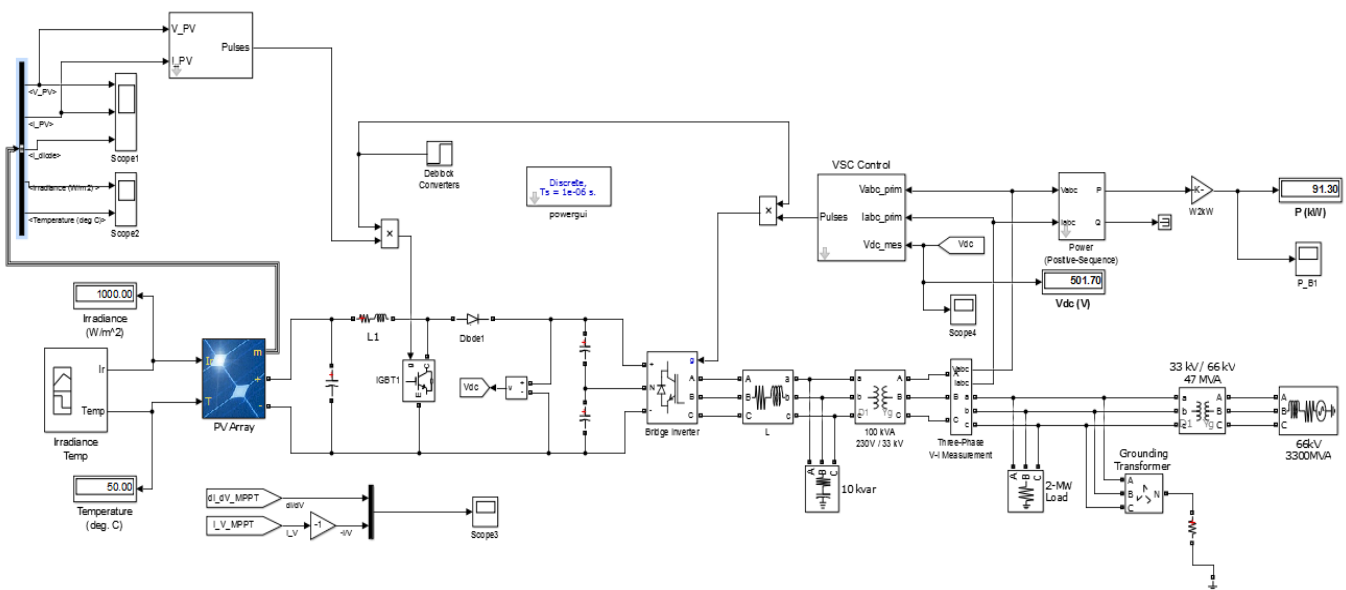

Fig -5: Simulink model for Incremental Conductance method

Table -1: Simulation Parameters

Parameters	Values
No. of Parallel String	66
No. of Series String	5
Open Circuit Voltage	6402 V
Short Circuit voltage	5.96 A
Maximum Power Voltage	54.7 V
Maximum Power Current	5.58 A

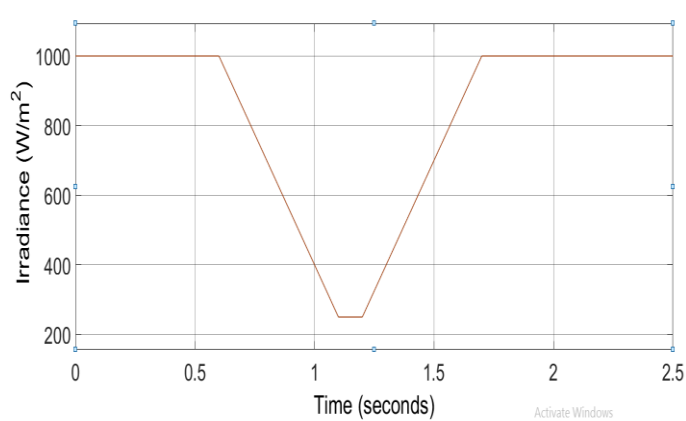|	
Maximum Power	305.2 W
Inverter DC Input	500 V
Grid Voltage	66 KV
Grid Frequency	50 HZ
Synchronising Transformer	33-66 KV
Resistive Load	2 MW

6. SIMULATION RESULTS
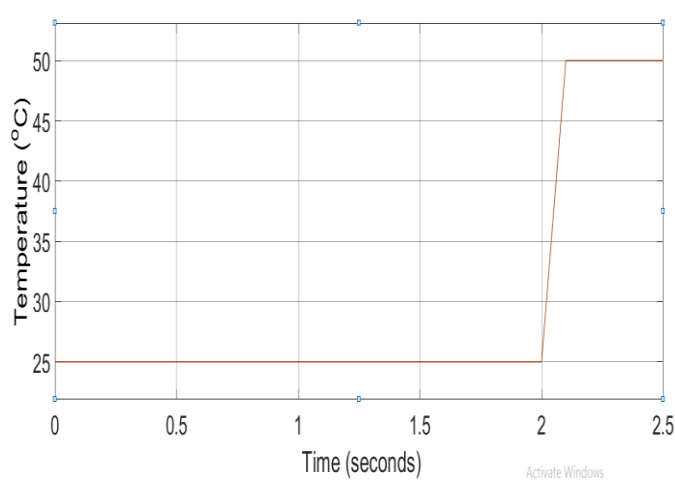
Chart -1:. Irradiance Curve
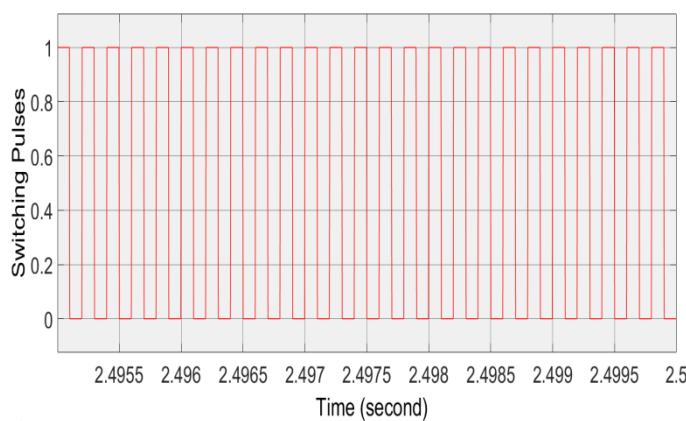
Chart -2: Temperature Curve
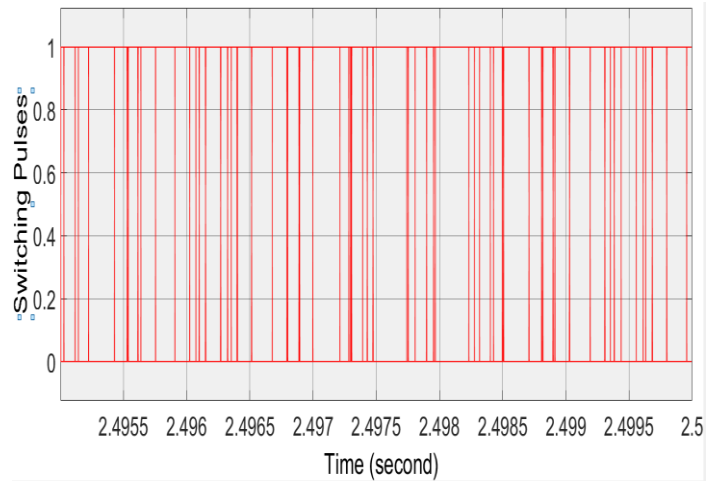
Chart -3: Converter Pulses
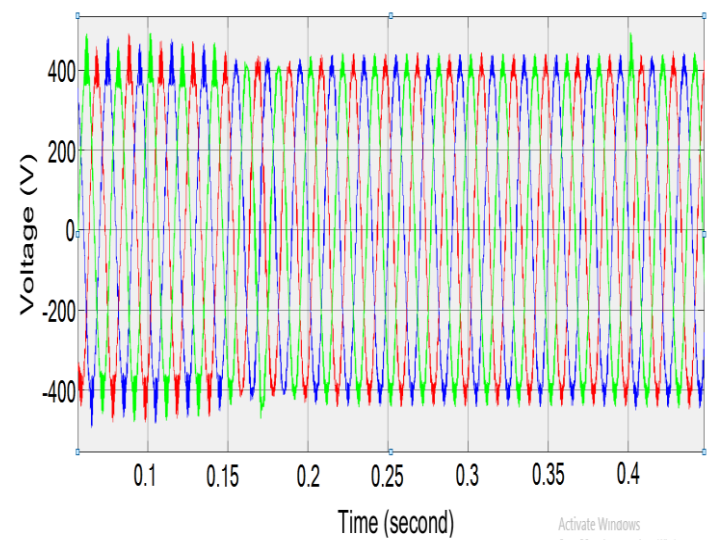
Chart -4: Inverter Pulses
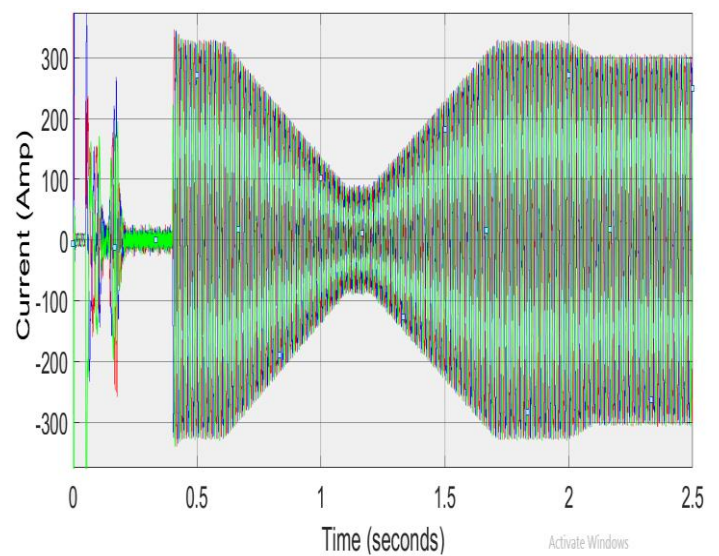
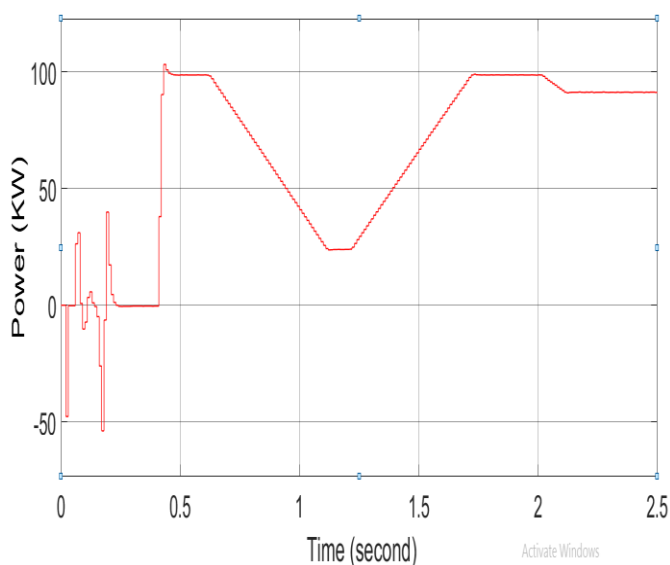**Chart -5**: Inverter Output Voltage

Chart -6: Inverter Output Current

Chart -7: System Output Power Curve

7. ANALYSIS OF SIMULATION RESULT

Fig 6. shows the Irradiance curve. From Fig 6 & 7 we can see that we have considered variable temperature and irradiance condition so that we can analyze power generation under variable condition. In fig 6. The irradiance is varied between 300 W/m^2 to 1000 W/m^2 & in fig 7. The Temperature varied from 25$°C$ to 50$°C$.

Fig 8 shows the switching pulses which are generated by MPPT algorithm & these pulses will be given to IGBT of the Boost Converter. According to the switching pulses, IGBT will be ON & OFF and output voltage will be boosted. Fig 9 shows the switching pulses that are given to the gate of the Bridge Inverter.

Fig 10. Shows the 3phase Inverter output voltage in sinusoidal with 120$°C$ phase shift. Fig 11. Shows 3 phase Inverter output current in sinusoidal with 120$°C$ phase shift. Fig 12. Shows the Power output curve with Power in KW on Y-axis and Time in seconds on X-axis.

The capacitor gradually discharges and charges in the time span between 0.6& 1.7 seconds which we have considered in the Irradiance. From the simulation results shown above, it can be seen that change in solar irradiance affects power generation more than the change of temperature

8. CONCLUSIONS

Solar energy is genesis for all forms of energy. This energy can be made use of in two ways the Thermal route i.e. using heat for drying, heating, cooking or generation of electricity or through the Photovoltaic route which converts solar energy in to electricity that can be used for a myriad purposes such as lighting, pumping and generation of electricity.

With its pollution free nature, virtually inexhaustible supply and global distribution- solar energy is very attractive energy resource. Solar Energy can be utilized for varied applications.

In this work, modelling and simulation of 100 kWp solar PV power plant proposed at J.C.O.E.T is reported. One MPPT method, namely Incremental Conductance, is used to perform the simulation in MATLAB/Simulink. It was observed that as expected the power generated increased as the irradiance is increased.

From this we can conclude that the self generated solar power can be used by college as well as the extra generated power can be sold to the utility grid. This will result in decrease in energy bills and also college can earn from it.

ACKNOWLEDGEMENT

REFERENCES

[1] G. M.Masters, Renewable and Efficient Electric Power Systems, Wiley-Interscience,John Wiley, 2004.

[2] T. Salmi, M. Bouzguenda, A. Gastli, and A. Masmoud, "MATLAB/Simulink-based Modelling of Solar Photovoltaic Cell," International Journal Of Renewable Energy Research,vol. 2, no. 2, pp. 213–218, 2012.

[3] P. Mohanty, "Control stratergies for distributed generation based micro-grids", Ph.D Thesis, Indian Institute of Technology, Delhi,India, 2012.

[4] Rawoof, Rafia, R. Balasubramanian, and N. Moorthy Muthukrishnan. "Modeling and simulation of 100 kwp grid-connected photovoltaic power system." 2015 Conference on Power, Control, Communication and Computational Technologies for Sustainable Growth (PCCCTSG). IEEE, 2015.

[5] J.M.A.Myrzik and M.Calais "Sting and module integrated inverters for single phase grid-connected photovoltaic systems" in Proc. of IEEE Power Tech Conference, Bologna, June 2003.

[6] J. Kasera, V. Kumar, R.R. Joshi, and J.K. Maherchandani, "Design of grid connected photovoltaic system employing incremental conductance MPPT algorithm," Journal of Electrical Engineering, vol. 12, ed. 4, pp. 172-177, 2012.

[7] Gebreel, Abd Almula GM. Simulation and implementation of two-level and three-level inverters by Matlab and RT-LAB. Diss. The Ohio State University, 2011.

[8] Mohanty, Piyus, and Saransh Sahoo. Analysis of two level and three level inverters. Diss. 2010.