Simulation of Three Phase Grid Connected Photovoltaic System using MATLAB /Simulink

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Abstract— This paper presents a complete simulation model of three phase grid connected electrical photovoltaic system. The main component of the three phase grid connected photovoltaic system are, a PV array, a buck boost converter, a multilevel inverter and maximum power point tracking controller. Maximum power point tracking algorithm is used to achieve high efficiency of the PV system. The simulation model is designed in MATLAB using MATLAB SIMULINK software. In this paper we coupled the photovoltaic array with the buck boost converter. To get a constant voltage buck boost converter is used. The grid requires three phase AC supply, to achieve the DC-AC power for grid we used multilevel inverter to convert the DC supply into AC supply.

Key words: Grid connected PV system, DC-DC buck boost converter, DC-AC Inverter, MPPT

I. INTRODUCTION

Now a days the demand of electrical power in increasing day by day however the presence fossils fuels area on the verge of end. Thus it's time to search out a different way to get the availibility. The employment of electric solar cell energy is taken into account to be a primary source. At present, photovoltaic cell (PV) generation is assumptive importance as a renewable energy sources. Among all the renewable energy resources, this alternative energy looks to be a significant competition because it is extensive in nature and its conversion to electricity through electrical phenomenon (PV) method is pollution free. Increasing interest in PV systems, demand growth in analysis and development activities in numerous aspects like maximum power point tracking (MPPT), PV arrays, stability and responsibility, power quality and power electronic interface.

Comparing with other renewable energy sources solar power is that largest contributors to the world energy. A grid connect solar PV system is a form of electrical inverter that convert DC electricity from PV module into alternating current (AC). Once the PV system is connected to the grid, it will transfer the additional energy to the grid when fulfilling the native demand. But when the system generates what's needed to support the native demand, than additional energy is extracted from the grid. The main device of PV device is a solar cell.

Grid connected PV power generation systems will be found in several sizes and power levels for various desires and applications.

The aim of this paper is by using MATLAB/SIMULINK software to establish the simulation of PV system connected to three phase electrical grid.

II. MATHEMATICAL MODEL OF A PHOTOVOLTAIC CELL

A photovoltaic cell system converts daylight into electricity. Photovoltaic cells may be stored to make panels or modules. Panels may be stored to make large photovoltaic cell arrays. The term array is usually used to explain a photovoltaic cell panel. the output characteristics of a PV module depend on the solar isolation, the cell temperature and therefore the output voltage of the PV module.

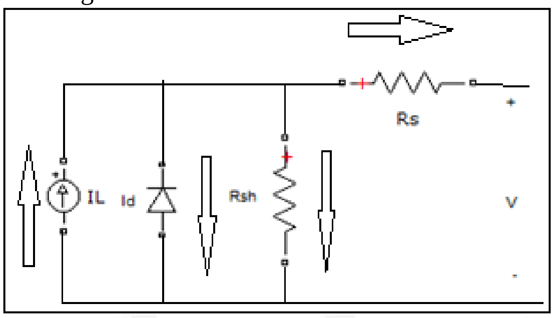

Fig. 1.1: Equivalent Circuit of Solar Cell

Typically a photovoltaic cell will be modeled by a current supply associated with a diode connected in parallel. The PV cell has its own series and shunt resistance. Series resistance is due to the diode resistance & resistance of metal contacts whereas parallel resistance represents the electron hole. The shunt resistance in parallel is very high. Losses are represented by series and shunt resistance. Bypass diode connected in reverse bias. Bypass diode permits a series (called a string) of connected cells or panels provide the ability at reduced voltage. The output current of equivalent circuit of photovoltaic cell is given by

$$I = I_L - I_D - I_{sh} \text{.......(1)}$$

Here, I represent the total current of the cell. And I_L represents the light generated current of the cell R_{sh} and R_s is the shunt and series resistance. In this equivalent circuit of photovoltaic cell, the equation for the diode is given by

$$I_D = I_O \left[exp\left(\frac{V + IR_s}{nV_T}\right) - 1\right] \text{......(2)}$$

$$V_T = \frac{kT_c}{q} \text{....(3)}$$

In equation (3), V_T is the diode ideality factor,

K is the Boltzmann's constant (1.381*10^-23J / K) and the q is the electric charge, the value of q is(10602*19^-19C).

The short circuit current of the photovoltaic cell

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \text{....(4)}$$

Put the value of equation (2), (3), (4) in equation (1) and we get the complete equation for the single diode model photovoltaic equivalent circuit.

$$I = I_L - I_O - \left[\exp\left(\frac{V+IR_s}{nV_T}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad \text{.....(5)}$$

In thus equation there are following parameter namely light current, series resistances, diode reverse saturation current, and diode ideality factor.

In the photovoltaic system the cells are connected in series and parallel. And all cell working in terms of temperature & irradiation. The equation for generated current and voltage for the module is

$$I_{module} = I_{cell}$$
$$V_{module} = N_s \times V_{cell}$$

The single diode equation for the photovoltaic array or modules become

$$I_M = I_L - I_O \left[exp\left(\frac{V_M + I_M N_S R_S}{nN_s V_T} \right) - 1 \right]$$
$$\frac{V_M + I_M N_S R_S}{nN_s V_T} \ldots.(6)$$

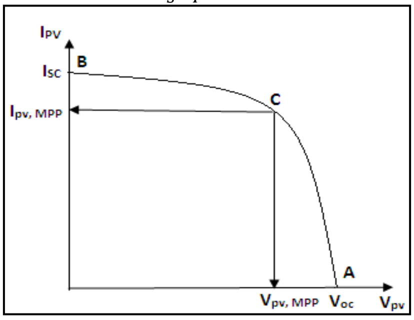

Fig. 1.2: I-V and P-V Characteristics of Photovoltaic System

III. SIMULATION OF THE THREE PHASE GRID CONNECTED PHOTOVOLTAIC COMPONENT

A grid connected solar PV system could be a type of electrical inverter that converts DC electricity from PV module into alternating current (AC). Grid connected PV system consists of PV array, DC-DC buck boost converter, DC-AC inverter and maximum power point tracking.

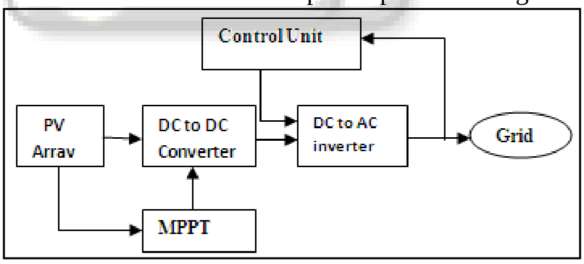

Fig. 1.3: Grid Connected Photovoltaic System

A. *Photovoltaic Array*

The PV array consists of PV cell and its organized series and parallel combination produce the specified DC voltages and current. PV cell is formed from semiconductor component and each component cell generates 0.6 V. The requirement is of bulk power, like in many hundred watts, KW, and in MW. So as to own an outsized power generation, these solar PV modules are connected in series and parallel combination.

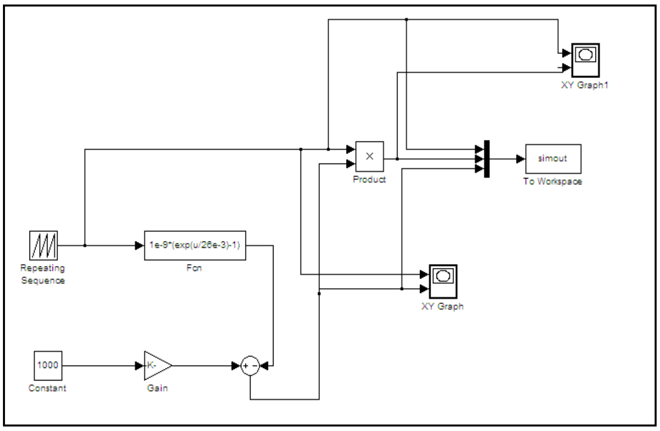

Fig.1.4 Simulink Model of Photovoltaic System

The simulink model of photovoltaic system is shown in fig. 1.4 Modeling of PV device is necessary. As a input variables it takes weather data, irradiation and temperature. The output of the PV device can be current, voltage, power or other However, needs of these three variables, to trace the characteristics of I (V) or P (V).

B. *Buck boost converter*

The buck boost converter is form of DC-DC converter whose output voltage magnitude is either greater or less than the magnitude of input voltages. The DC-DC buck boost converter works in both buck and boost mode. The input voltage of DC-DC buck boost converter is depending on the output voltage of the solar (PV) system. The input and output voltage of the buck boost system changes on varying the radiation. In buck mode once switch S1 is operated and S2 is continuously in off mode. Once S1 is closed offer voltage seems across the load, and by this time inductance stores the energy. Presently switch S1 is opened, the hold on energy with the inductance freewheels through load and diodes D1, D2. For operation in boost mode, switch S1 is kept continuously in ON mode and S2 is operated. Once S2 is closed, inductance L stores energy and S2 is opened, the supply voltage seems across the load and therefore the energy within the inductance because the additive energy to the load, therefore boost operations is performed. In buck boost converter the designing of inductance (L) and capacitor (C) is very important half for each software and hardware implementation as a result of each buck and boost converter operations depends on the energy of inductance. The circuit diagrams of buck boost converter are shown in figure 1.5.

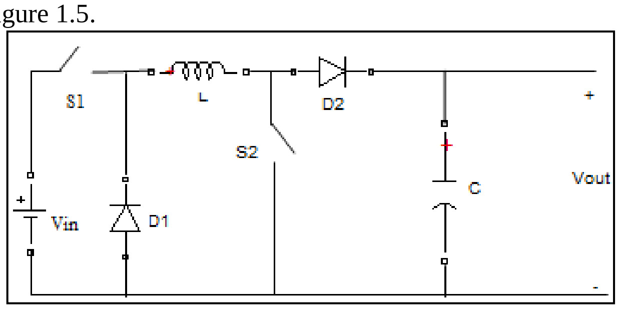

Fig 1.5 Circuit Diagrams Of Buck Boost Converter

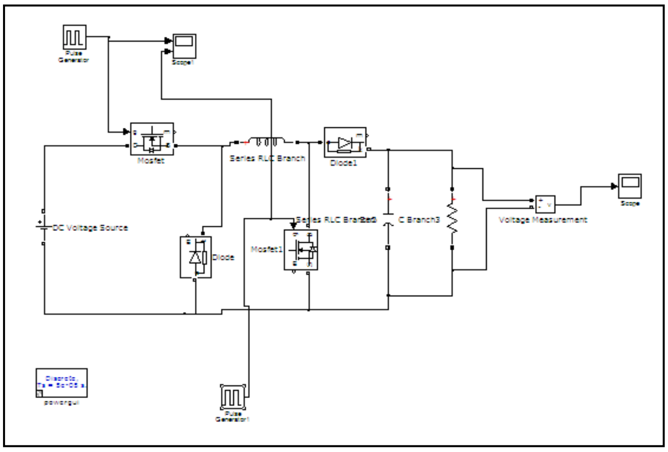

Fig.1.6 Simulink Model of Buck Boost Converter

Simulation model of buck boost converter is shown in fig. 1.6. In this simulink model, MOSFET is used as a switching element. When we get 74V from the solar panel as a output, we are giving this 74V as input to buck boost converter and we are using its buck mode, which bucks it to 60V. And when we get 45V from the solar panel as a output, we are giving this 45V as input to buck boost converter and we are using its boost mode which boosts it to 60 V. To get a constant voltage, buck boost converter is used. At Switching frequency f_s, inductance$(H) = 1e-3$, capacitance $(F) = 500e-20$ and resistance $(ohms) = 100\Omega$ run the simulation model of buck boost converter and display show the final output.

C. Maximum power point tracking

A solar panel converts solar irradiation into electrical energy. To improve the efficiency of the solar panel, maximum power point technique is used. According to maximum power transfer theorem, when the Thevenin impedance of the circuit (source impedance) matches with the load impedance, the output power of a circuit is maximum. By adjusting source impedance equal to load impedance, output power of any circuit can be maximize, so the MPP algorithm is equivalent to the problem of impedance matching.

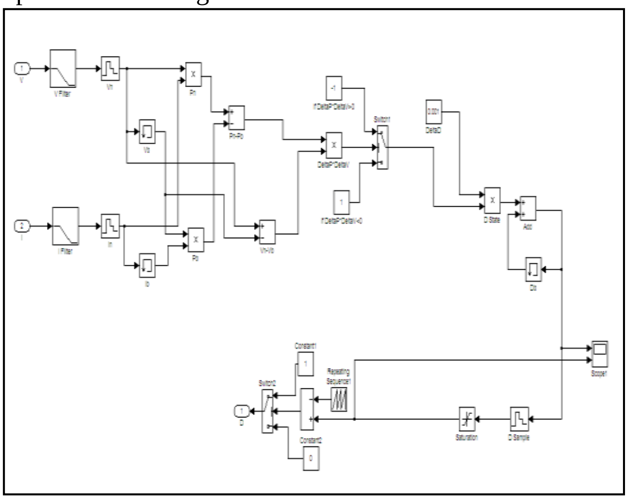

Fig.1.7.Simulink Model Of Maximum Power Point Tracking

Simulation model of MPPT is shown if fig. MPPT is used to improve the efficiency of the solar panel. To maximize the output power, MPPT algorithms are used in PV array. MPPT block takes photovoltaic voltage and photovoltaic current as input and generates reference voltage.

D. DC-AC inverter

Inverter takes direct current (DC) and produce alternating current. Initially most electrical inverter technology used silicon controlled rectifier. As power transistor became more popular, most low to medium power electrical converter systems replaced the SCR with the MOSFET or the IGBT. In grid connected PV system, inverters are used for interfacing the utility grid.

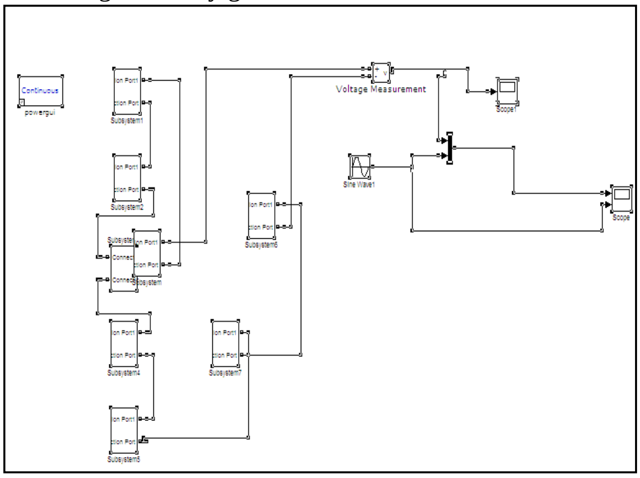

Fig. 1.8: Simulink Model of Multilevel Inverter

Simulation model of multilevel inverter is shown in fig.1.8. When we get 60V as a output from the buck boost converter, we are giving this 60 volt as an input to 8 subsystem of multilevel inverter. From that we are getting 480 volt as output. with the help of PWM controller we get 440V as an output from the inverter. And we supply this 440V to the grid.

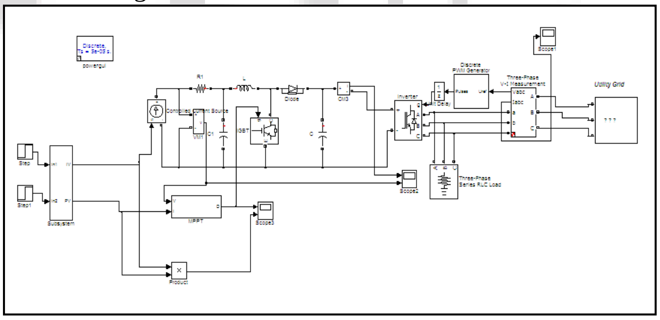

Fig. 1.9: Simulink Model of three phase Grid-Connected PV System

Simulation model of three phase grid connected photovoltaic system is shown in fig 1.9.

The model contains:

- At 1000 W/m^2 sun irradiance PV array delivering a maximum power of 10 KW.
- Buck boost converter steps up and steps down the output of solar. And we get constant output voltage of 60V.
- To improve the efficiency of the solar panel, maximum power point technique is used.
- MPPT controllers uses the perturb and observe technique.
- Output voltage of buck boost converter is 60 V. this voltage is given to the 8 subsystem of multilevel inverter. That means total output voltage of converter is

480 V. with the help of PWM controller we get 440V as an output from the inverter. And we supply this 440V to the grid.

Specifications for 250 W modules are:

- Number of series connected cells : 60
- Open circuit voltage : Voc= 36 V
- Short circuit current: Isc= 8.8 A
- Voltage and current at maximum power: Vmp= 30 V, Imp= 8.4V

These ratings are at STC 1000 w/m^2, 1.5 AM,25°C.

The photovoltaic system is designed using a 15 KW array in centralized mode. In the photovoltaic array when 2 panels are connected in series and 24 panels are connected in parallel than we are getting 74 volt as output from the panel. We are giving this 74 volt as input to buck boost converter and we are using its buck mode which bucks it to 60 volts. And in the solar array when 1 panel is connected in series and 39 panels are connected in parallel we are getting 45 V as output from photovoltaic array. We are giving this 45 volt as input to buck boost converter and we are using its boost mode which steps up it to 60 volt. With the help of buck boost converter we get constant voltage. We are giving this 60 volts as an input to 8 subsystem of multilevel inverter. From that we are getting 440 volt as output. We supply this voltage to grid.

IV. MATLAB SIMULINK RESULTS

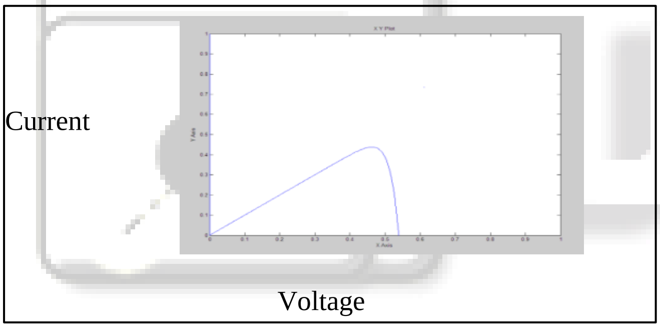

Fig. 1.10: Output I-V Characteristics with Varying Irradiation (1000W/M^2)

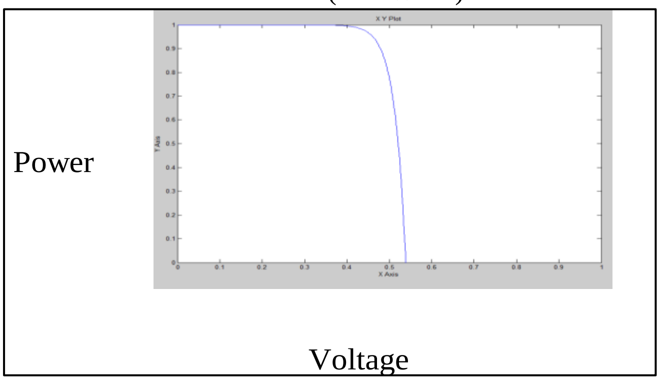

Fig. 1.11: Output P-V Characteristic with Varying Irradiation (1000 W/M2)

Fig. 1.10 shows the with varying irradiation (1000W/m^2) at constant temperature the I-V output characteristics of photovoltaic module. Fig. 1.11 shows the with varying irradiation (1000W/m^2) at constant temperature the P-V output characteristics of PV module.

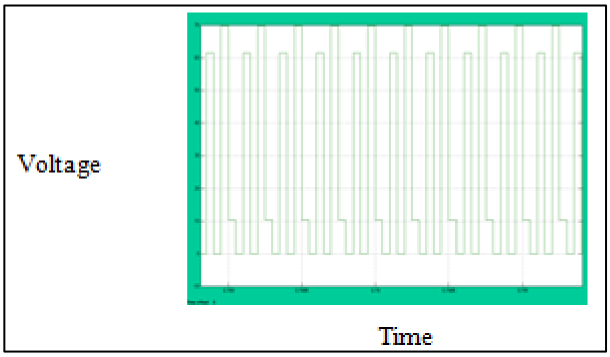

Fig. 1.12: Simulation waveform of buck boost converter at 60V when the input voltage is 74V.

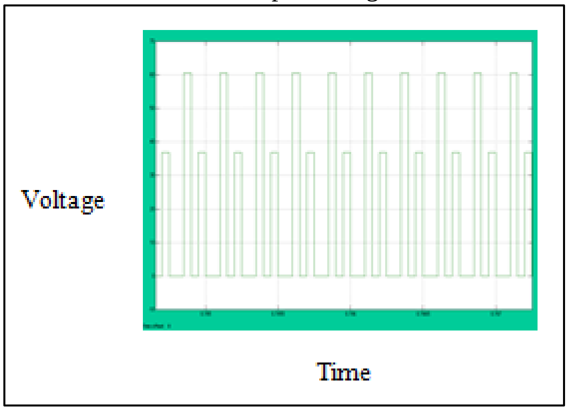

Fig. 1.13: Simulation waveform of buck boost converter at 60V when the input voltage is 45V.

Fig 1.12 and 1.13 shows the output voltage of buck boost converter is 60 V.

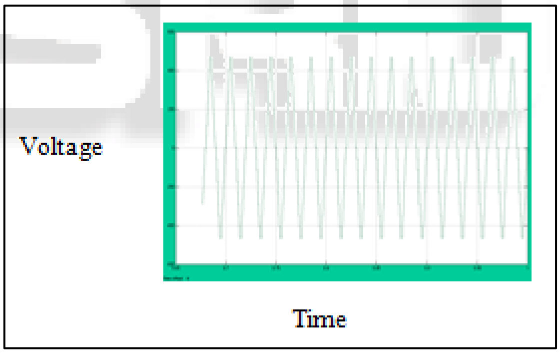

Fig. 1.14: Simulation Waveform of Multilevel Inverter at voltage 440V.

At 440 V the simulation waveform of multilevel inverter is shown in fig 1.14.

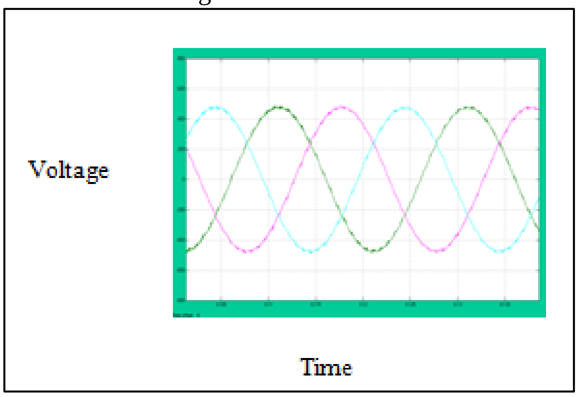

Fig. 1.15: Simulation Waveform Of Three Phase Grid-Connected Photovoltaic System at 440 V

Fig. 1.15 shows the grid voltage is 440 V. at 1000 W/m^2 solar irradiation when system voltage is 74V then the injected current to grid is near about 202 A. and when the system voltage is 45 V then the injected current to grid is 333 A.

V. CONCLUSION

This project presents a study on the analysis and simulation of three phase grid connected photovoltaic system. The main three common power electronics devices used in this project are DC-DC buck boost converter, MPPT and multilevel inverter. Modeling of a PV module, buck-boost converter, MPPT and multilevel inverter is shown in the simulation model. For varying temperature & varying irradiance we get the curve between I-V and P-V is shown. In this project we coupled the PV array to the grid through buck boost converter and multilevel inverter. In high solar radiation level, the output of PV array is high. The output of photovoltaic array depends on the solar radiation. Vary the input radiation and get the constant output voltage of buck boost converter. The grid required AC supply, to achieve the DC-AC power for grid we used inverter to convert the DC supply into AC supply.

REFERENCES

[1] Santosh S. Raghuwanshi[1], Kamlesh Gupta[2],"Modelling Of a Single-Phase Grid-Connected Photovoltaic System Using MATLAB /Simulink", IEEE International Conference on Compute, Communication abd Control (IC4-2015).
[2] Almas Hossain Mollah[1], Prof. GK Panda[2], Prof. P K Saha[3], " Three Phase Grid Connected Photovoltaic System With Maximum Power Point Tracking", International Journal Of Advanced Research In Electrical, Electronics And Instrumentation Engineering, Vol. 4, Issue 5, May 2015.
[3] Jeyraj Selvaraj, Nasrudin A. Rahim, " Multilevel Inverter For Grid – Connected PV System Employing Digital PI C controller", IEEE Transactions On Industrial Electronics, vol. 56 , No. 1, pp. 149-158, 2009.
[4] Savita Nema, R. K. Nema, Gayatri Agnihotri, " MATLAB / Simulink Based Study Of Photovoltaic Cells / Modules / array / And Their Experiment Verification", International Journal Of Energy And Environment, vol.1, No. 3, pp 487-5000,2010.
[5] Huan- Liang Tsai, Ci-Siang Tu, Yi-Jie Su, " Development Of Generalized Photovoltaic Model Using MATLAB / Simulink", Proceedings Of The World Congress On Engineering And Computer Science WCECS, San Francisco, USA, 2008.
[6] Calais , M., Myrzik J. M. A., Spooner T., Agelids, V.G., Inverters For " Single-Phase Grid Connected Photovoltaic System"- A Review, IEEE Power Technology Conference Proceeding, vol. 2, Pages (S): 8 PP.,2003.
[7] M.G. Molina, And P. E. Mercado "Modeling And Control Of Grid Connected PV Energy Conversion System Used As a Disersed Generator", 978-1-4244-2218-0/08/2008 IEEE.
[8] Peng Lei, Yaoyu Li, Member, IEEE, And John E. Seem, Member, IEEE " Sequential Esc- Based Global MPPT Control For Photovoltaic Array With Variable Shading", IEEE Transactions On Sustainable Energy, vol, 2,No. 3, July 2011.
[9] S. Leva, D. Zaninelli, "Technical And Financial Analysis For Hybrid Photovoltaic Power Generation System", WSEAS Transactions On Power Systems, vol. 5, No. 1, May 2006, pp. 831-838.
[10] Pritam Chowdhury[1], Indrajit Koley[2], Sougata Sen[3], Dr.Pradeeo Kumar Saha[4], Dr. Gautam Kumar Panda[5], " Modeling Simulation And Control Of A Grid Connected Non Conventional Solar Power Generation System Using MATLAB " , International Journal Of Advanced Research IN Electrical, Electronics And Instrumentation Engineering, vol.2, Issue 4 , Apri l 2013.