

Matlab/Simulink Based Modelling and Simulation of Residential Grid Connected Solar Photovoltaic System

L Siva Chaitanya Kumar¹

PG Student

Department of Electrical Engineering
Andhra University College of Engineering (A)
Visakhapatnam, Andhra Pradesh, India.

K Padma²

Assistant Professor

Department of Electrical Engineering
Andhra University College of Engineering (A)
Visakhapatnam, Andhra Pradesh, India.

Abstract- Solar energy maintains life on the earth and it is an infinite source of clean energy. Over fifty years, numerous studies have been performed on different design aspects and performance characteristics of Photovoltaic (PV) cells with a common goal of producing fully integrated PV modules to compete with the traditional energy sources. There is an increasing trend for the use of solar cells in industry and domestic appliances because solar energy is expected to play significant role in future smart grids as distributed renewable source. This reviews the generalized mathematical modelling and simulation of Solar Photovoltaic System. One-diode equivalent circuit is employed in order to investigate I-V, P-I and P-V characteristics of a 170W Mitsubishi solar module Perturb and Observe MPPT algorithm, Step up DC-DC transformer, PMDC motor and a Single phase grid tied inverter using MATLAB/Simulink.

Keywords— Boost Converter, Choppers, DC-AC Converter DC-DC Converter, Grid, Inverter, Maximum Power Point (MPP), Maximum Power Point Technique (MPPT), Perturb and Observe (P&O), Pulse Width Modulation (PWM), Solar Photo-voltaic System (PV), Photo-voltaic modelling, Standard Test Condition (STC), Step up DC Transformer, Matlab/Simulink R2013a.

I. INTRODUCTION

Among the renewable energy resources, the energy due to the photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resource because of the ubiquity, abundance, and sustainability of solar radiant energy.

Regardless of the intermittency of sunlight, solar energy is widely available and is free. Recently, Photovoltaic system is recognized to be in the forefront in renewable electric power generation. It can generate direct current electricity without environmental impact and contamination when exposed to solar radiation. Being a semiconductor device, the PV system is static, quiet, free of moving parts, and has little operation and maintenance costs. Application of Photovoltaic as electrical energy source shows increasing trend both in implementation on spread area over the world and in capacity of plant. This trend is triggered by many factors such as the increasing of fossil fuel cost and declination of production cost per kW electric from Photovoltaic and also technology

development that cause the Photovoltaic power conversion more efficient [1].

PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of a PV module depend on the solar insolation, the cell temperature and the output voltage of the PV module. Owing to changes in the solar radiation energy and the cell operating temperature, the output power of a solar array is not constant at all times. Consequently, during the design process of PV array powered systems; a simulation must be performed for system analysis and parameter settings. Therefore an efficient user friendly simulation model of the PV arrays is always needed. The PV array model proposed in this paper is a circuitry based model to be used with Simulink.

Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications. Photovoltaic generation system can either be operated in isolated system or be connected to the grid to form integrated system, and with other electrical renewable energy source can form distributed renewable energy generation [9] as shown in figure 1.

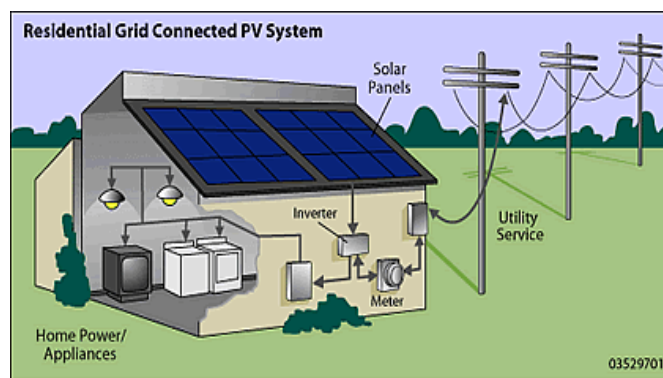


Figure 1. Residential Grid tied PV System

Other aspect concerning to application of photovoltaic as a part of distributed generation is the power quality resulted from their operation, especially for voltage unbalance and

harmonics. Trend application of some single phase PV inverters and its PV array connected together to supply three phase system as alteration of high capacity centralized three phase PV inverter can be a factor that effect to unbalance grid voltage due to diversity of irradiance among array.

II. PV MODULE MATHEMATICAL MODELLING

a. Solar cell

A Solar cell (also called a Photo-Voltaic cell) is an electrical device that converts the electrical energy of light directly into electricity as in figure 2 and figure 3.

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. Regardless of size, a typical silicon PV cell produces about 0.5-0.6 volt DC under open circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 1.580*0.800 square metres will produce about 170W peak power.

If the sunlight intensity were 40 percent of peak, this cell would produce about 67W [1].

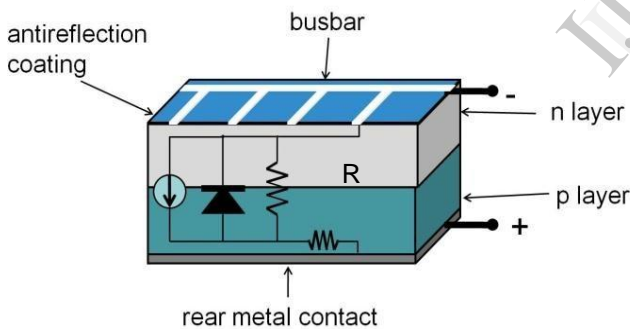


Figure 2. PV module configurations in a PV plant

b. Mathematical modelling of a solar cell

The mathematical modelling describing the figure 2 and figure 3 of a solar cell is given as:

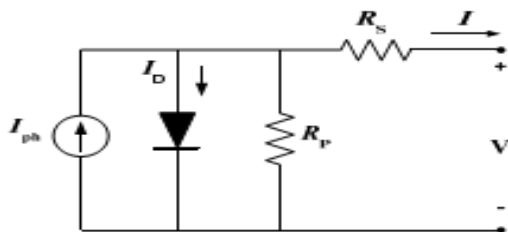


Figure 3. Equivalent circuit of a Solar cell

$$I = I_{ph} - I_d \quad \text{(Ideal solar cell)} \tag{1}$$

$$I_{ph} = (I_{sc} + K_i(T - T_r)) \tag{2}$$

$$I_d = I_{sat} \left(e^{\frac{V}{N_s A V_T}} - 1 \right) \tag{3}$$

$$V_T = \frac{kT}{q} \tag{4}$$

(Practical solar cell)

$$I = I_{ph} - I_{sat} \left(e^{\frac{V + IR_s}{N_s A V_T}} - 1 \right) + \frac{V + IR_s}{R_p} \tag{5}$$

Where,

I_{ph} is photon generated current (A)

I is Load current (A)

I_d is diode current (A)

I_{sat} is saturation current of Diode (A)

V is Forward Voltage (V)

q is electron Charge (1.60217646 e-19 Coulomb)

A is diode ideality factor ($1 \leq A \leq 1.5$)

K is Boltzmann constant (1.3806503 e-23 J/K)

V_T is the diode thermal voltage

S is solar irradiation (Watt per square meters)

T is Temperature [Kelvin]

R_s is Series resistance (Ω)

R_p is Shunt resistance (Ω)

The equation for a single diode equivalent equation for a solar cell under illumination is given in equation (2).

Using solar cell equations (1), (2) and (3), model of PV module is built in Simulink. The model of a solar cell is shown in Figure 2 which is coded to obtain a PV module.

i. Light generated current

The short circuit current (I_{sc}) is the current value that occurs when the voltage is zero ($V=0$). The I_{sc} is equivalent to the photo generated current (I_{ph}) unless the series resistance is high and there is a significant amount of leakage current flowing through the shunt resistance.

ii. Open circuit voltage

The open circuit voltage (V_{oc}) is a measure of the voltage across the PV module terminal when the leads are left open ($I=0$). It can be expressed as

$$V_{oc} = V_T \ln \left(\frac{I_{ph}}{I_{sat}} + 1 \right) \tag{6}$$

iii. Fill factor

The Fill factor (FF) is the ratio of maximum power output to the product of short circuit current (I_{sc}) and open circuit voltage (V_{oc}).

$$FF = \frac{P_{max}}{V_{oc} I_{sc}} \tag{7}$$

iv. Efficiency

The efficiency of the solar module can be calculated from the equation

$$\eta = \frac{P_{max}}{SA} \tag{8}$$

c. Solar modules and Arrays

Due to the low voltage of an individual solar cell (typically 0.5-0.6V), several cells are wired in series in the manufacture of a "laminare". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel.

Modules may then be strung together into a photovoltaic array.

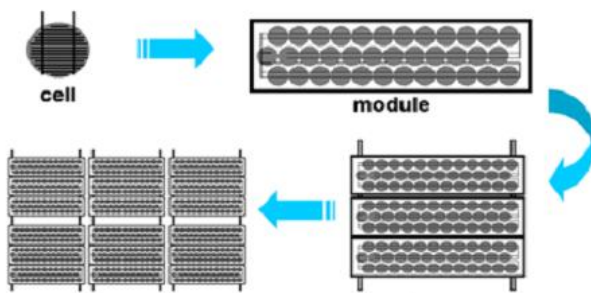


Figure 4. Photovoltaic cell, module, arrays and panels.

d. Specifications of MITSUBISHI PV-Module

Model name	MITSUBISHI PV-MF170EB3 _{170WP}
Cell type	Polycrystalline silicon 150mm square
No. of cells	50 in series
Maximum Power rating (Pmax)	170W
Warranted minimum Pmax	161.5W
Open circuit voltage (Voc)	30.6V
Short circuit current (Isc)	7.38A
Maximum Power Voltage(Vmp)	24.6V
Maximum Power Current (Imp)	6.93A
Dimensions	1580*800*46mm (62.2*31.5*1.8")
Weight	15.5kg
Module efficiency	13.5%

e. Characteristics of a PV cell

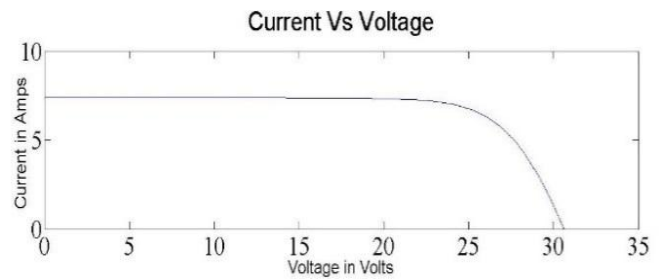


Figure 5. Current Vs Voltage curve at STC

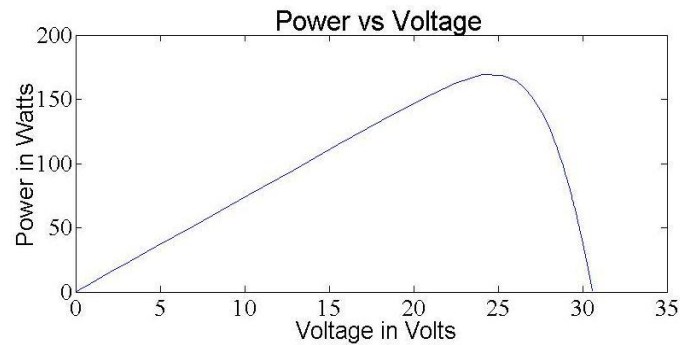


Figure 6. Power Vs Voltage curve at STC

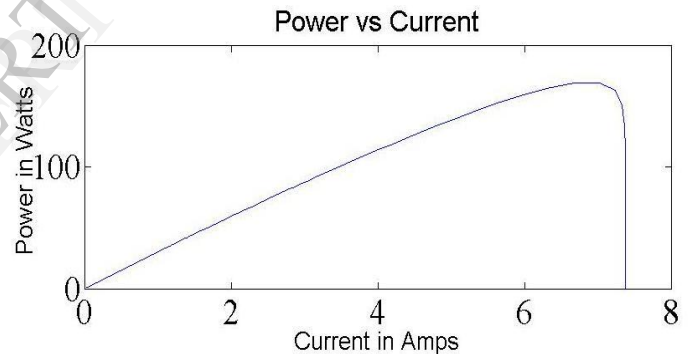


Figure 7. Power Vs Current curve at STC

f. P-V, I-V and P-I characteristics of a MITSUBISHI PV-MF170EB3_{170WP} under different climatic conditions

i. Impact of Solar irradiation

Change in Irradiance affects the photon generated current, corresponding change on the open circuit voltage is less. The short circuit current (Isc) is directly proportional to the solar insolation (Irradiation). Thus, the change in photon generated current by the variation in irradiance is given by,

$$I_{sc}(S) = I_{scr} \left(\frac{S}{S_r} \right) \tag{9}$$

Where

S is the Irradiation (W/m²)

Sr is the Irradiance at STC (1000W/m²)

Iscr is the short circuit current at STC (A)

Cutting the Irradiance in half, for instance, leads to drop in Isc by half. Decreasing irradiance also reduces Voc, but it does so follows a logarithmic relationship that results in a relatively modest changes of Voc. The relationship may be described as follows:

$$V_{oc}(S) = V_{oc}(S_r) + N_s V_T \ln\left(\frac{S}{S_r}\right) \tag{10}$$

$$V_{mp}(S) = V_{mp}(S_r) + N_s V_T \ln\left(\frac{S}{S_r}\right) \tag{11}$$

$$I_{mp}(S) = I_{mp}\left(\frac{S}{S_r}\right) S_r \tag{12}$$

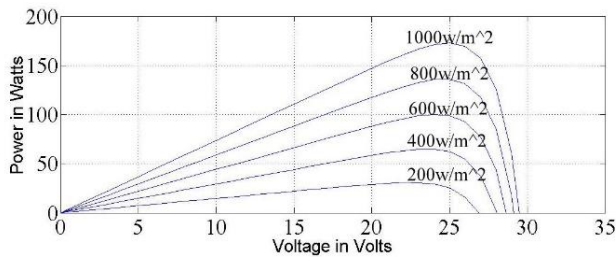


Figure 8. Power vs voltage curve

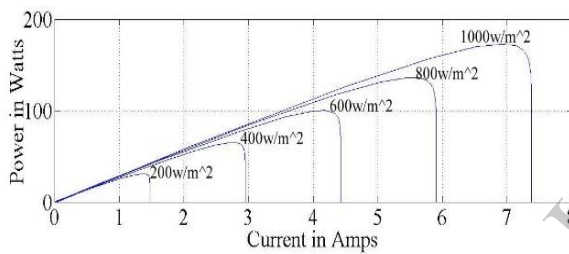


Figure 9. Power vs current curve

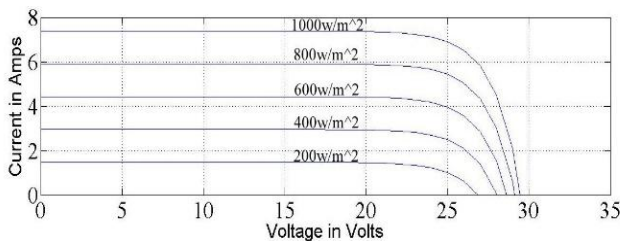


Figure 10. Current vs voltage curve

Figure 8, Figure 9 and Figure 10 demonstrate the results of the generated curves at different irradiation values related to the STC ($T=25^{\circ}\text{C}$). K_i and K_v are obtained from the datasheet as $0.057\%/^{\circ}\text{C}$ and $-0.346\%/^{\circ}\text{C}$, respectively.

ii. Impact of temperature

Further temperature variation also affects the open circuit voltage, corresponding short circuit current change is less. For almost all PV devices, high operating temperatures significantly reduce their voltage output. On the other hand their current increase with temperature, but only slightly, so the net result is a decrease in power and efficiency. If modules are exposed to high temperatures for a long time, this may

lead to an early degradation of the module encapsulation. PV systems in general, perform the best on normal, clear days than hot ones. To forecast the PV module I-V and P-V characteristics on temperatures other than the standard test condition, one needs temperature coefficients from datasheet for the module used.

The Change of temperature has an effect on the performance of the PV module according to the following equations

$$V_{oc}(T) = V_{oc}(T_r) + K_v(T - T_r) \tag{13}$$

$$I_{sc}(T) = I_{sc}(T_r) + K_i(T - T_r) \tag{14}$$

$$I_{sat}(T) = \frac{I_{sc}(T)}{\frac{V_{oc}}{eAN_sV_T} - 1} \tag{15}$$

$$I_{ph}(T) = I_{ph}(STC) + K_i(T - T_r) \tag{16}$$

$$I_{mp}(T) = I_{mp}(T_r) + K_i(T - T_r) \tag{17}$$

$$V_{mp}(T) = V_{mp}(T_r) + K_v(T - T_r) \tag{18}$$

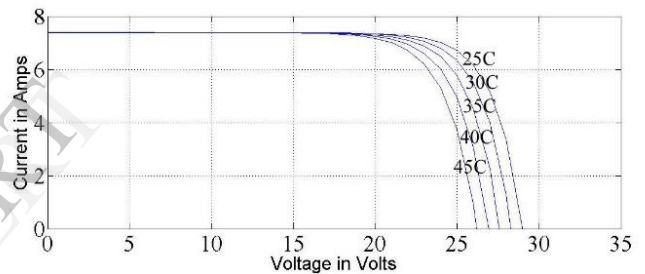


Figure 11. Current vs voltage curve

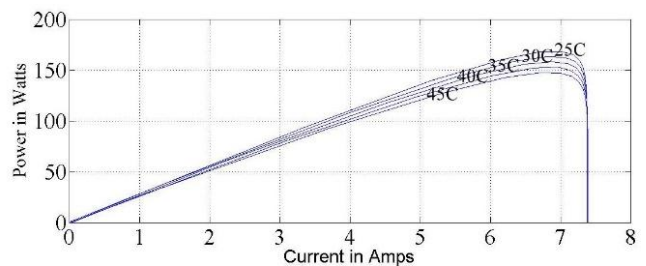


Figure 12. Power vs current curve

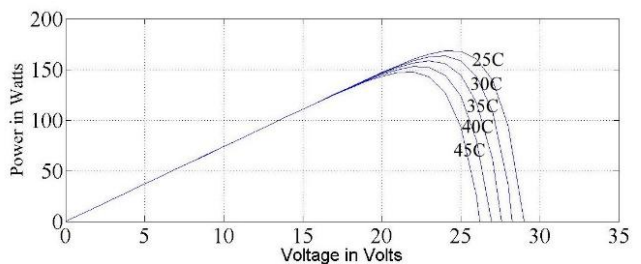


Figure 13. Power vs Voltage curve

Figure 11, Figure 12 and Figure 13 demonstrate the results of the generated curves at different temperature values related to the data at STC ($T=25^{\circ}\text{C}$). K_i and K_v are obtained from the datasheet as $0.057\%/^{\circ}\text{C}$ and $-0.346\%/^{\circ}\text{C}$, respectively.

III. MAXIMUM POWER POINT TRACKING (MPPT)

a. Maximum Power point(MPP) and Perturb and Observe Algorithm

For PV converters the maximum power available is decided by the PV cell characteristics, but this value often mismatches the maximum power point (MPP) of the load. By implementing MPPT in a PV system, the MPP of the PV cell can be maintained (i.e. tracked) and hence the number and size of the PV panels can be reduced or the energy yield can be optimized.

Due to moving Sun, which leads to change in irradiance Angle on the PV panels and the variation in amount of the Irradiation hitting the panels, the energy which the PV panels are able to absorb do not stay constant over time. When this happens, the I-V characteristics changes and the MPP will move. If the system was previously operating at the MPP, there will most probably a power loss with same operating point and new conditions.

To overcome this problem, MPPT has been developed. This system includes no moving parts (where the modules are turned to track the Sun).

MPPT tracks/searches for the maximum power independent of the environment conditions (like variable Solar Irradiation and Temperature) and making the PV terminal voltage is set constant at maximum value. The most used method of MPPT is Perturb and Observe (P&O) method. The Perturb and Observe (P&O) algorithm is as shown in figure 14.

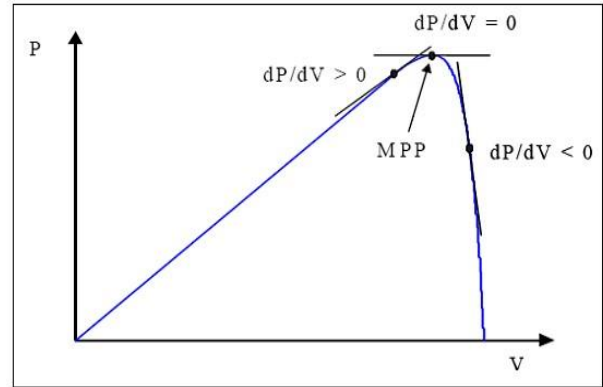


Figure 15. Power vs current curve showing MPP

Perturbation (dV)	Change in power (dP)	Next perturbation (Action)
$dV > 0$	$dP > 0$	Positive
$dV > 0$	$dP < 0$	Negative
$dV < 0$	$dP > 0$	Negative
$dV < 0$	$dP < 0$	Positive

Table 1. Summary of the working principle of the P&O algorithm

b. Advantages of Perturb & Observe algorithm

P&O MPPT algorithms are easily implemented in digital circuits. We know that only terminal voltage and current of PV panels are sampled to compute the output power of PV panels and result is compared with previous one to determine the direction of next perturbation depending on the comparison results, which can be easily done with digital circuits

P&O methods have desirable adaptability to slowly fluctuating solar irradiation, temperature, and even variation of the PV panels.

P&O method is cheap, requiring only panel voltage and current measurements.

IV. DC-DC CONVERTERS (CHOPPERS)

a. DC-DC Converter

A DC-DC converter is a static device which converts or transfers the DC Power from one circuit to another from fixed voltage to variable and vice versa. In high power applications these are called Choppers circuits Switched mode power systems (SMPS).

A chopper is a high speed on/off semiconductor switch [5]. DC/DC converter also helps in regulating the PV output voltage to the required level. Buck, Boost and Buck-boost converters are used for power conditioning purposes [11].

In Buck and Buck-boost, the source current is highly discontinuous due to the presence of high frequency mosfet switch on the source side. The source current will have more harmonic distortion. In order to filter out these harmonics, these three topologies require additional source filter, where as in Boost converter input inductor will serve the purpose and there doesn't require source filter.

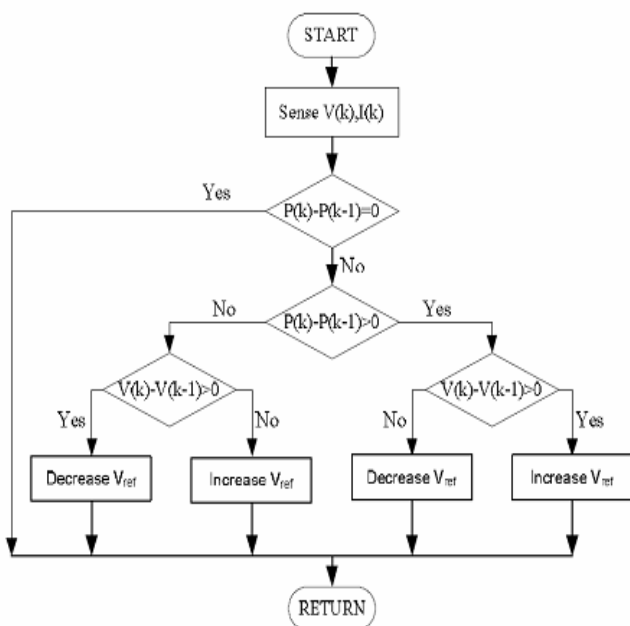


Figure 14. Perturb And Observe Algorithm

b. Boost converter

Boost Converter is a DC-DC converter for which output voltage is greater than input voltage. When the MOSFET switch is ON, the current through the inductor increases and the inductor starts to store energy. When the MOSFET switch is closed, the energy stored in the

S.no	Parameter	Value
1.	Input Voltage(Vs)	75V
2.	Output Voltage(V0)	250V
3.	Switching frequency(Fsw)	2500Hz
4.	Inductor(L)	105mH
5.	Capacitor(C)	170μF

inductor starts dissipating. The current from the voltage source and the inductor flows through the fly back Diode D to the load. The Voltage across the load is greater than the input voltage and is dependent on the rate of change of the inductor current. Thus the average voltage across the load is greater than the input voltage and is determined with help of the duty cycle of the gate pulse to the MOSFET switch [5].

Figure 16 shows the schematic diagram for the boost converter used in this research work to step up the PV output voltage to a higher level suitable for the DC/AC inverter operation that connected to the utility grid [11].

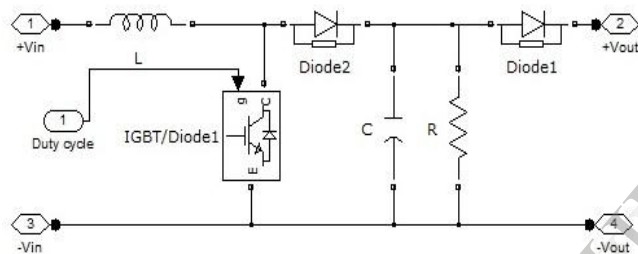


Figure 16. Boost converter (step up)

$$V_o = \frac{V_s}{1-D} \quad (19)$$

$$D = \frac{T_{on}}{T_{sw}} \quad (20)$$

$$T_{sw} = T_{on} + T_{off} \quad (21)$$

Where

Vs is source voltage

Vo is the output voltage of the converter

D is the duty cycle

Fsw=1/Tsw is switching frequency of the converter

Ton is on time period of the semiconductor switch

Toff is off time period of the semiconductor switch

c. DC-DC Converter control in PV converter Systems

All electrical systems containing a converter stage with controllable switches often requires some sort of control. This control ensures that the required power available is transferred to the output according to the pre-set limitations.

$$V_o = f(D) \quad (22)$$

d. Sizing of a Boost Converter

$$L \geq \frac{V_s D}{\Delta I_{Fsw}} \quad (23)$$

$$C \geq \frac{I_o D}{\Delta V_{Fsw}} \quad (24)$$

Where,

L is the Inductance (H)

C is the Capacitance (F)

Table 2. Parameters of boost converter

e. DC-link capacitor

The dc link capacitor (Cdc) reduces the voltage ripple in the input to the DC-AC converter (Inverter) and also provides a hold-up time during which the insolation swings quickly between high and low.

Sizing of DC link Capacitor

$$C_{dc} = \frac{P}{2\omega_g V_{dc} \Delta V} \quad (25)$$

Where

P is Power of PV plant

ω is the frequency of the grid

Vdc is the input voltage to the inverter

ΔV is the ripple in the inverter output voltage

The battery plays an important role in case of the solar power system. The battery stores part of the energy generated by the solar PV power source and delivers to the load during the periods when the solar power source is unable to supply the power to the load due to any reason.

The capacity of the battery depends on the daily load and days of autonomy.

V. PERMANENT MAGNET DC (PMDC) MOTOR

a. DC Motor

An Electric Motor is a Machine which consumes electrical energy into mechanical energy, and due to its straightforward operating characteristics and simple and stable control, it is still being used to some extent in speed-controlled applications. The speed of the motor is controlled by controlling the armature voltage, and the torque by the armature current, that is, the flux and the torque can easily be controlled separately. This is the main principle on which all the modern AC control methods nowadays rely. The first DC motors were controlled with some chopper technology, such as the pulse width modulation (PWM). Network-connected thyristor bridges were mainly used in higher power range, typically in a variety of applications such as in printing and paper industry, passenger lifts, and any kinds of drives subjected to high transient loading, such as in rolling mills. Chopper technology was mainly used in the lower power range, such as in machine tool applications.

b. Mathematical modelling of PMDC Motor

Development in permanent magnet materials introduced a permanent magnet DC (PMDC) motor, in which the stator excitation coil was replaced by permanent magnets [14].

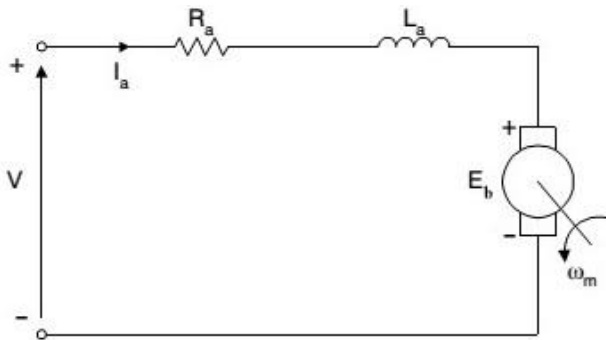


Figure 17. Circuit of the PMDC Motor

The Voltage (V) across motor under steady state is related to the armature Current (I_a), armature resistance and the back Emf (E_b):

$$V = E_b + I_a R_a \quad (26)$$

$$I_a = \frac{V - E_b}{R_a} \quad (27)$$

$$\omega_m = \frac{2\pi N}{60} \quad (28)$$

From the basic principle of DC motor, we can write as:

$$E_b I_a = T_e \omega_m \quad (29)$$

On rearranging equations (28) and (29)

$$T_e = \frac{\phi Z P I_a}{2\pi A} = K_m I_a \quad (30)$$

$$E_b = K_m \omega_m \quad (31)$$

From equations (27) and (31)

$$\omega_m = \frac{V - I_a R_a}{K_m} \quad (32)$$

However, the speed control of permanent-magnet DC motor via changing the field current is not possible. Its dynamical model in Figure 17 can be summarized as [13]:

$$L_a \frac{di_a}{dt} = V - I_a R_a - K_m \omega_m \quad (33)$$

$$J \frac{d\omega_m}{dt} = k_m i_a - T_L \quad (34)$$

$$\frac{di_a}{dt} = \frac{1}{L_a} (V - I_a R_a + K_m \omega_m) \quad (35)$$

$$\frac{d\omega_m}{dt} = \frac{1}{J} (T_e - T_l - B_m \omega_m) \quad (36)$$

Where,

K_m is the Torque Constant (V/rpm)

ω_m is the No load speed (rpm)

T_e is the electrical torque (Nm)

T_l is the Load torque (Nm)

J is the Rotor moment of inertia (gcm^2)

B_m is the Friction torque (Nm)

b. Advantages of PMDC Motor

Due to absence of the field current and field winding, permanent magnet machines exhibit high efficiency in operation, simple and robust structure in construction, some advantages in using permanent magnet excitation were decreased copper losses, higher power density, and a smaller torque ripple at low speeds. Using permanent magnet material in the magnetic circuit causes a low armature inductance and hence a low armature reaction. Extremely linear speed-torque characteristics of the motor, which result from the permanent magnet-provided constant field flux at all speeds, makes the control of the PMDC very straightforward; the speed of the motor is controlled by simply adjusting the armature DC voltage. PMDC machines were, however, limited to the lower power range due to the absence of the proper magnets until the 1980s. Typical applications of PMDC were low-voltage battery powered applications, such as machine tools, automotive auxiliary drive applications, and solar powered applications. Above the 10 kW range, the separately excited DC motor was the only solution, as it provided high dynamic performance especially when fully compensated.

c. Specifications of FAULHABER SERIES 2607 SR

Model name	FAULHABER SERIES 2607 SR
Nominal Voltage(V)	24
Armature Resistance(R_a)	128 Ω
Armature Reactance(L_a)	8.400 μH
No load speed(ω_m)	6200rpm
Torque Constant(K_m)	3.83mV/rpm
Rotor Inertia(J)	0.68 gcm^2
Friction Torque(B)	0.07mNm

VI. DC/AC CONVERTER (INVERTER)

In this paper single phase full bridge inverter is used. This is the DC-AC stage that converts DC power into AC power at desired output voltage and frequency. The power stage designed in this paper converts the 250V DC output voltage of the DC-DC converter to the grid voltage of 230V AC – 240V AC at 50 Hz frequency.

The single phase full bridge topology is shown in Figure 18 which consists of four switching devices, two of them on each leg. Single-phase converters are used where transformation between DC and AC Voltage is required; more precisely where converters transfer power back and forth between DC and AC [5]. Unfiltered output voltage is created by switching the full-bridge in an appropriate sequence.

The output voltage of the bridge, V_{ab} can be either be $+V_d$, V_d or 0 voltage depending on how the switches are controlled [5].

The input voltage V_d at the DC link or bus link capacitor C is a fixed-magnitude voltage and the output voltage is V_{ab} which can be controlled in both polarity and magnitude. The DC/AC inverter allows the PV to be connected to the grid [12]. Its main tasks are to generate an AC voltage that follows the grid one with the same frequency as well as producing as low harmonics as possible [10]. It uses PWM scheme with a switching frequency in the range of 2-20 kHz.

In PV generation system, PV inverter hold the role as interface between photovoltaic module and ac power grid. In this function, PV inverter and associated generation system equipment should have ability to maximize power extracting from the array, match DC voltage output from PV array, produce sinusoidal ac voltage with minimum distortion on output side, and control the power flow.

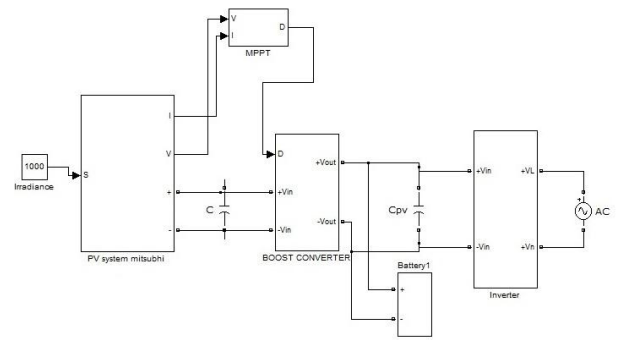


Figure 19. Matlab/Simulink model of Single phase grid connected Photo-voltaic System

VII. SIMULATION RESULTS

The basic characteristics of a PV cell are obtained using Matlab/Simulink as shown in figure 5, figure 6 and figure 7. Also with different climatic conditions are as shown in figure 8, figure 9, figure 10, figure 11, figure 12, and figure 13.

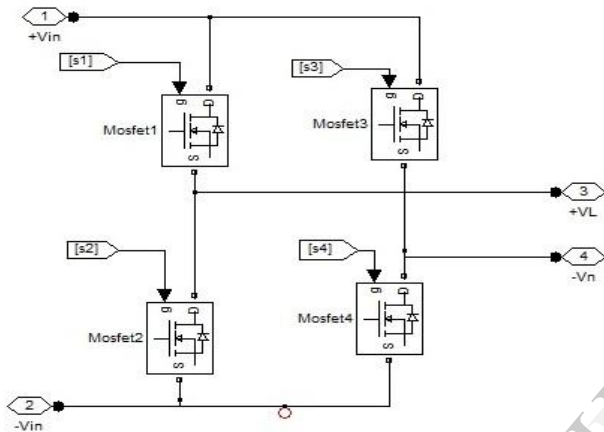


Figure 18. Single Phase full bridge Inverter

A low-pass (LC) filter is used to get the desired output voltage (50 Hz fundamental frequency) by separating it from the switching frequency and rejects any frequency above its cut-off frequency. The cut off frequency can be obtained by equation (37) as

$$f_c = \frac{1}{2\pi\sqrt{LC}} \tag{37}$$

The switching harmonics resulted from 20 kHz switching frequency are around half the switching frequency. The switching frequency is selected at 20 kHz to provide clean 50Hz fundamental frequency [15].

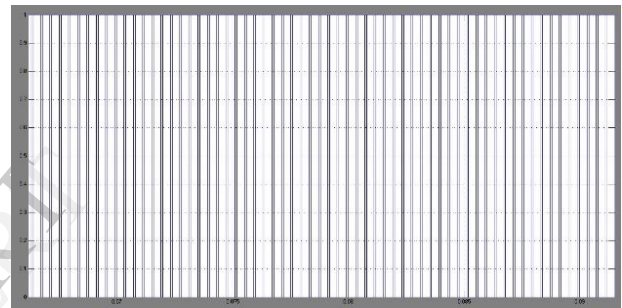


Figure 20. Duty cycle from the MPPT algorithm

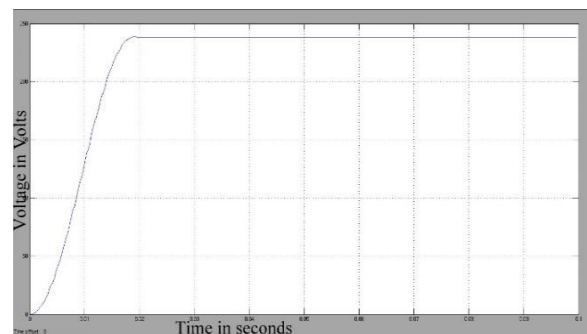


Figure 21. Output Voltage wave of boost converter

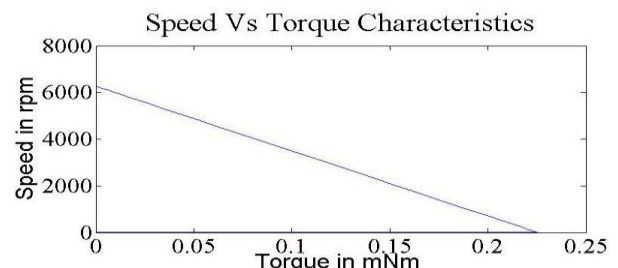


Figure 22. Speed vs Torque at 1000Watts per square metres

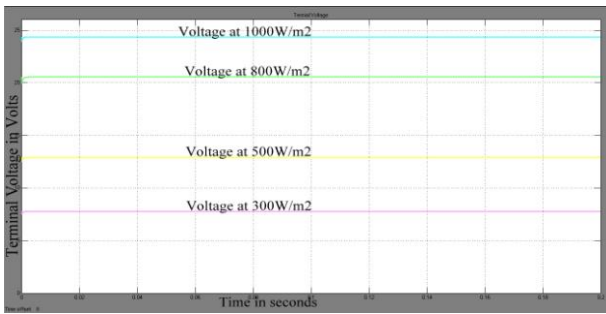


Figure 23. Terminal Voltage at different Irradiations

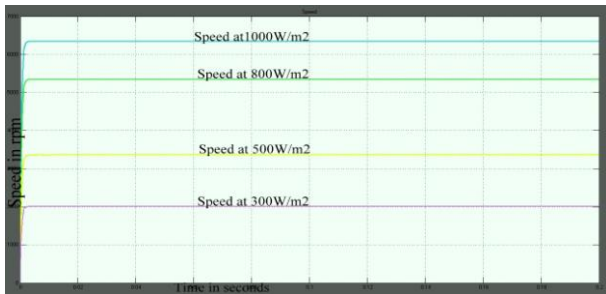


Figure 24. Speed at different Irradiations

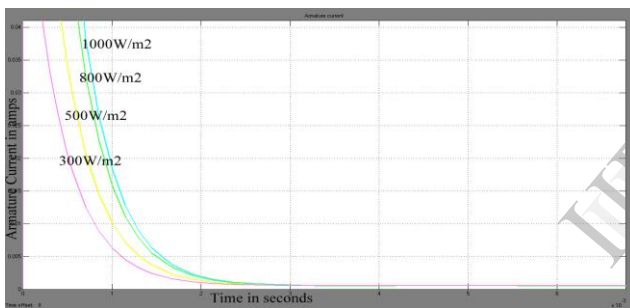


Figure 25. Armature Current at different Irradiations

Irradiation of the Sun in W/m ²	Speed of the motor in rpm	Terminal Voltage in volts	Armature Current in amps
1000	6343	24.35	0.5468*10 ⁻³
800	5346	20.53	0.5468*10 ⁻³
600	4029	15.49	0.5468*10 ⁻³
400	2682	10.33	0.5468*10 ⁻³
200	1333	5.164	0.5468*10 ⁻³

Table 3. Speed, Terminal Voltage and Speed at different Irradiations

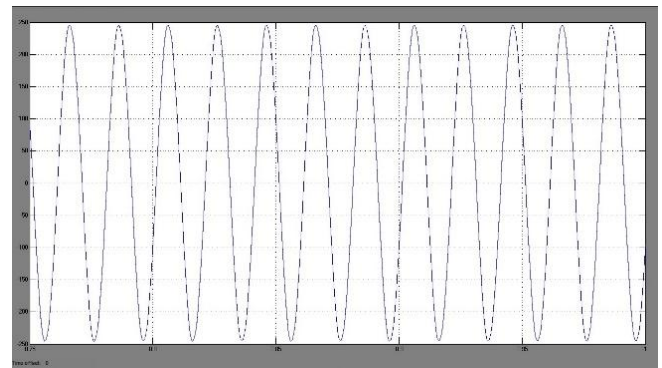


Figure 26. Output voltage wave of Inverter

VIII. CONCLUSION

In order to convert the solar energy efficiently, the maximum power point of the PV array should be tracked to ensure the PV array provide most power to both grid and the load. When solar irradiance or temperature fluctuates, PV generation will change as a result. The controller must act to maintain the DC bus voltage constant as possible and improve the stability of the whole system. A Solar Coupled PMDC motor model has been selected and proposed as the DC load in order to give an example of Standalone DC load feeding. Residential grid-connected photovoltaic power systems which have a capacity less than 10 kilowatts can meet the load of most consumers. They can feed excess power to the grid, which in this case acts as a battery for the system. Photovoltaic wattage may be less than average consumption, in which case the consumer will continue to purchase grid energy, but a lesser amount than previously. If photovoltaic wattage substantially exceeds average consumption, the energy produced by the panels will be much in excess of the demand. In this case, the excess power can yield revenue by selling it to the grid shown in figure 1 and figure 19. Depending on their agreement with their local grid energy company, the consumer only needs to pay the cost of electricity consumed less the value of electricity generated. This will be a negative number if more electricity is generated than consumed. Additionally, in some cases, cash incentives are paid from the grid operator to the consumer.

REFERENCES

- [1] <http://global.mitsubshielectric.com/solar>
- [2] Kjaer SB, Pedersen JK, Blaabjerg F., "A review of single-phase grid-connected inverters for photovoltaic modules" IEEE Trans IndAppl Sep./Oct. 2005;41(5):1292-306
- [3] .Ayedh H. ALQahtani, "A Simplified and Accurate Photovoltaic Module Parameters Extraction Approach using Matlab", Industrial Electronics (ISIE), 2014 IEEE International Symposium pp. 1748-1753, 28-31 may 2012.
- [4] D. B. Raut & A. Bhattarai, "Performance Analysis of Grid Connected Solar PV System Using Matlab/Simulink", Rentech Symposium Compendium Volume 3, pp. 48-54, September 2013.
- [5] M.D Singh & K B Khanchandani (2011), "Power Electronics", Tata Mcgraw Hill publishers, Second edition, pp. 135-670.
- [6] I. H. Altas and A.M. Sharaf, "A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment," IEEE, Clean Electrical Power,

- International Conference on Clean Electrical Power (ICCEP '07), June 14-16, 2007, Ischia, Italy.
- [7] Matlab and Simulink, the Math works, Inc. as of December 2013, <http://www.mathworks.com>.
- [8] <http://www.faulhaber.com/servlet/com>.
- [9] http://solarwork.com/greatsolar_solarpvelectric.html
- [10] Zhilei Yao and Lan Xiao, "Control of Single-Phase Grid-Connected Inverters ", IEEE Transactions On Industrial Electronics, Vol. 60, No. 4, pp. 1384-1389 April 2013
- [11] Syam M S & T. Sreejith Kailas, "Grid Connected PV System using Cuk Converter", International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013).
- [12] Neha Adhikari, Bhim Singh & A.L.Vyas, "Design and Control of Small Power Standalone Solar PV Energy System", Asian Power Electronics Journal, Vol. 6, No. 1, pp. 17-24, Oct. 2012.
- [13] S K Pillai , "A First Course on Electrical Drives", New Age International Publishers, 2012, Third edition, pp. 3-54.
- [14] P S Bimbhra, "Electrical Machinery", Khanna Publishers, 2001, pp. 457-693.
- [15] Wen xi Yao, Zhengyu Lu, Huang Long, Bin Li, "Research on grid-connected interleaved inverter with L filter", IEEE National Natural Science Foundation of China (51177148), Zhejiang Key Science and Technology Innovation Group Program (201 OR50021) and Delta Environmental & Education Foundation, 2013.

IJERT