Simulation of Standalone PV System Using P&O MPPT Technique in Matlab/Simulink

Keyurkumar Patel[1], Kedar Nikhade[2], Arpitkumar Patel[3], Sagar Patel[4]

[1]*B.E. Student, Electrical Engineering Department, Itm Universe Vadodara*
[2]*B.E. Student, Electrical Engineering Department, Itm Universe Vadodara*
[3]*B.E. Student, Electrical Engineering Department, Itm Universe Vadodara*
[4]*Assistant Professor, Electrical Engineering Department, Itm Universe Vadodara*

Abstract: *The Photovoltaic (PV) module is the interface which converts light into electricity. This paper includes mathematical and simulation model for PV cells. The model is able to simulate both the P-V & I-V characteristics curves. One of the main challenge is harvesting power from a PV source is maximum power point tracking (MPPT). It is due to non linear behavior & characteristics of PV array. Proposed system consists of high gain boost converter feeding three level diode clamped inverter. 60W Solarex MSX60 PV panel is chosen for evaluating the developed model.*

Keywords: *PV Panel, MPPT, DC to DC Boost Converter, Perturb & Observe (P&O) Method, Diode Clamped Inverter, Total Harmonic Distortion (THD).*

I. INTRODUCTION

The power demand is increasing day-by-day and the conventional sources are not enough to meet the power requirement. The generation of energy from the use of the non-renewable energy sources causes pollution problems and also these sources are diminishing day by day .

After the search for the alternative ways, the solar photovoltaic (PV) system and wind power generation systems are found to be more advantageous compared to all different types of renewable energy sources for the desirable environmental and safety aspects. Among these two renewable sources, solar power systems attract more attention [1]. Solar energy sources has its own advantages like long life with little maintenance, high power capability per unit of weight and highly mobile. In the solar photovoltaic, solar cell is the basic element which converts the solar energy into the electrical energy. To form solar PV module there are combination of several solar cells need to be used.

The output of solar cell depends on the weather conditions (temperature and irradiation), which are fluctuating in nature. Under normal operating conditions, each solar PV module offers unique maximum operating point. If solar PV module operates at that optimum operating point, can get maximum efficiency at the load. To achieve good efficiency from the solar PV system there is a need to extract maximum power from module. This can be achieved by placing MPPT methods. The solar energy comes from the sunlight in the form of solar irradiation and temperature. The energy conversion efficiency of solar PV array is very low and thus, the maximum power point tracking (MPPT) control technique is required to extract the maximum power from the solar PV array in order to increase the overall efficiency of the solar PV system [2][3]. Every photovoltaic solar cell has optimum operating point which is called maximum power point (MPP). This maximum power point can varies if there will be any variation in the cell temperature and irradiation level. MPPT tries to match the impedance of the module with the load/battery by changing the duty ratio of the DC to DC converter. In this paper 12V solar PV module is modeled with the help of mathematical equations in the MATLAB. For getting 1KW power 16 PV modules are used in which 4×4 series-parallel combination. DC to DC boost converter has to be designed properly to attain high DC bus voltages. In this paper DC to DC boost converter is designed to achieve V_{mpp} (Voltage at Maximum Power Point) calculated by P&O method. It is preceded by three level diode clamped inverter to achieve three phase AC output supply which is filtered by LC low pass filter. The output AC supply can be utilized for domestic applications.

II. PV Panel Modelling

A equivalent circuit of a solar cell is a current source in parallel with a diode and shunt resistance (R_{sh}). Series resistance (R_s) is considered in series with the load. The output of the current source is directly proportional to the solar energy (photons) that hits on the solar cell (photocurrent I_{ph}).
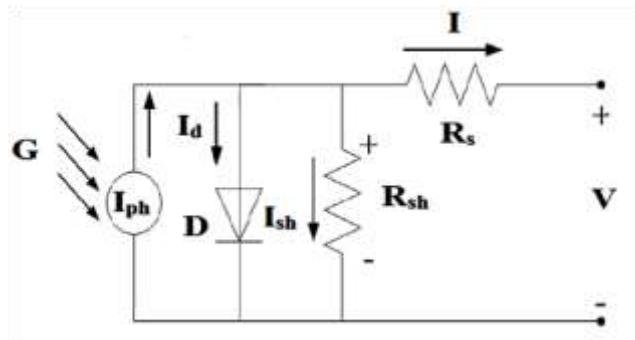
International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering
(RTEECE 08th – 09th April 2016)

Fig.1(a) Circuit diagram of a PV cell[4]

The PV cell output current can be defined as follow in equation.[4]

$$I = I_{ph} N_p - I_d - I_{sh} \tag{1}$$

$$I_{ph} = G_k [I_{sc} + k_I(T_{op} - T_{ref})] \tag{2}$$

$$I_d = [e^{\frac{(V+IR_s)}{(nV_t CN_s)}} - 1]I_s N_p \tag{3}$$

$$I_{sh} = \frac{V+IR_s}{R_{sh}} \tag{4}$$

Where;

G_k= Solar irradiance ratio, V_t= Thermal Voltage(V), k= Boltzmann's Constant(1.38e-23), T_{op}= Cell Operating Temperature in °C, T_{ref} = Cell Temperature at 25°C, I_{rs} = Shunt Current(A), V= Output Voltage from the PV Panel(V), n= Diode Ideality Factor(1.36), N_s= Number of Panel in Series, C= Number of Cells in a PV Panel(36), N_p=Number of Panel in Parallel, I_s= Diode Reversed Saturation Current(A)

I-V & P-V characteristic of the solar cell for a different ambient irradiation 'G' and fixed cell temperature 'T' is shown in Fig 1 (b) Fig 1 (c) respectively.
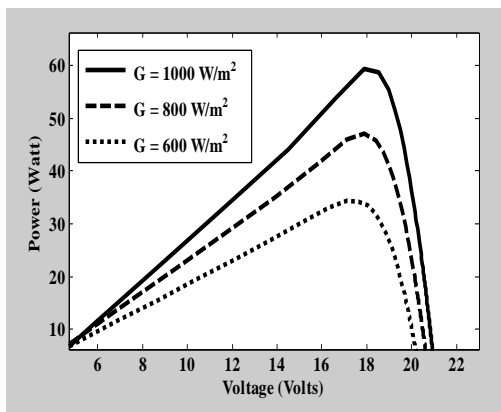

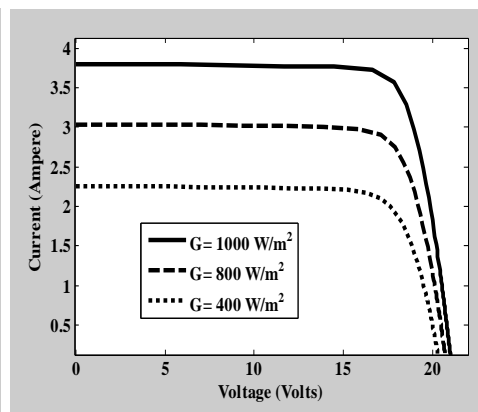Fig.1(b) P-V characteristics of PV panel   Fig.1(c) I-V characteristics of PV panel

III. MPPT Methods

In the solar PV system, the efficiency is very low because of solar PV module provides very low efficiency. The method which is used to increase the efficiency of the solar PV system by tracing the maximum power point, such a method is called maximum power point tracking (MPPT)[3][4][6]. Some methods are as below:

- Perturb & observe method
- Incremental conductance
- Fraction open circuit voltage
- Fractional short circuit current
- Fuzzy logic control
- Neural network

Among all the methods P&O method is widely used because of its simplicity for implementation.

International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering
(RTEECE 08th – 09th April 2016)

A. Perturb and observe method:

P&O method is most common method of MPPT. In P&O method, the MPPT algorithm is based on the calculation of the PV output power and the power change by sampling both the PV current and voltage [6]. The most basic purpose of the P&O algorithm, it adjust the operating voltage of photovoltaic solar system and observe whether the output power of the system is increase or decrease. If it observes that the output voltage is increase, the algorithm will continues to adjust the output voltage in the same direction. If it observes that the output voltage is decrease, the algorithm adjusts the output voltage in the opposite direction.

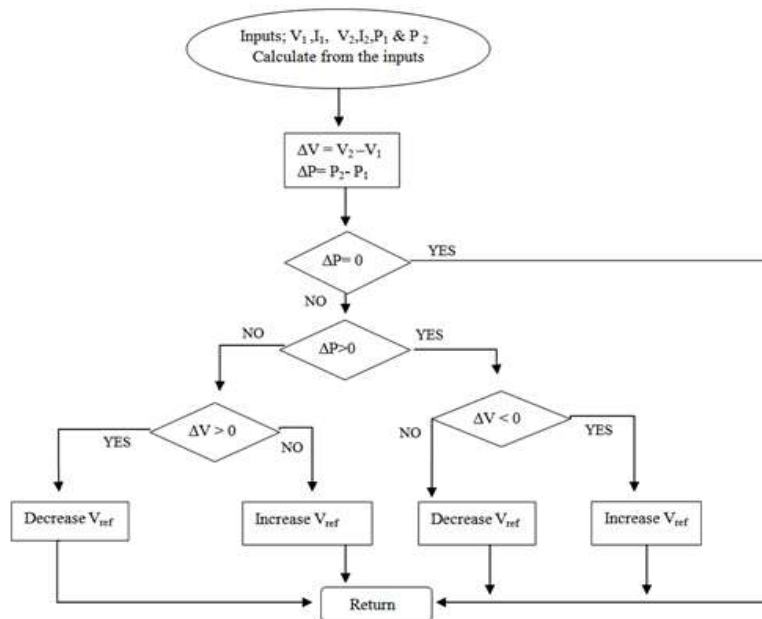Flow chart for P&O method is shown in fig.2[10]

Fig.2 Flow chart of P&O Method

B. Boost converter: A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it steps up the source voltage. Since power (P = VI) must be conserved, the output current is lower than the source current. In this paper boost converter is used to boost output voltage of PV panel array to V_{mpp} . Also upto V_{mpp} increase in voltage will not cause decrease in current hence maximum power is obtained from PV panel. Following are the equations for design consideration of boost converter[5][8].

$$L = V_{in} \times \frac{V_{out} - V_{in}}{\Delta I_L \times f_s \times V_{out}} \tag{5}$$

$$D = 1 - \frac{V_{in}}{V_{out}} \tag{6}$$

Where; V_{in} = Typical Input Voltage, V_{out} = Desired Output Voltage, f_s = Minimum Switching Frequency of the Converter, ΔI_L = Estimated Inductor Ripple Current, D = Duty Cycle.

IV. MULTILEVEL DIODE CLAMPED INVERTER

Inverter is a DC to AC converter that provides output with desired voltage and frequency. In two level inverter output voltage waveform is produced by using pulse width modulation (PWM) with two voltage levels. This causes the output voltage and current to be distorted and the THD of the voltage is poor. In three level inverter output voltage and current is much more sinusoidal and the THD is better.

Advantages of multilevel inverter over two level inverter

- Lower THD in output voltage
- Reduced switching Stresses on devices
- Higher voltage levels are produced
- Applicable for high voltage applications
- Since $\frac{dv}{dt}$ is low the EMI from system is low
- Lower switching frequency can be used in and hence reduction in switching losses

International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering
(RTEECE 08th – 09th April 2016)

Three different topologies have been projected for multilevel converters: Diode clamped converter; Flying capacitor converter (Capacitor Clamped); and lastly cascaded converter. Several modulation and control strategies have been developed or being used for multilevel converters including the following: Multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination, and space-vector modulation (SVM)[7].

In this paper Diode clamped three level has been used as it offers several advantages over other topologies. Multilevel sinusoidal pulse width modulation is used for gating control of three level diode clamped inverter.

Diode clamped inverter is advantageous as no charging circuit is required as required in the case of flying capacitor topology. Also number of switches are less which results into less switching losses.

Low pass LC filter is used to filter hormonics in output voltage of inverter. The LC filter is a second order filter. Since the L filter achieves low attenuation of the inverter switching components, a shunt element is needed to further attenuate the switching frequency components. This shunt component must be selected to produce low reactance at the switching frequency. But within the control frequency range, this element must present a high magnitude impedance. A capacitor is used as the shunt element. The resonant frequency is calculated from [9].

$$f = \frac{1}{2\pi\sqrt{LC}}$$
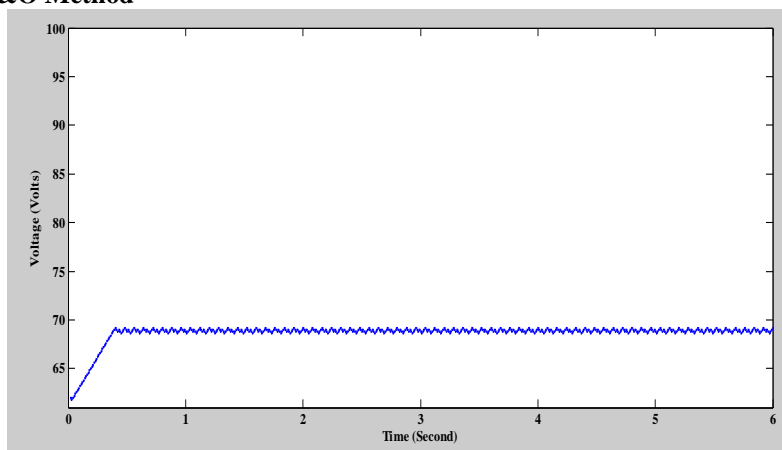(7)

V. SIMULATION RESULTS

A. MPPT using P&O Method

Fig.3 Vmpp using P&O Method

This results show $V_{mpp} = 69\ Volts$ for irradiance $G = 1000\ \frac{W}{m^2}$. Similar results are obtained for $G = 800\ \frac{W}{m^2}$, $V_{mpp} = 66.5\ Volts$, & $G = 400\ \frac{W}{m^2}$, $V_{mpp} = 62.8\ Volts$.

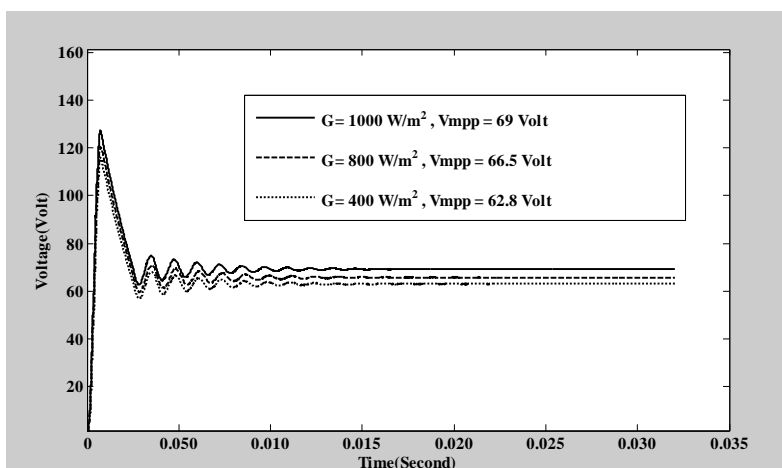**B.Boost converter:** Boost converter will boost output voltage to V_{mpp} to get maximum power as shown in fig 4.

Legend:
- G= 1000 W/m² , Vmpp = 69 Volt
- G= 800 W/m² , Vmpp = 66.5 Volt
- G= 400 W/m² , Vmpp = 62.8 Volt

Fig.4 Boost Converter Voltages for Different Irradiances

International Journal of Engineering Research and Development (IJERD) ISSN: 2278-067X
Recent trends in Electrical and Electronics & Communication Engineering
(RTEECE 08th – 09th April 2016)

C. Three Level Diode Clamped Inverter:

This voltage further boost to constant DC voltage which is fed to inverter to get three phase AC output voltage. Inverter is preceded by low pass filter to obtain low THD value in output voltages as shown in fig.5. THD analysis of line voltage is shown in fig. 6
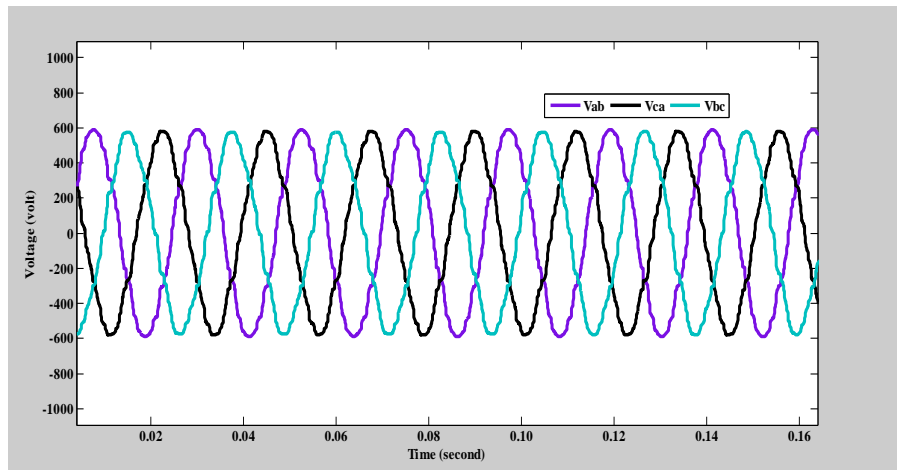

Fig.5 Inverter Output Voltages (with filter)
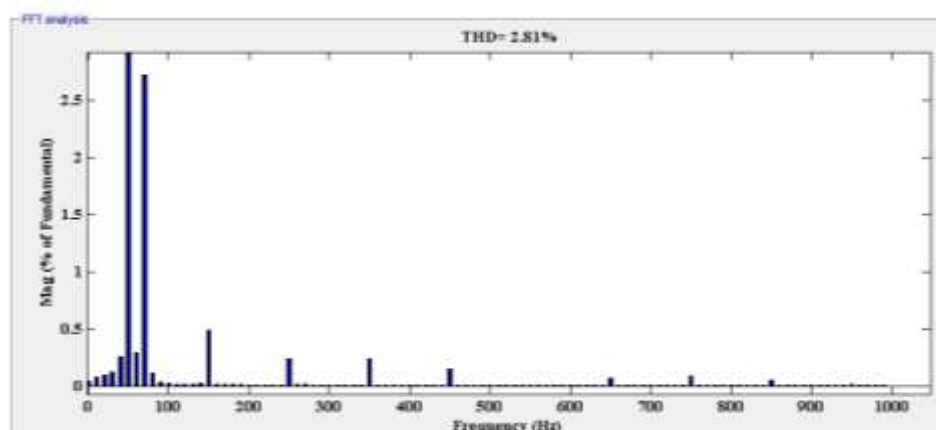
Fig.6 THD analysis of line voltage of 3 level diode clamped inverter with Low pass LC filter

VI. CONCLUSION

This paper presents the complete Simulation of standalone PV system using P&O MPPT method in Matlab/Simulink. Using MPPT method maximum power can be drawn from PV panel. Using boost converter DC voltage is boost to V_{mpp} which is fed to three level diode clamped inverter with low pass LC filter to get 3 phase AC supply with minimum THD value. This system can be employed for domestic applications.

ACKNOWLEDGEMENT

REFERENCES

[1]. Simple Modeling and Simulation of Photovoltaic Panels Using Matlab/Simulink, Advanced Science and Technology Letters, Vol.73 (FGCN 2014), pp.147-155.

[2]. Kinal Kachhiya, Mukesh Patel, Makarand Lokhande, "MATLAB/Simulink Model of Solar PV Module and MPPT Algorithm", National Conference on Recent Trends in Engineering & Technology, 13-14 May 2011.

[3]. Hanja Cha and Sanghoey Lee, "Design and Implementation of Photovoltaic power conditioning system using a current based maximum power point tracking", Industry Applications Society Annual Meeting,

[4]. 2008. IAS '08. IEEE, vol., no., pp,.1-5,5-9 Oct. 2008.

[5]. A PHOTOVOLTAIC PANEL MODEL IN MATLAB/SIMULINK Shivananda Pukhrem, DATASET · AUGUST 2013 DOI: 10.13140/RG.2.1.2628.4645

[6]. Basic Calculation of a Boost Converter's Power Stage, Brigitte Hauke, SLVA372C–November 2009 Revised January 2014, Texas Instruments

[7]. Mohamed Azab, "A New Maximum Power Point Tracking for Photovoltaic Systems", International Journal of Electrical & Electronics Engineering, 3:11 2009.

[8]. Operation and Design of Multilevel Inverters, Developed for the Office of Naval Research

[9]. December 2003.

[10]. M.RASHID, POWER ELECTRONICS.

[11]. Passive Filter Design for Three-Phase Inverter Interfacing in Distributed Generation Khaled H. Ahmed, Stephen J. Finney and Barry W. Williams, Electrical Power Quality and Utilisation, Journal Vol. XIII, No. 2, 2007

[12]. Stability Analysis of FPGA Based Perturb and Observe Method MPPT Charge Controller for Solar PV System Tripti Saini, Dogga Raveendhra and Padmanabh Thakur, 978-1-4673-5630-5//13/$31.00 ©2013 IEEE