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Simulation of A Modified Perturb and Observe Algorithm for A Photovoltaic System Connected To the Grid

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***Abstract*-The power output of the solar array is dependent upon the irradiance, temperature and internal properties of the materials used to make solar cells. These factors contribute to the position of the Maximum power point. Changes in atmospheric conditions affect directly the output of the solar panel. Therefore, there is a need to track the Maximum power point to ensure that the system delivers the maximum power and the losses are reduced at any given time despite the change in temperature and irradiation throughout a day. The maximum power point tracking(MPPT) of the PV output for all sunshine conditions is a key to keep the output power per unit cost low for successful PV applications. Several techniques have been proposed for maximum power point tracking. The most commonly used technique for MPPT is the perturb and observe technique. It is known that the P&O method exhibits erratic behavior under rapidly changing irradiance level that causes incorrect or slow maximum power tracking. The Modified P&O (MP&O) method was proposed to solve this problem by decoupling the PV power fluctuations caused by hill-climbing process from those caused by irradiance changing. MATLAB was used to simulate the Perturb and observe and the modified perturb and observe techniques. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. The algorithms utilized for MPPT are generalized algorithms and are easy to model or used as a code. The algorithms are written in m files of MATLAB and utilized in simulation where the values of the irradiance and temperature were chosen based on the average values in Benue State. The solar cell is modeled using SIM Power Systems blocks. The results obtained clearly show that the conventional perturb and observe algorithm used in the overall system fails to track the maximum power point as the duty cycle goes below the lowest limit (0.4) while the system using the modified perturb and observe algorithm tracks the maximum power point at all time; it can also be seen that the system using the modified perturb and observe method has a stable voltage, current and power output as compared with the system using the conventional perturb and observe method when the irradiance and temperature are suddenly varied.**

***Keywords*- Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), VSC converter, Photovoltaic (PV), Pulse width Modulation (PWM), Modified Perturb and Observe (MP&O).**

I. INTRODUCTION

In today‘s world, renewable energy sources play important role in electricity generation. Several sources like wind, solar, biogas etc. are important energy sources. Energy from the sun is the best option for renewable energy as it is available almost everywhere and is free to harness [1]-[2]. Solar radiation from the sun is converted to electrical energy by using solar cells which exhibit photovoltaic (PV) effect. However, for PV systems, the amount of electric power generated changes continuously with weather conditions.

For solar to be a competitive energy source it is extremely important to extract the maximum power from each panel and lower the cost per kilowatt. It turns out that this is not as simple as just hooking a panel to a battery or grid; there are many variables that affect the performance of a panel, such as shade, shadows, and ambient temperature—thus the need for MPPT algorithms. Solar cells, like other silicon diodes, have an exponential transfer function from voltage to current. A small change in voltage results in a large change in current. Two important factors that have to be taken into account are the irradiation and the temperature. In general, I-V curve for a PV array is non –

linear so a specific point on the curve namely maximum power point needs to be tracked so that the whole system operates at maximum efficiency and produces maximum output power. Hence, Maximum Power Point Tracking (MPPT) algorithm is used for extracting maximum power available from a PV module under different conditions. Out of numerous available techniques the one that is used most widely and commonly is Perturb & Observe (P&O) algorithm. P&O is also called as hill climbing method because it checks the rise of the curve till MPP and the fall after that point[3]-[8].

Using P&O algorithm the controller adjust voltage and measures power and if this measured power is greater than the previous value of power, adjustments are made in the same direction until there is no more increment in power. Generally, the MPPT controller is embedded in the power electronic converter systems, so that the corresponding optimal duty cycle is updated to the photovoltaic power conversion system to generate the maximum power point output. Figure 1 shows the block diagram of the

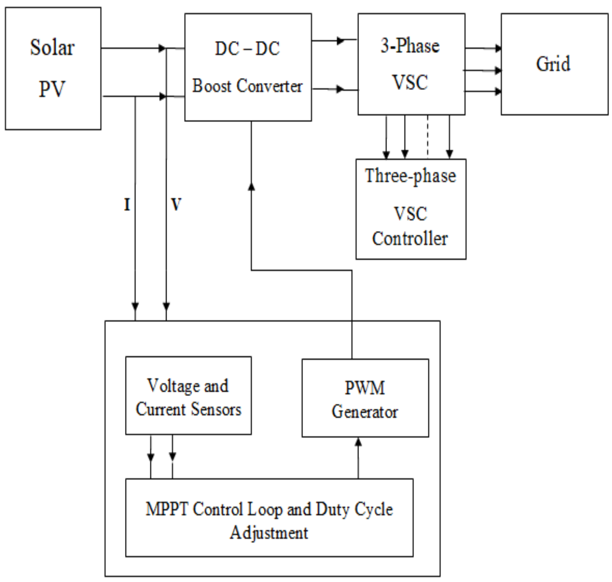

Figure 1 Block diagram of the proposed system.

II.REVIEWS

1.The Solar Cell

The solar cell is the basic building block of solar photovoltaic. The cell can be considered as a two terminal device which conducts like a diode in the dark and generates a photo voltage when charged by Sun [1]. When charged by the Sun, this basic unit generates a dc photo voltage of 0.5 to 1volt and in short circuit, a photocurrent of some tens of miliamperes per cm2.

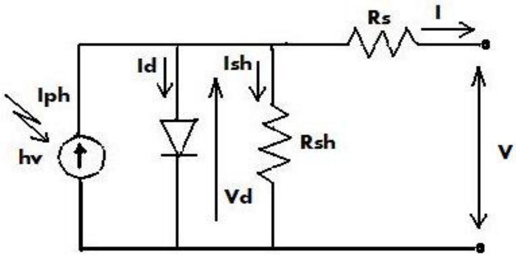

Figure 2 Equivalent circuit of PV solar cell.

PV arrays are built up with combined series or parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Figure2 and/or by an equation as in equation (1).

$$I = I_{ph} - I_0\left[\exp\left\{\frac{q(v+R_s I)}{nKT}\right\}-1\right]-\left[\frac{V+R_s I}{R_s h}\right] \quad (1)$$

The output characteristic of a photovoltaic (PV) array is non-linear and is influenced by solar irradiance level, ambient temperature, wind speed, humidity, pressure, etc. The irradiation and ambient temperature are the two primary factors. To study the output characteristics of PV cell, some experiments based on simulation of PV cell have been done. For constant temperature (25˚C) and different intensity (400-1000W/m2) The PV array current constant up to some voltage level and then it will be decreased. The PV array current always increases with intensity.

2.The Boost Converter

The boost converter was chosen for its benefits in terms of cost saving, simplicity and efficiency. The values of some components such as inductor and capacitor were determined by using suitable equations in order to make sure continuous conduction mode is sustained. Figure 3 depicts the basic circuit of an ideal boost converter with Vd and Vo as input and output voltages respectively and figure 4 shows the waveforms of the boost converter.

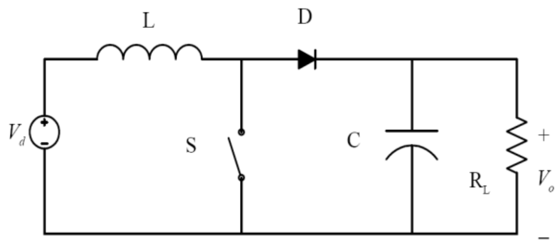

Figure 3 Ideal boost converter.

There are two modes of operation of a boost converter. The operation mainly based on the ON and OFF mode of the switch. Firstly, when the switch is closed, this can be known as charging state as shown in figure 5. After that, second mode of operation will be initiated by opening the switch, and this state is known as discharging mode of operation.

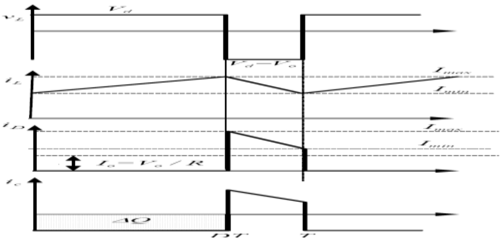

Figure 4 The waveforms of Boost Converter.

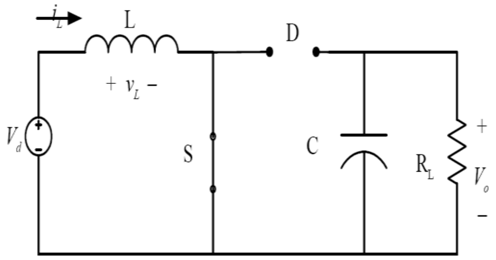

Figure 5 Equivalent Circuit of Boost Converter when the Switch Closed

$$V_d = V_l \quad (2)$$

$$V_d = L\frac{(I_{max} - I_{min})}{dt} \quad (3)$$

$$I_{max} = I_{min} + \frac{V_d}{L}dt \quad (4)$$

During discharging mode of operation, the switch is open and the diode is forward biased, as shown in Figure 6. At this time, the inductor is discharged to the capacitor and meets the load demand. The ripple in output load current and voltage usually is very small if suitable value of capacitor is used.

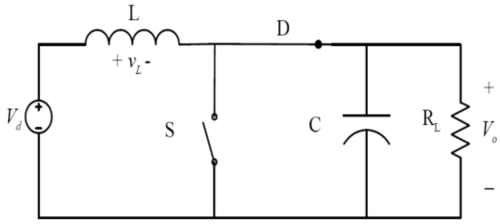

Figure 6 Equivalent Circuit of the Boost Converter when Switch Opened.

$$-V_d + V_L + V_0 = 0 \quad (5)$$

$$\frac{V_0}{V_d} = \frac{I}{I-d} \quad (6)$$

1. Vsc Converter

The proposed inverter structure is designed to make use of a three-level topology called neutral point clamped. The IGBT semiconductor is used due to its lower switching losses and reduced size when compared to other power electronic devices. Indeed, the control of the output voltage is provided by the PWM technique. The three-level VSC regulates DC bus voltage at 500 V and keeps unity power factor. Id current reference is the output of the DC voltage external controller. Iq current reference is set to zero in order to maintain unity power factor. Vd and Vq voltage outputs of the current controller are converted to three modulating signals Uref_abc used by the PWM three-level pulse generator. The control system uses a sample time of 100 μs for voltage and current controllers. In the detailed model, pulse generators of Boost and VSC converters use a fast sample time of 1μs in order to get an appropriate resolution of PWM waveforms.

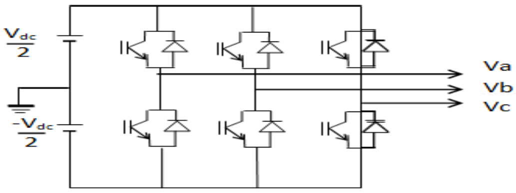

Figure 7 3-Level Inverter

2. Maximum Power Point Tracking Techniques

2.1Perturb and observe technique

In Perturb and observe (P&O) [9] method, the MPPT algorithm is based on the calculation of the PVpower and the power change by sampling both the PV current and voltage. The tracker operates byperiodically incrementing or decrementing the solar array voltage. Figure 8 shows the flow chart of the conventional P&O technique.

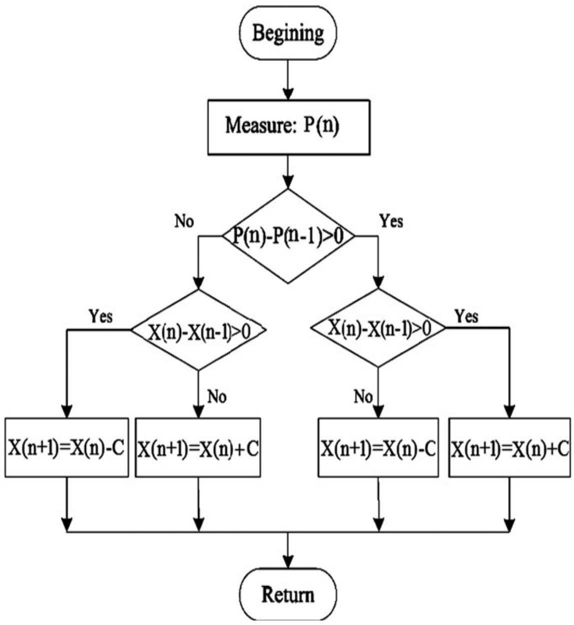

Figure 8 Conventional Perturb and Observe algorithm.

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2.2 Modified Perturb and observe technique

The Modified Perturb and Observe (MP&O) method was proposed to solve the oscillation problem by decoupling the PV power fluctuations caused by hill-climbing process from those caused by the irradiance changing. This method adds an irradiance-changing estimate process in every perturb process to measure the amount of power change caused by the change of atmospheric condition and then compensates for it using a perturb process. Figure 9 shows the flow chart of the MP&O method and figure 10 shows the complete circuit diagram.

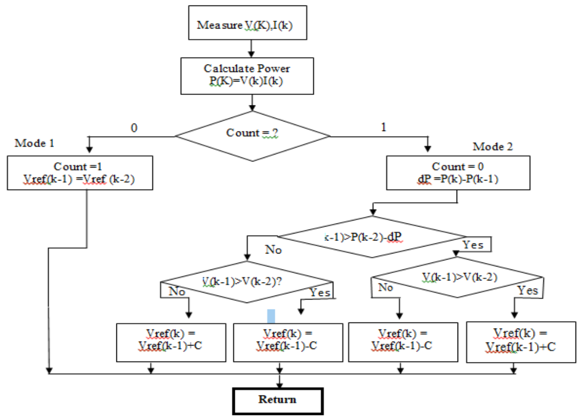

Figure 9 Modified Perturb and Observe algorithm

Where,

V(k) is the measured voltage
I(k) is the measured current
V(ref) is the reference voltage
C is the step size.
P(k-1) is the measured power of the previous state
P(k-2) is the measured power of the two previous state
V(k-1) is the measured voltage of the previous state
V(k-2) is the measured voltage of the two previous state

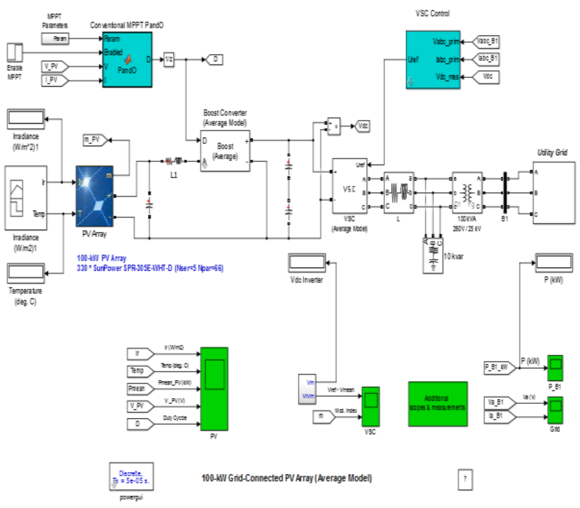

Figure10 Proposed circuit diagram.

IV. RESULTS AND DISCUSSION

1. Irradiation and Temperature Variations

Figure 11 shows the irradiance and temperature variations generated as inputs on the solar array. The irradiance is generated at a constant value of 1000Kw/m2for 0.5 second, decreases at 250Kw/m2 for 0.5 second. The system increases steadily from 250Kw/m2 at 0.5seconds to 1000Kw/m2 at 2 seconds and is maintained constant. It also shows a simulated behavioral pattern of temperature variation on the PV module. At a temperature of 250C (room temperature) for a period of 2 seconds, the PV module output varies as its temperature increases to an extreme value of 500C.

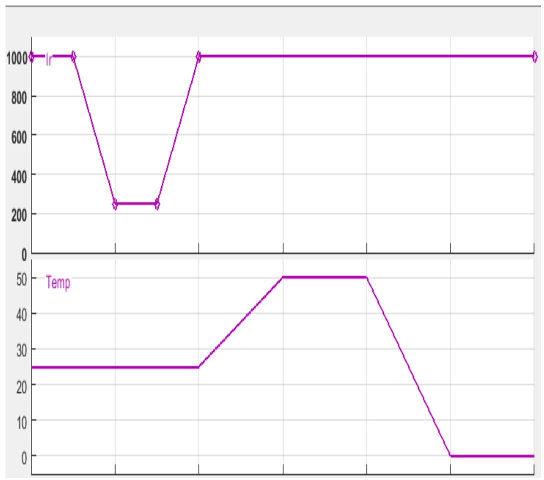

Figure 11 irradiance and temperature variations.

2.Solar Panel Results

Figure 12 depicts the I-V curve from the PV array Sunpower SPR 305E-WHT-D 100kW and I_{MPP} of 5.58A at 1000kW/m^2 irradiance. The two input parameters of the solar panel are the temperature and the irradiance. It shows the output signal of the I-V curve with fixed irradiance (1000KW/m^2) at 0^oC, 25^oC, 30^oC, 35^oC, 40^oC, 45^oC respectively.With a fixed temperature of 25^oC at 1000KW/m^2, 800KW/m^2, 600KW/m^2, 400KW/m^2 respectively, figure 13 shows the P-V curve where the power is plotted against voltage.Similarly in Figure 14, a plot of the P-V curve with fixed irradiance (1000KW/m^2) at 25°C, 30°C, 35°C, 40°C, 45°C respectively shows how variations in temperature can affect the power output of the PV array while figure 15 shows the P-V curve with varied irradiance.

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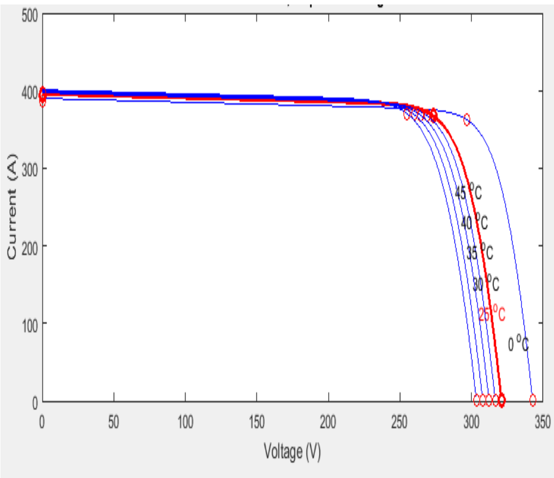

Figure 12 I-V curve with varied temperature

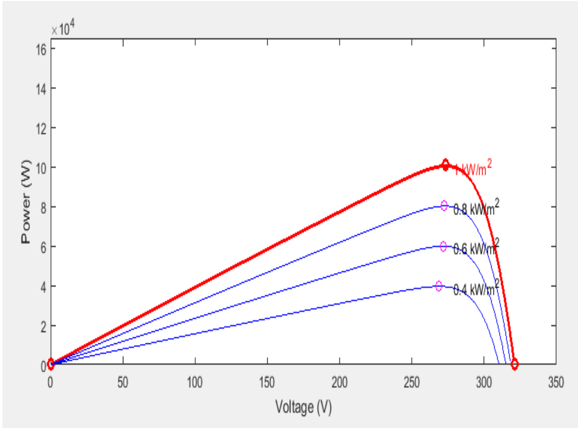

Figure 15 P-V curve with varied irradiance

3.Results from the boost converter

Figure 16 shows the duty cycle of the DC converter over a period of 5.5seconds which also varies a lot as the irradiance and temperature are varied. The duty cycle goes below 0.4 which is the minimum value under which the MPP is no longer tracked. Figure 17 shows the duty cycle using the modified P&O technique which is within 0.4-0.6, showing that the power is tracked at all time.Figure 18 and 19 show the current output curves using the conventional and modified technique respectively and fluctuations can be observed.Figure20 and 21 shows the voltage curves of the conventional and modified P&O respectively where fluctuations can also be seen. Figure 22 and 23 show the power curves using the P&O and modified P&O techniques respectively where the effects of sudden changes in irradiance and temperature can be observed on the conventional P&O and a smoother curve while using the modified P&O.

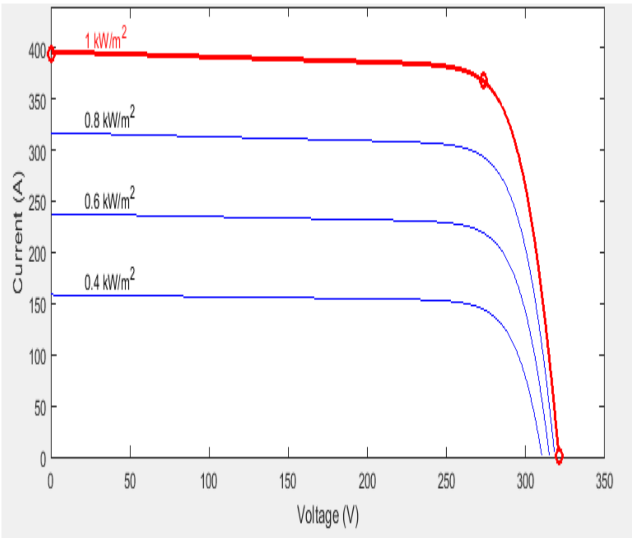

Figure 13 I-V curve with varied irradiance

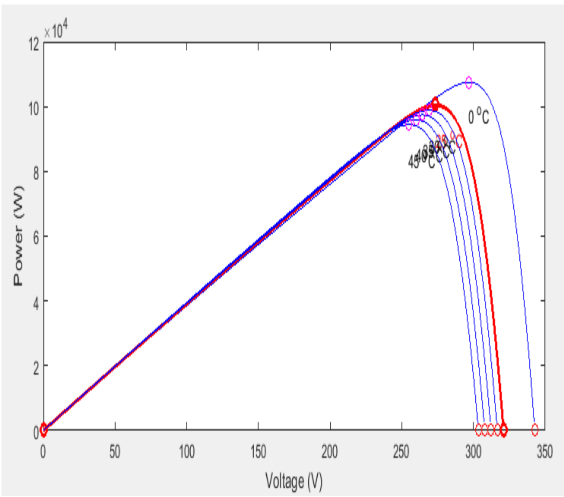

Figure 14 P-V curve with varied temperature

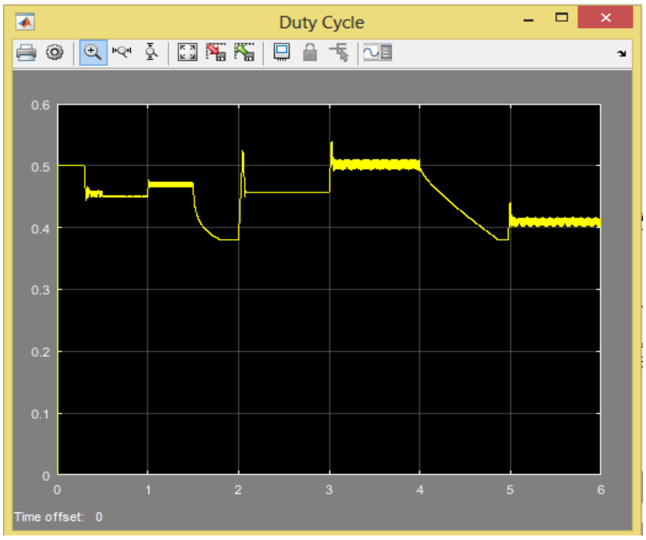

Figure 16 Duty cycle of the conventional P&O technique

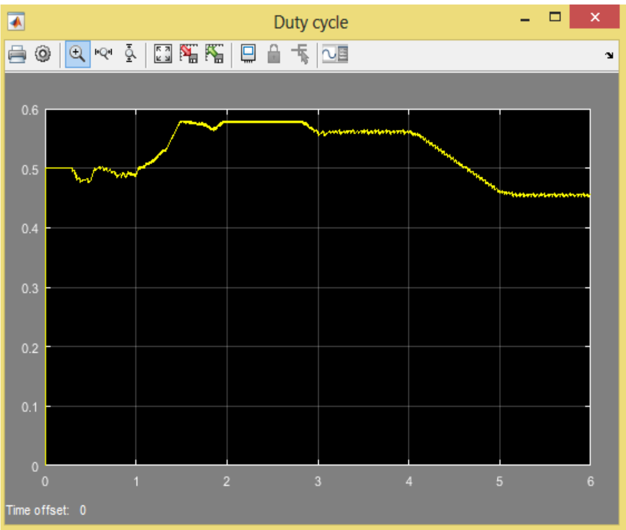

Figure 17 Duty cycle of the Modified P&O technique

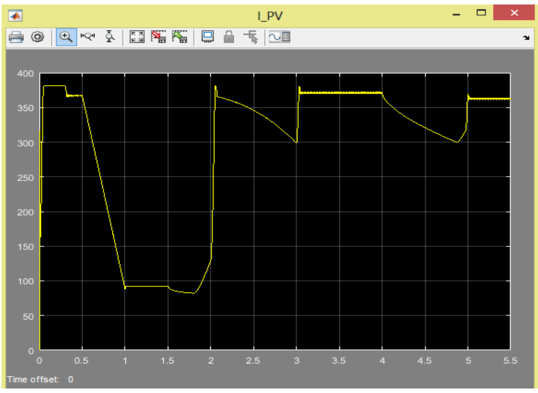

Figure 18 Current of the conventional P&O technique.

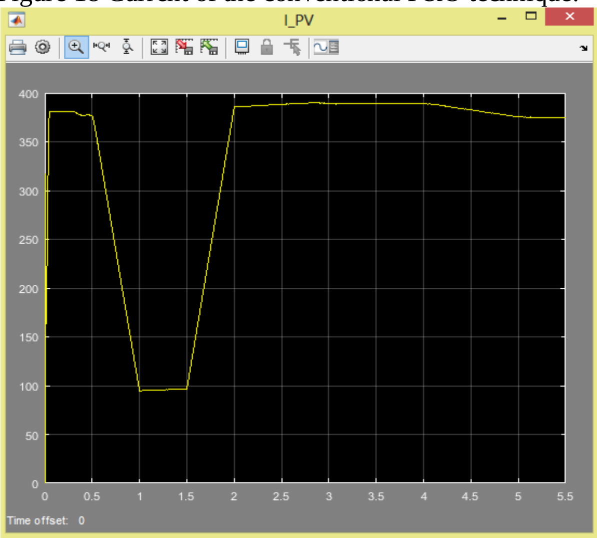

Figure 19Current of the Modified P&O technique.

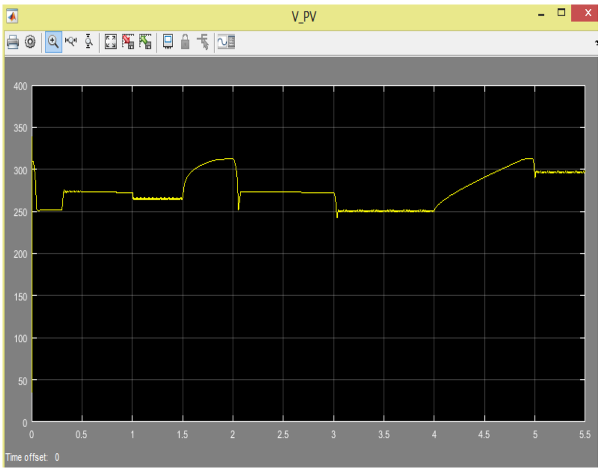

Figure 20 Voltage of the conventional P&O technique.

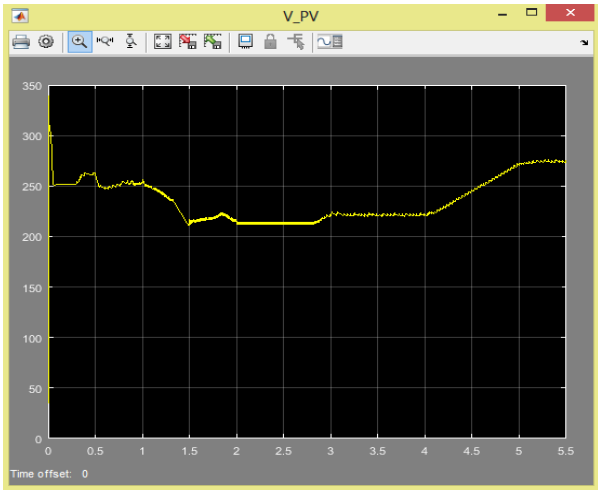

Figure 21Voltage of the Modified P&O technique.

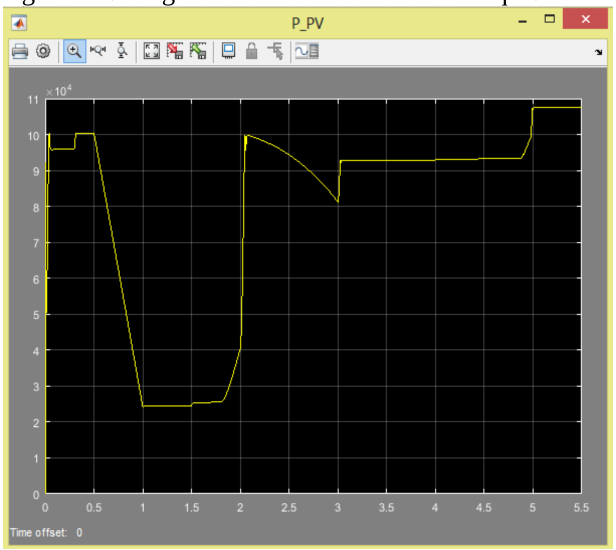

Figure 22Power of the conventional P&O technique.

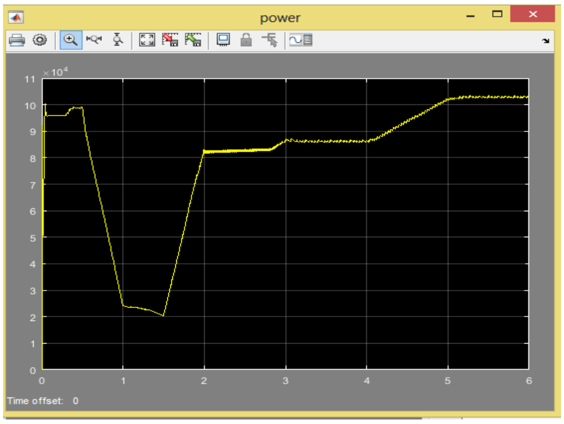

Figure 23 Power curve using the Modified P&O technique

4. Results from the VSC converter

Figure 24 shows the current, voltage, power and modulation index respectively which are affected by the variations of the irradiance and temperature and figure 25 show the current, voltage, power and modulation index curves which are smoother than the curves using the conventional P&O techniques.

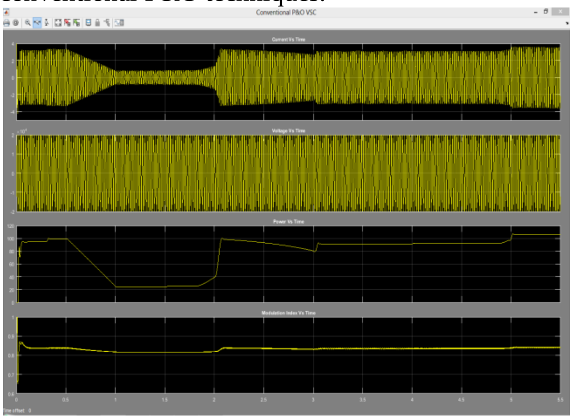

Figure 24 Current, voltage, power and modulation Index using the P&O technique.

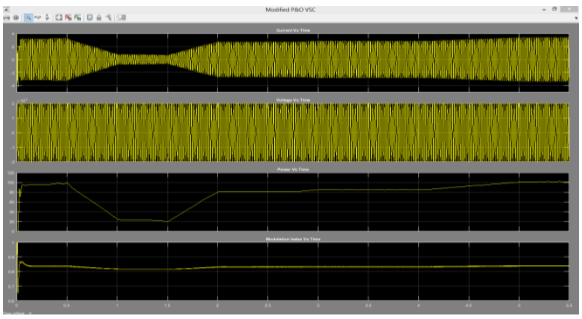

Figure 25 Current, voltage, power and modulation Index using the Modified P&O technique

V. CONCLUSION

The power ratings of PV panel and climate conditions are also factors in certain areas and in some applications. From the study it had been observed that the modified MPPT technique is most preferred. MPPT techniques aremeant for mismatched conditions such as partial shedding, non-uniformity of PV panel temperatures, dust effects, damages of panel glass. Cases studied and discussed in the paper give us a brief idea of PV panel working with a connected load. It also gives an advantage of pre evaluating overall system before going into real time implementation.

The whole PV panel – MPPT – Grid tied system is created in MATLAB/Simulink. PV panel Simulink block did undergo I-V, P-V characteristic check and results were obtained. The results validate that a system using the modified perturb and observe MPPT technique can significantly stabilise the energy produced from PV and increase the performance of the PV system compared with the system using conventional perturb and observe MPPT technique.

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