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# A COMPARISON BETWEEN PERTURB AND OBSERVE AND MODIFIED PERTURB AND OBSERVE MPPT TECHNIQUES

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**Abstract—** *A comparison between two methods of maximum power point tracking for Solar Photovoltaic (PV) is attempted here. A modified method is proposed and evaluated. Perturb & Observe (P&O) method is selected for analysis as this method requires reduced implementation cost with better performance output. A Modified P & O method using directional step size is suggested here that can effectively tackle steady state variations around maximum power point and dynamic variations in environmental conditions of solar radiation. This is achieved by determining a step size that switches to 'zero' during the above conditions. Thus, the proposed method provides a stable PV voltage. A switched capacitor (SC) based inverter is used to track the maximum power point (MPP) of a photovoltaic (PV) source and generates a pure sine wave output. The circuit is simulated by using the PLECS software.*

***Keywords—*** *Photovoltaic, Maximum Power Point Tracking, P&O, Switched Capacitor, PLECS.*

## 1.INTRODUCTION

The main concern in the power sector is the day-to-day increasing power demand and the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.

Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever and wherever necessary. In order to tackle the present energy crisis one has to develop an efficient method in which maximum power has to be extracted from the incoming solar radiation. The acceptance of Solar PV has to be boosted by reducing cost and increasing reliability. This is an important consideration in the solar applications. One possible area of improvement is to increase the efficiency of the maximum power point tracking (MPPT) algorithm [5].

Huang *et al* proposed a modular self-controlled photovoltaic (PV) charger with P&O MPPT. Usually in battery charging applications the P&O responds in a slower manner. Here the author has given a new idea of a fast MPPT method by narrowing the charging period [6]. Mohammed *et al* gives a complete assessment of P&O algorithm implementation techniques. A detailed assessment on the reference voltage perturbation and direct duty ratio perturbation is simulated, implemented, and analysed and concludes with the advantage and disadvantages of both methods. This paper also describes the advantages of P&O that it is a simple algorithm and it is easy to implement [7]. Kun Ding *et al* proposed a complete MATLAB / Simulink based PV module with the P&O technique and have analysed the results for both the conditions of uniform and non-uniform irradiance [8]. T.Esram and Patrick served with a convenient reference with the comparison on different MPPT techniques and it is mentioned that P&O technique is the most used MPPT control technique due to its simplicity and ease to implement. It is also given that the main drawback in P&O is the efficiency of the MPPT decreases under rapidly changing irradiance [9].

This paper focuses on simulation of two P&O MPPT methods in PLECS to realise which algorithm has better performance. The evaluation of the algorithms is based on simulation. In particular, this paper discusses stand-alone PV array connected to a switched capacitor inverter and a resistive load.

A switched capacitor (SC) based inverter that a track the maximum power point (MPP) of a photovoltaic (PV) source and generates a pure sine output is presented in [1]. A DC-AC inverter containing no inductors or transformers is presented in [2]. The role of the magnetic devices is played by a switched-capacitor (SC) circuit, formed by two sub circuits. In [3], using CMOS-TG as a bidirectional switch, the various topologies can be integrated in the same configuration for achieving two functions: boosting and alternating; boosting for getting a sinusoidal output in which the peak is the result of a many times step-up of the input; alternating to realize the positive/negative half sinusoidal of the output.

### A. Switched Capacitor Benefits

The common inverter always contains the magnetic elements, and so it results in the electromagnetic interference (EMI) problem. For avoiding the EMI effect, it is a quite excellent choice to adopt a switched capacitor circuit scheme, containing only capacitors and switches. Although the circuit leads to efficiency problem, it is the most excellent one of their advantages that the SC circuits do not require any magnetic elements (inductor/transformer), so the IC fabrication is not only promising but the EMI problem is also improved [3].

### B. Single stage conversion

In a single stage operation, the DC supplied by the solar cell is directly converted into AC by employing inverters.
Under two stage operations, the DC output of PV cell is boost up by employing DC-DC converters and then this DC is inverted into AC by using inverters. When Comparing between two stage and single stage conversion, the dc output from the PV source is increased or decreased by the converter and it is inverted by using the inverter. The two stage conversion has an overall efficiency of $\eta 1 * \eta 2$. In the single stage conversion the dc output from the PV module is directly converted into ac by employing inverters. A single stage is not only more efficient but is also cost effective due to lower component.

## 2. SYSTEM OVERVIEW

This section describes the block diagram of the switched capacitor based inverter using in standalone operation. The capacitor charging and discharging operations are controlled by the switches. The PV source is produced the electrical energy and is stored in the source capacitance $C_{PV}$. The source capacitance acts like a definite source. The switched capacitor blocks are connected across the PV source. Diode is used for the freewheeling operation. The LC filter is used to remove the unwanted signals. The output of LC filter is a unipolar waveform. This waveform is converted into bipolar waveform by using the single phase H-bridge inverter. Unified Sinusoidal Pulse Width Modulation is used to turn on and turn off the switches. Maximum Power Point Tracking tracks the MPP and given the duty cycle as the output.

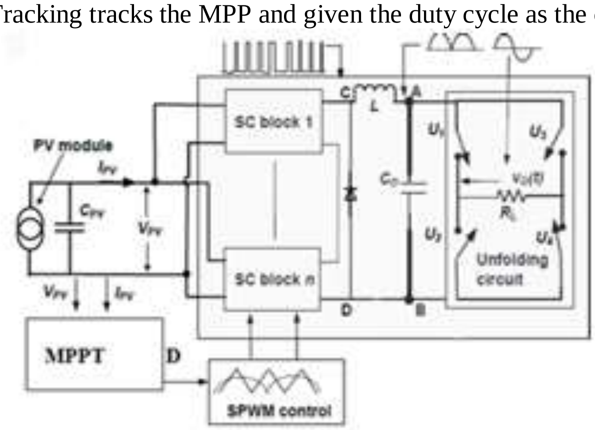


***Fig.1 Overall configuration of PV module integrated single stage SC inverter***

### A. Switched Capacitor Block

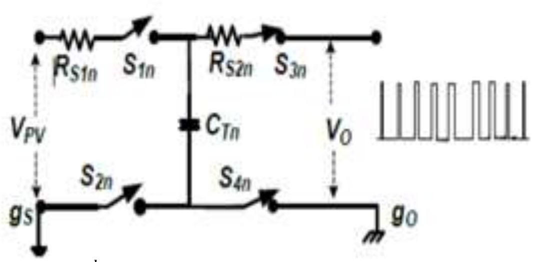


*Fig. 2 $n^{th}$ basic SC building block of the inverter*

The SC converter is shown in figure2. The S1 and S2 represent the input switches. The S3 and S4 represent the output switches. The switches are turned ON and OFF by using the SPWM. When S1 and S2 are closed, the capacitor $C_{Tn}$ is charging. Then there is a dead time when all switches are opened. When S3 and S4 are closed, $C_{Tn}$ is discharging into the load. Thus this topology generates a floating output voltage with respect the source $V_{PV.}$ By connecting the inputs of multiple basic SC blocks in parallel across the input source $V_{PV}$ and their floating output in series, the topology can be used as a buck.

### *B. LC Filter*

During the buck mode, the input current can be treated as the input filter's inductor's current, whose ripple is much reduced from the filtering effect. Thus the input inductor is designed based on the current ripple in boost mode. It acts as a buck topology since a $V_o < V_{PV}$ can be obtained by connecting an output filter capacitor.

## 3. DESIGN PROCEDURE FOR THE SC INVERTER

***Selecting $C_{PV}$***

A constant voltage must be presented to the input of the SC inverter. A capacitor $C_{PV}$ is connected across the PV module's output for this purpose where [4],

$$C_{PV} = \frac{Ppv}{4\Pi fo Vpv\ \Delta Vpv} \longrightarrow (1)$$

Here $P_{pv}$ is the maximum power that the PV array can deliver and $\Delta V_{PV}$ is the maximum allowed ripple on the PV voltage.

***Design of L***

L is designed to always operate in discontinuous conduction mode to minimize its size. Let $I_{L\text{-}peak}$ be the peak value of $i_L(t)$. It is assumed that $I_{L\text{-}peak} = 4I_{0\text{-}peak}$[1].

$$L = V_{0peak}.dt/di \longrightarrow (2)$$

***Selecting $C_0$***

$C_0$ affects the average output ripple $\Delta V.R_L$ is supported by L and $C_0$ when all switches are off. Thus $C_0$ is given by,

$$C_0 = \frac{-0.5Ts}{R*\ln\{{Vo\text{-}peak - \Delta V}/{Vo\text{-}peak}\}} \longrightarrow (3)$$

### *A. Components Selection*

| Components | Values |
|---|---|
| $C_{PV}$ | 10µF |
| $Rs_1$ | 0.4Ω |
| $Rs_2$ | 1.6Ω |
| $C_T$ | 10µF |
| $C_0$ | 0.47µF |
| L | 850µH |
| $R_L$ | 180Ω |

*Table.1*

### *B. Sinusoidal Pulse width Modulation*

In SPWM (Sinusoidal Pulse Width Modulation) two signals are compared. The Modulating reference signal is sinusoidal and the carrier wave is triangular. Gating pulses are produced by comparing the two signals and the width of each pulse is varied is proportion to the amplitude of the sine wave. The frequency of the reference signal determines the inverter output frequency and the reference peak amplitude controls the modulation index and the RMS value of the output voltage. In this paper unipolar sinusoidal pulse width modulation is used. The positive half cycle is considered to produce the pulses. The frequency of triangular wave will be greater than the frequency of sine reference wave. So that let $f_s$ = 70 KHz and $f_0$= 100Hz.

## 4. MAXIMUM POWER POINT TRACKING

### *A. Perturb and Observe Algorithm*

It is the most popular algorithm belonging to the class of the direct MPPT techniques. It is characterized by the injection of a small perturbation into the system and the resulting effects are used to drive the operating point toward the MPP. The PV operating point is perturbed periodically by changing the voltage at PV source terminals, and after each perturbation, the control algorithm compares the values of the power fed by the PV source before and after the perturbation. If after the perturbation the PV power has increased, this means that the operating point has been moved toward the MPP; if after a voltage perturbation the power drawn from the PV array decreases, this means that the operating point has been moved away from the MPP.

Even though, this method is simple and reliable, it has three main demerits, when the maximum power point (Vm) is reached, the P & O algorithm will fluctuate around it resulting in a loss of PV power. This is especially true in cases of constant or slowly varying atmospheric conditions (steady state variations). Next demerit is that it cannot cope with the sudden or dynamic change in the irradiance and the operating point could not converge to the MPP locus. This also results in energy loss. Finally, it is seen that for small perturbation steps, the tracking is slow but the variations in PV reference voltage is minimal. For large perturbations, faster tracking is realized with increased variations in the output of the MPPT. These are some of the major disadvantages of this method.

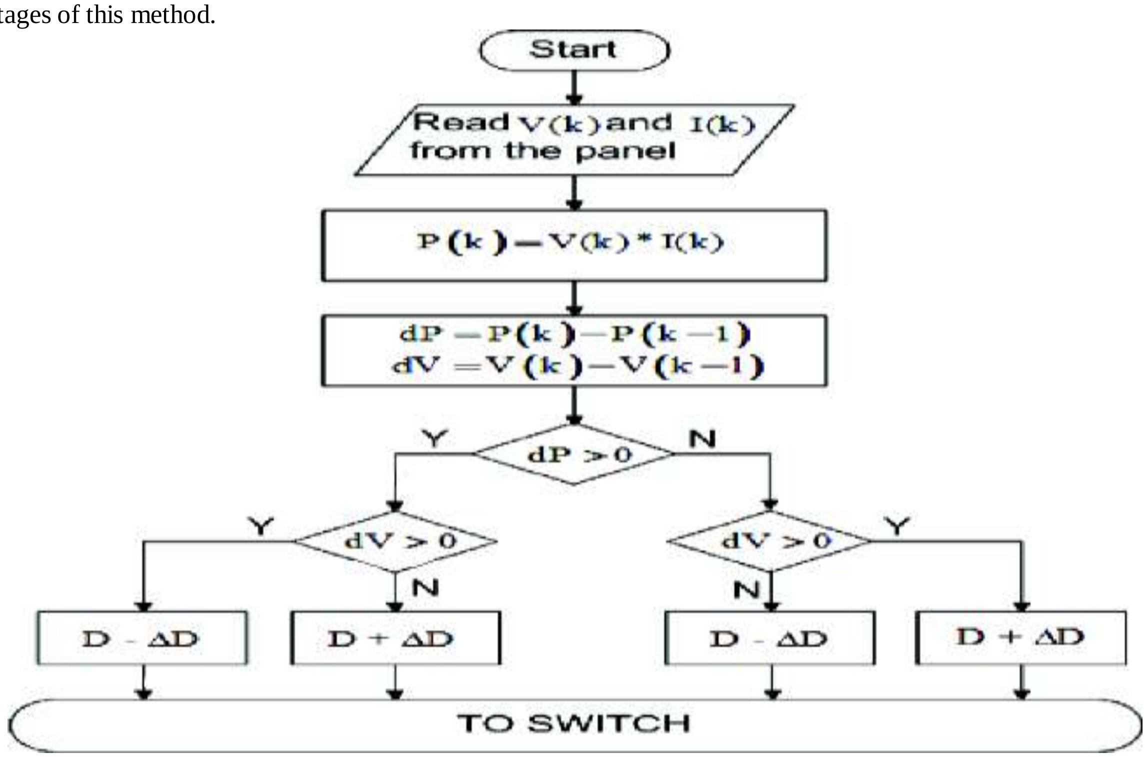


***Fig.3 Flow chart of P&O algorithm***

*B.Modified P and O algorithm*

A modified P & O technique is therefore used that can overcome the limitation of hill climbing P & O method. The flow chart of the MP&O method is given in Fig.4. This modified method uses sign of the change in power and voltage. Here, when the magnitude of power change ΔP is increasing, the sign of perturbation C(K) is positive. But, when the power decreases/increases rapidly after an increase/decrease, caused by change in atmospheric conditions, the sign of the change in voltage ΔV and power ΔP multiplied together changes accordingly and sign of perturbation C(K) changes in such a direction to make the sum ΔC =0 for one instant. Next instant, when the change in power continues to become positive/negative, the algorithm follows the hill climbing method.

$$\text{Signof}(\Delta V \times \Delta P) = \text{signof } C(K) \longrightarrow \quad (4)$$

$$\Delta C = C(K) + C(K-1) \longrightarrow \quad (5)$$

$$V_{refk} = V_{ref(k-1)} + \Delta C \longrightarrow \quad (6)$$

where C(K) is a constant value of perturbation with only sign value change induced during the process of algorithm (±C= constant) and C(K-1) is the constant value of perturbation with sign at (K −1)th instant with sign value changed as required for the constant C.

Thus in the modified MPPT method, the perturbation ΔC toggles between three values 0 and ±ΔC. When there is a sudden change in atmospheric conditions, ΔC is equal to zero. So, the PV reference voltage will remain un-incremented/un-decremented. This leads to unchanged output power of the MPPT converter. The value of C shall not be less than 0.0007% of PV open circuit voltage at STC. Otherwise, PV array reference voltage picks very slowly and the output power will not follow the input resulting in reduced efficiency.

 

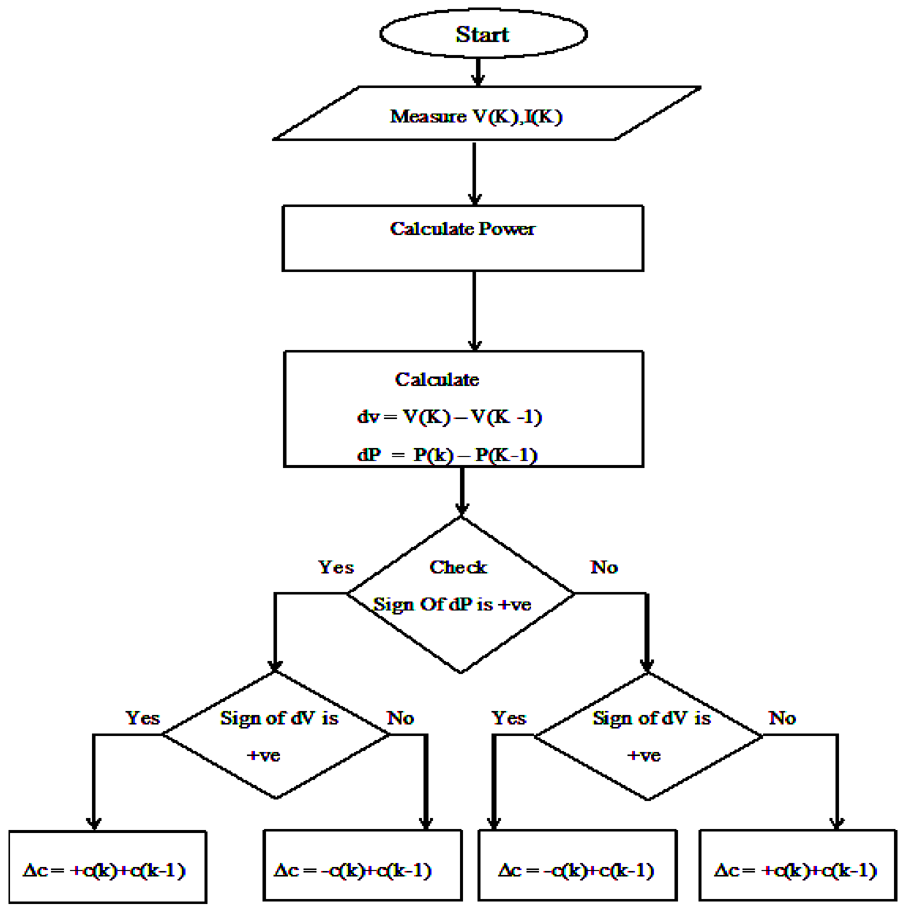


*Fig.4 Flowchart of Modified P and O algorithm*

### C. Behaviour of Modified P and O algorithm:

| ΔP | ΔV | C(K-1) | Signof C(K)= sign of(ΔP*ΔV) | ΔC= C(K-1)+ΔC | $V_{ref}$= V(K-1)+ΔC |
|---|---|---|---|---|---|
| + | + | +0.003 | +0.003 | +0.006 | ↑ |
| - | + | +0.003 | -0.003 | 0 | constant |
| + | - | -0.003 | -0.003 | -0.006 | ↓ |
| - | - | -0.003 | +0.003 | 0 | constant |

*Table.2*

 

## V SIMULATION RESULTS

The circuit is simulated by using PLECS software as shown in Fig.5.

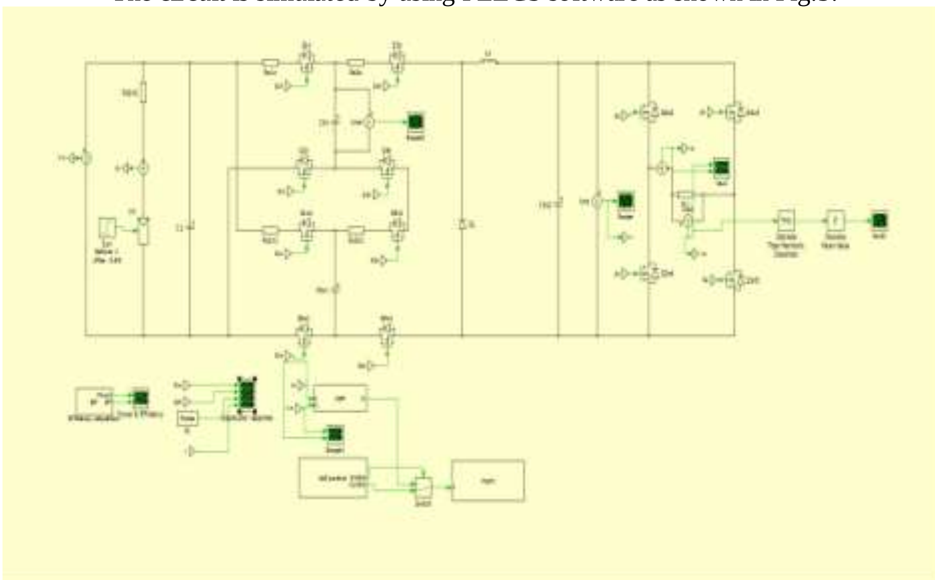

*Fig.5 Simulation circuit*

### *A. Irradiation Pattern*

The below figure shows that the irradiation pattern .Irradiation pattern are changed in the form of step signal.Intially the step signal is in unit step and after 0.5 sec, it attains 0.7.

*Fig.6 Irradiation Pattern*

### *B. Comparison between P&O and MP&O*

***Duty Cycle variation***

The below figures shows that the duty cycle variation of Perturb and Observe algorithm and Modified Perturb and Observe algorithm. In the P and O algorithm, when the irradiation changes, the duty cycle is changed abruptly from one position to another position. But in the Modified P and O algorithm, when the irradiation changes, the duty cycle is varied by step by step.

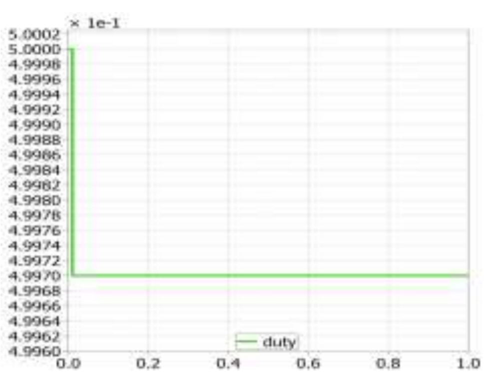


*Fig.7 Duty cycle of P&O*

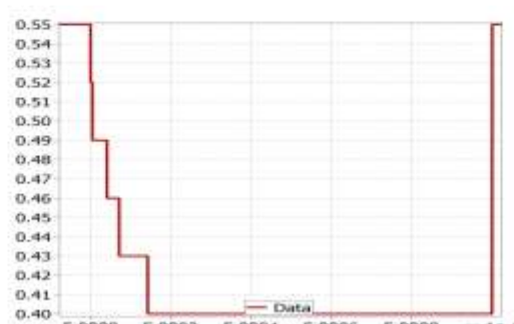


*Fig.8Duty cycle of MP&O*

 

***Output Voltage and Output Current***

From Fig.10, it is clear that output voltage generated by MP&O algorithm is smooth and variations are not noticeable. On the other hand, the generated profile of output voltage of hill-climbing P & O method, as illustrated in Fig.9, exhibits large variations. The input voltage is 160V and the corresponding output voltage is 190V$_{peak-peak.}$The rms value of the output voltage is 134V.

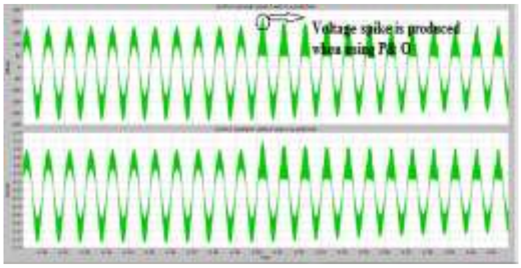


*Fig.9 Output Voltage and Output Current waveform Using P&O*

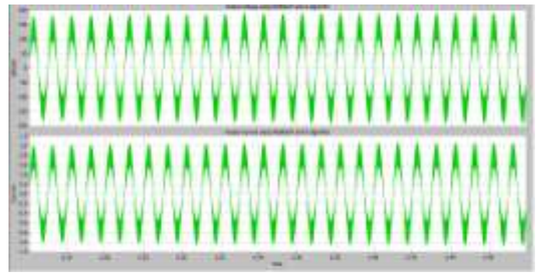

*Fig.10 Output Voltage and Output Current waveform using MP&O*

***Input Power Vs. Output Power***

From the Fig.11, the P&O algorithm takes 0.30sec to track maximum power point. When the irradiation is changed on 0.5sec, it takes 0.11 sec to resettle.

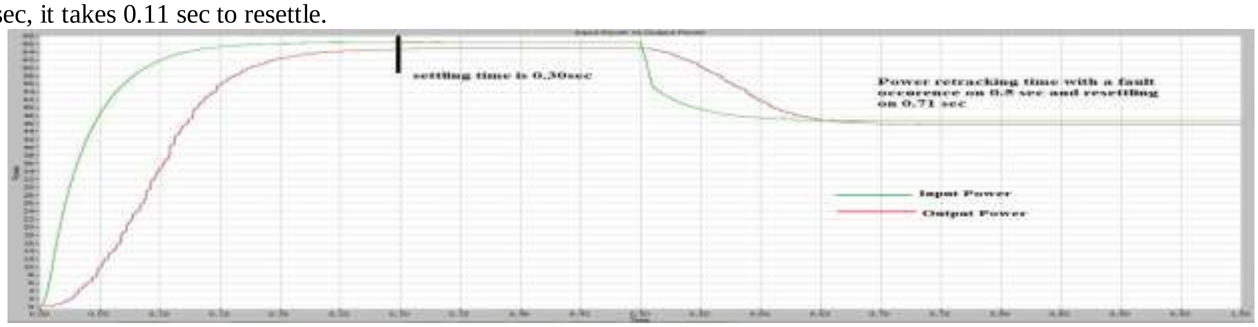


*Fig.11Power Curves using P&O*

From the Fig.12, the modified perturb and observe algorithm takes 0.14sec to track the maximum power point. The tracking time is less when compared to the perturb and observe algorithm. When the irradiation is changed on 0.5sec, it takes 0.10sec to resettle.

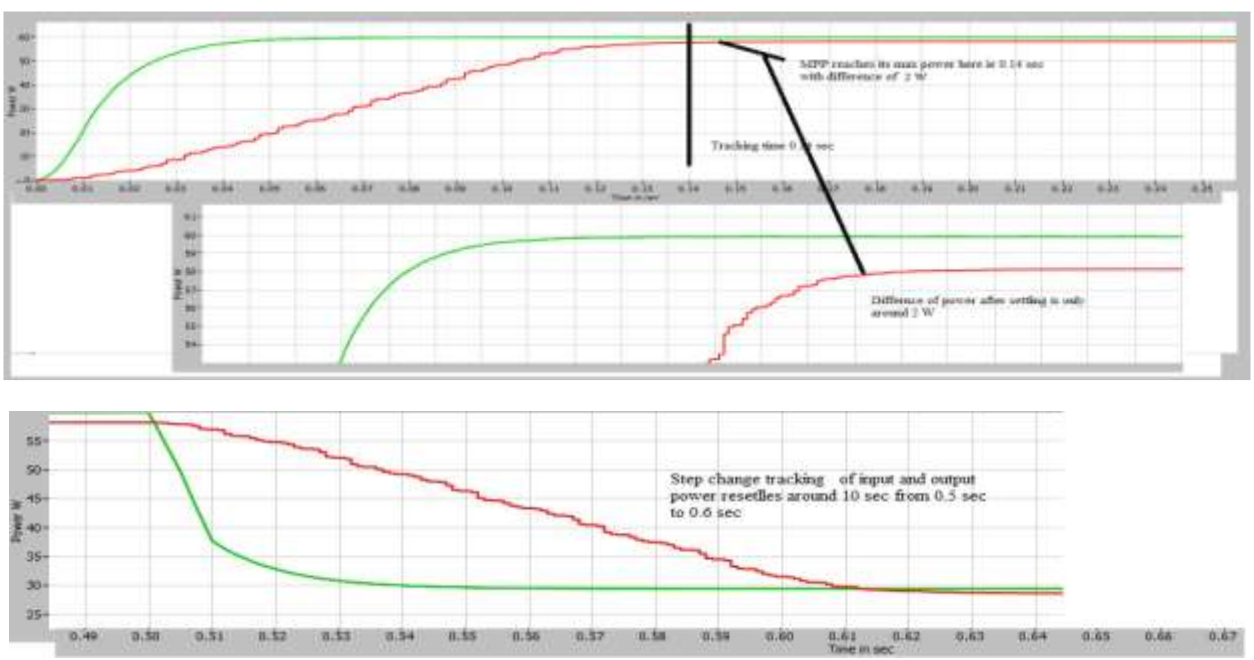


*Fig.12 Power Curves using MP&O*

 

## VI CONCLUSION

This paper proposed a new method to track the maximum power point tracking (MPPT) for PV system. The modified design makes only minor changes in the algorithm of conventional P & O, with a unique technique to dynamically alter the perturbation step. The modified P & O is simulated in PLECS software and its performance is compared with the conventional P & O. Based on the simulation results, the modified P & O consumed less tracking time and resettling time when compared to the P & O. With the modifications made in the algorithm, the MP&O method can track effectively for sudden changes in atmospheric conditions.
This paper also discussed a switched capacitor based dc-ac inverter with the following features. (a) The inverter is fed from a PV module; (b) It's a single stage topology for PV module's MPP tracking, step down the input voltage and invert the input voltage. (c) It has scope for integration with the PV module due to inherent features of SC inverter like compactness, ruggedness, and light weight.

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