JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Design and Simulation of Maximum Power Point Tracking (MPPT) using Perturb and Observe Algorithm

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Abstract:

This paper presents a holistic view of the concept of Maximum Power Point Tracking (MPPT) generally used and implemented for solar applications, so as to maximize the output for a conventional solar panel. This paper comprises of detailed study in the field of MPPT in a simulative environment using MATLAB and the result is obtained using Perturb and Observe (P&O) algorithm. Improvement in the performance of a conventional solar panel is seen through the simulation in terms of output voltage of the boost converter connected as the main DC-DC converter device. This paper comprises of detailed study in the field of MPPT in a simulative environment using MATLAB and using Perturb and Observe (P&O) algorithm to optimize the energy conversion efficiency of PV system.

Introduction:

Concerns over environmental effects such as climate changes, global warming, depletion of fossil fuels and increase in fuel prices are making renewable energies more attractive. Among the various renewable energy sources, solar energy is a promising energy source as it is abundant, pollution free and noise free. The efficiency of commercially available solar cell is in the around 38-43% and solar system is around 25-29% .Hence it becomes necessary to use effective techniques in order to maximise energy conversion efficiency and thereby reduce the cost.

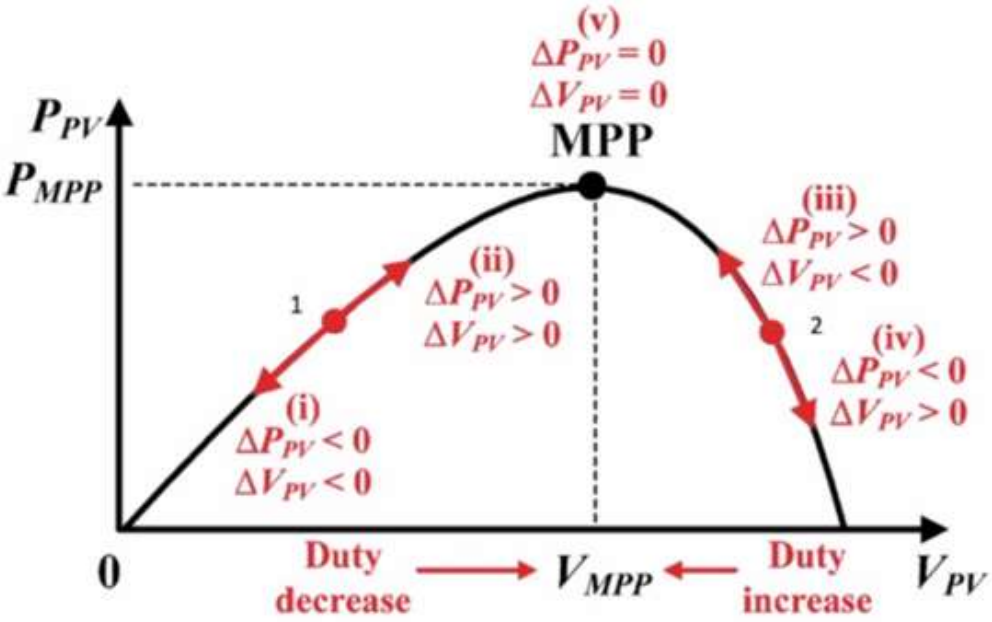
Due to the advent and development in the field of renewable energy sources, the dependence on fossil fuels and conventional energy sources has been decreased drastically. This has led to higher penetration and use of distributed resources. The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming has led to a need for a new source of energy that is cheaper and sustainable having less carbon emissions. Solar based energy systems have offered promising results in the quest of finding the solution to the problem.

So, a constant effort has been made by researchers to harness this energy resource to its maximum. That is why the concept of Maximum Power Point Tracking (MPPT) has been developed that can maximize the power output that ultimately improves the efficiency of the system.

A PV system converts solar energy into electrical energy by using PV effect. In a particular environment, there is only a maximum power point (MPP) due to the non-linear current-voltage characteristics of PV systems. The MPP keeps changing accordingly with the solar irradiation levels and cell temperature. Moreover, the impedance mismatch between solar panel and the load may reduce the output power. In order to solve this, a DC-DC converter is used between solar panel and the battery. A maximum power tracking technique will be required to solve the impedance mismatch. This is done by ensuring that PV array operates at a single operating point where the current and voltage of the cell provides maximum power output, regardless of the variations in solar radiation levels and temperature.

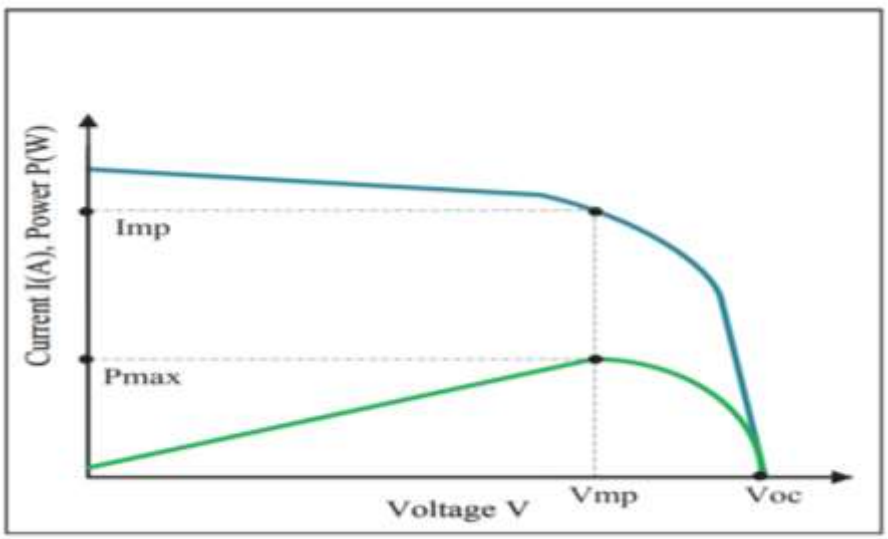
Literature Survey:

Maximum Power Point tracking is an electronic system that facilitates the PV modules to produce maximum power, that they are capable of by varying the operating point of module. The role of the MPPT is to match panel output power with load requirements. MPPT controller ensures that a PV module's operating point is maintained at reference voltage that will produce maximum power for varying atmospheric conditions. The mechanism is based on the principle of impedance matching between source and load, for maximum power transfer between load and PV array at different operating points. The MPPT controller varies the ratio between voltage and current to match impedance of a solar array until the operating point provides maximum power for a given set of conditions. It also ensures a proper charging condition for the batteries and avoids any overcharging and discharging to improve the battery life. A significant amount of research has been conducted to improve the efficiency of solar tracking systems. It is important to choose the most suitable MPPT based on factors like accuracy in predicting the true MPP, cost, convergence speed and sensitivity.



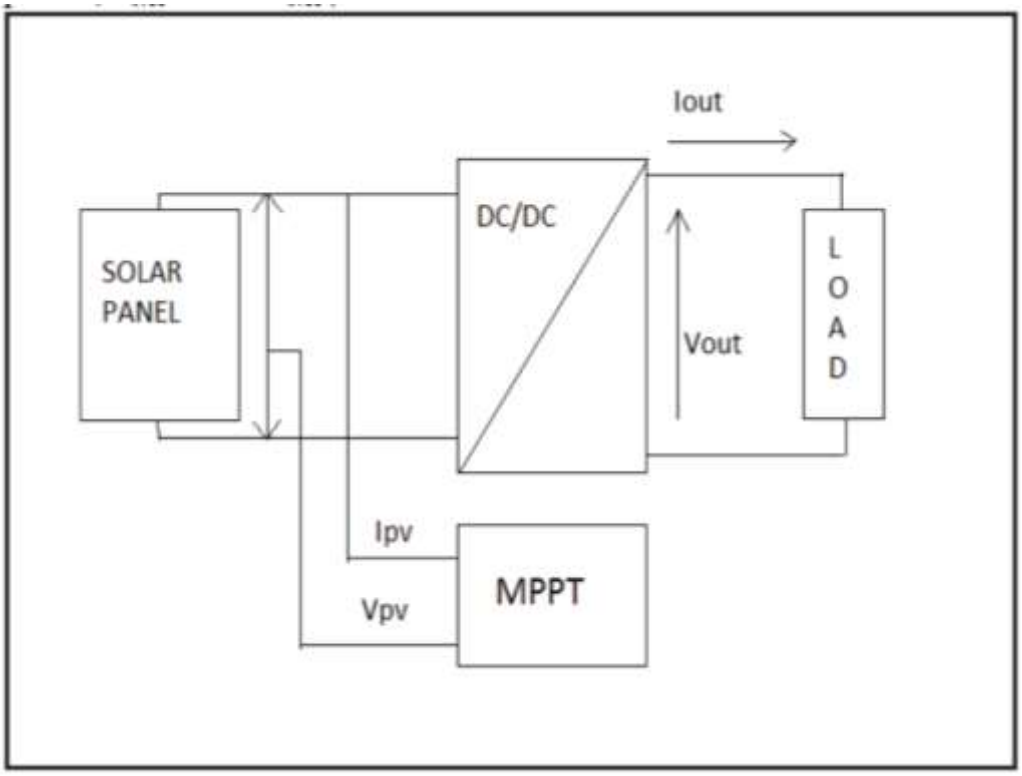
Methodology:

Maximum Power Point tracking, is an electronic system that facilitates the PV modules to produce maximum power, that they are capable of. It is NOT a mechanical system in which the module "physically moves" with the direction of solar radiations. Instead, it is an electronic system that varies the operating point of module to avail the maximum power. A typical I-V and P-V curve of a solar cell can be seen in figure below.



P-V and V-I Characteristics for a solar panel

The above curve represents the variation of current and power with respect to voltage. Maximum Power Point is tracked when the curve attains the maximum value of power, that is fundamentally, the product of current and voltage becomes maximum. That particular value of maximum power is Pmax as shown in the figure corresponds to current and voltage at that point, IMP and VMP.



The above figure represents the tracking system for the measurements of current and voltage to find power output of PV panel. A DC-DC converter is tied to a solar panel whose output is fed to a load. The values of Ipv and Vpv are sensed at each sample according to the sample rate and accordingly the controller provides gating pulse to the switch in the converter. This gating pulse will have a duty cycle that would be controlled by the MPPT controller. Ultimately, at the output is the desired voltage according to the P&O algorithm.

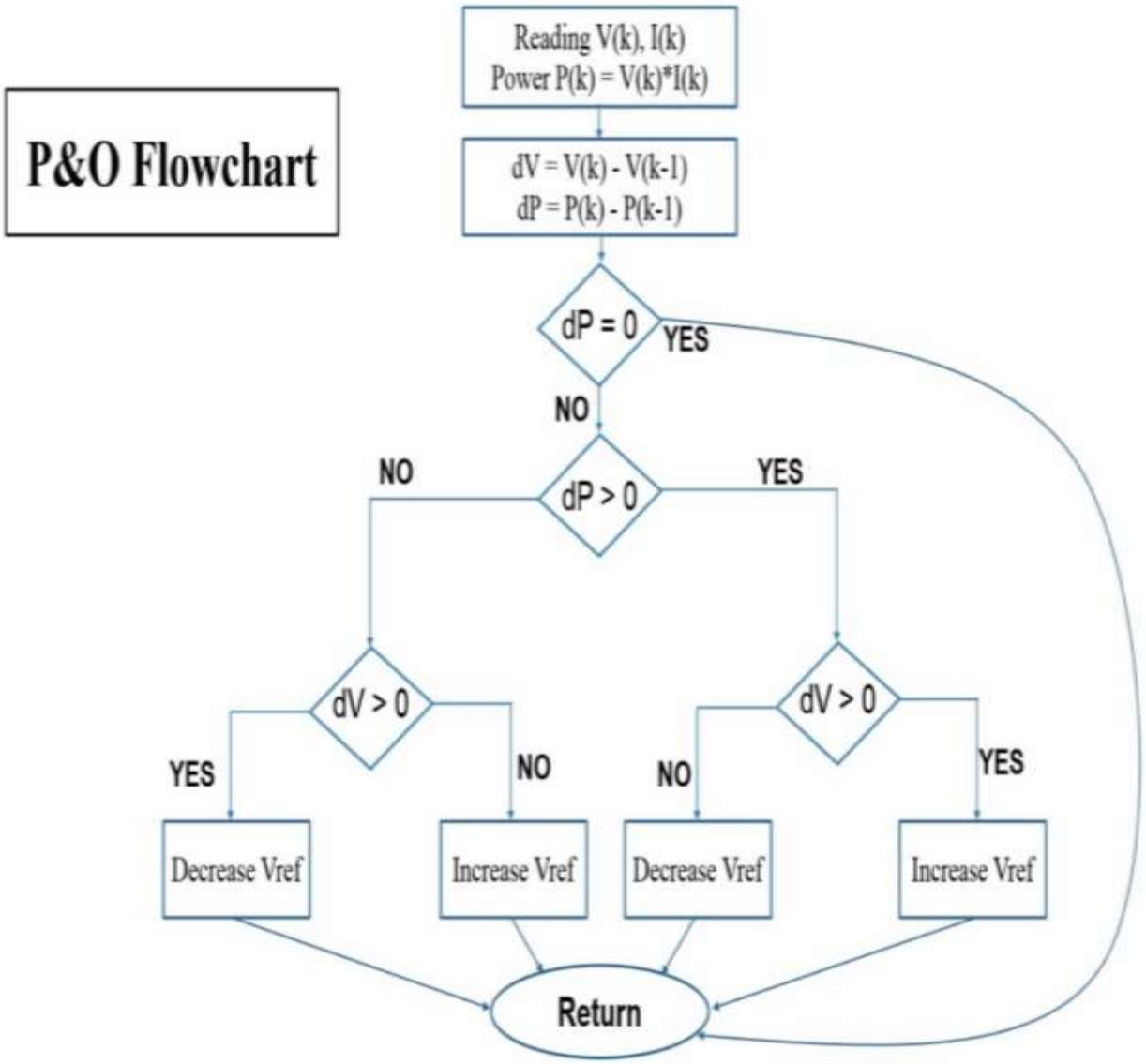
ALGORITHM FOR MPPT: Perturb and Observe(P&O):

The P&O algorithm is a relatively simple, yet powerful method to track the MPP. This algorithm utilizes an iterative approach at each and every sample that is collected by the control system. Perturb and observe is widely used MPPT algorithm because of its simplicity and low-cost in implementation. P&O perturb the operating voltage and power at one point and then it compares with previous value. It keeps on increasing or decreasing the voltage until it reaches the maximum output power where $dP/dV = 0$.

The algorithm is used to sense the power that is obtained at the output of the solar panel and according to the algorithm used, the next sample of the output power is conditioned. The previous iteration that has been stored in memory is compared with the sensed power, evaluated from the sensed voltage and current. In the first iteration, the current power is compared against some calculated constant power that is placed in the algorithm during programming. The algorithm compares the difference between current and previous powers against a predefined constant. This constant is defined within the algorithm to ensure that when the method has identified the Maximum Power Point (MPP) of the PV panel, the duty cycle will remain constant until the conditions change enough to change the location of the MPP.

If this step is not included, the algorithm would constantly vary the duty cycle, causing the ideal operating point of the panel to move back and forth across the MPP. The movement across the MPP is an unwanted oscillation that can be disruptive to power flow and could also cause unwanted loss. The next step in the algorithm is to check whether the current power is greater than or less than the previous sampled power. This would predict the next branch in the algorithm. In the next step the voltages and the current in the current sample are compared with the previous iterations. The comparison of voltage conveys which side of the MPP the operating point is at; thereby allowing the algorithm to adjust the duty cycle in the right direction (that may be either a positive or negative addition to the current duty cycle). The final step of the method is to actually change the duty cycle fed to the converter and wait for the converter to stabilize before the next sample is sensed.

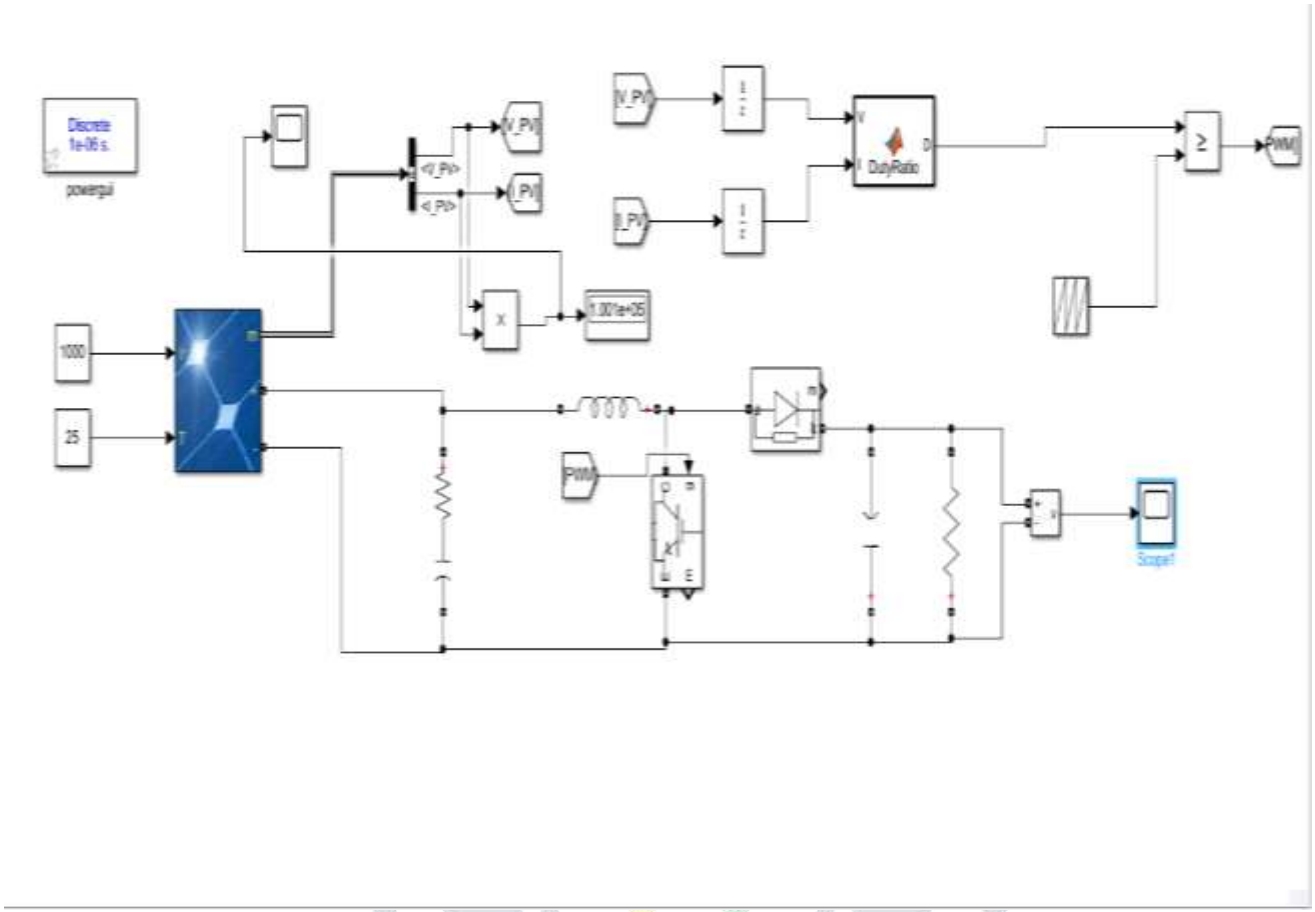
The P&O algorithm can be optimized so as to minimize the oscillations about the MPP. The first and most important way would be choosing of constants within the system optimally and carefully. A constant ‘r’, as shown in the flowchart tells the algorithm whether the MPP has changed or not and thus it needs to be sized just right. It should be big enough so as to prevent the oscillation effect once the MPP has been found but small enough to ensure that the algorithm will move to the correct point when the MPP changes even slightly. The duty cycle changes (Δd) also needs to be optimized with each perturb. This needs to be small and accurate enough to allow for a sufficient number of steps within the full duty cycle range.


P&O Flowchart
Reading V(k), I(k)
Power P(k) = V(k)*I(k)
dV = V(k) - V(k-1)
dP = P(k) - P(k-1)
dP = 0
YES
NO
dP > 0
NO
YES
dV > 0
dV > 0
YES
NO
NO
YES
Decrease Vref
Increase Vref
Decrease Vref
Increase Vref
Return

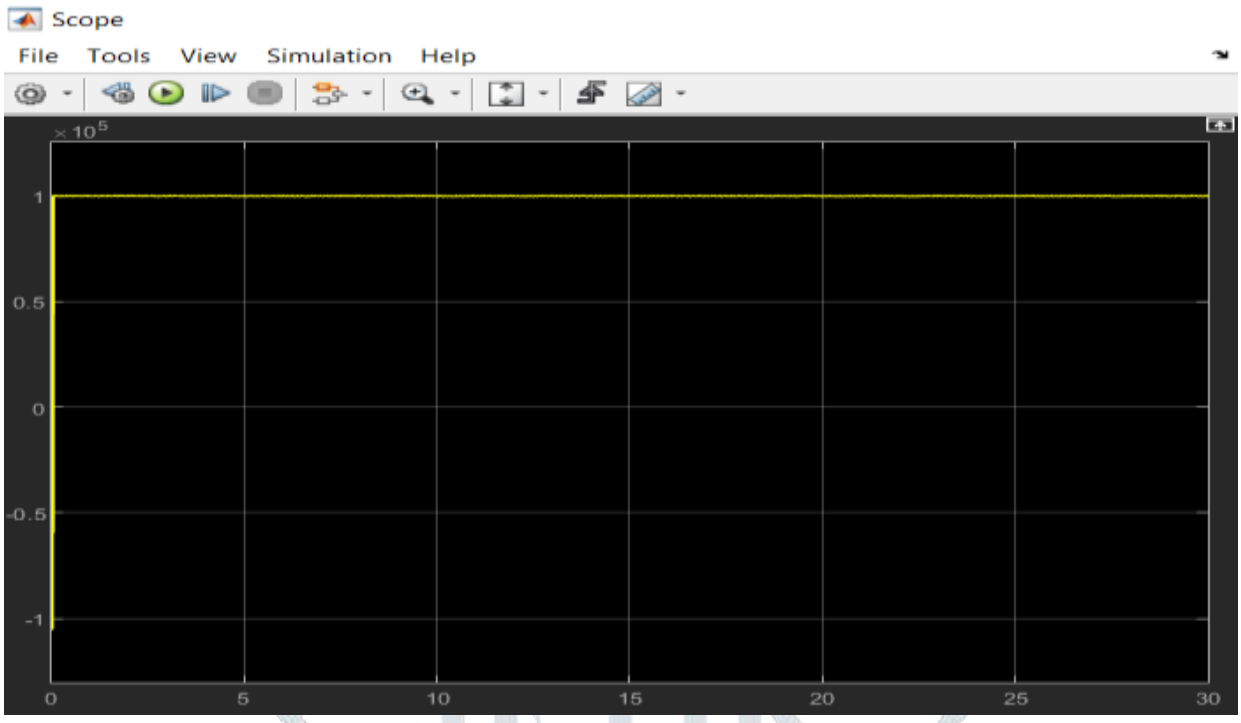
Result:

The simulation results illustrate the performance and effectiveness of Perturb and Observe algorithm in tracking the maximum power point.

The simulation circuit is shown below



The power and voltage graphs are shown below



Conclusion:

There are number of research groups actively involved in developing techniques to optimize energy conversion efficiency of PV systems. Thus, MPPT can be considered an important and useful algorithm to track and maximize the output of any system. This idea can also be extended to other renewable sources of energy. It can extract maximum available power from the PV module. This concept can be used for solar charging applications too. MPPT can be extended from the DC-DC converter to form a system, by connecting an inverter at the output terminals of the DC-DC converter. Many solar panels can be connected in series and a solar tied system can be implemented so as to feed the grid. The results obtained in simulation depicted how the output voltage (of the boost converter) remains constant and at its maximum value for a particular solar panel using P&O algorithm.

Reference:

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2. Ashwin Chandwani, Abhay Kothari "Design, Simulation and Implementation of Maximum Power Point Tracking (MPPT) for Solar based Renewable Systems" Alternate/Renewable Energy for Sustainability IEEE Transactions 2016 International Conference on Electrical Power and Energy Systems (ICEPES) Maulana Azad National Institute of Technology, Bhopal, India. Dec 14-16, 2016.