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Improved perturb and observe maximum power point tracking technique for solar photovoltaic power generation systems

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***Abstract*---**The primary concerns in the practical photovoltaic (PV) system are the power reduction due to the change in operating conditions, such as the temperature or irradiance, the high computation burden due to the modern maximum power point tracking (MPPT) mechanisms, and to maximize the PV array output during the rapid change in weather conditions. The conventional perturb and observe (P&O) technique is preferred in most of the PV systems. Nevertheless, it undergoes false tracking of maximum power point (MPP) during the rapid change in solar insolation due to the wrong decision in the duty cycle. To avoid the computational burden and drift effect, this article presents a simple and enhanced P&O MPPT technique. The proposed technique is enhanced by including the change in current (dI), in addition to the changes in output voltage and output power of the PV module. The effect of including the dI

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profile with the traditional method is explained with the fixed and variable step-size methods. The mathematical expression for the drift-free condition is derived. The traditional boost converter is considered for validating the effectiveness of the proposed methods by employing the direct duty cycle technique.

***Keywords*---**maximum power point tracking, perturb, observe, solar insolation, boost converter.

Introduction

A photovoltaic (PV) system is a system composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. Although PV systems can operate by themselves as off-grid PV systems, this article focuses on systems connected to the utility grid, or grid-tied PV systems. The PV characteristics are nonlinear, and it is a challenging issue to operate at the maximum power point (MPP) to produce maximum possible output power. Therefore, the solar PV panel characteristics, such as current (I)-voltage (V) and power (P)–V characteristics, get altered when solar insolation and the cell temperature change. Therefore, it is essential to track the MPP from the profile of the PV panel. The maximum output power from the PV module is extracted using MPPT techniques, and a power electronic-based converter plays an essential role in it. Therefore, the MPP can be tracked by adjusting the duty cycle of the power electronics converter.

There are numerous techniques introduced by many researchers to increase the tracking accuracy and efficiency of solar power generation systems. However, none of the MPPT methods is perfect. In this paper, proposed an easy and accurate MPPT technique to avoid failure in tracking the MPP under a fast change in solar insolation. The divergence problem and the steady-state power oscillation are reduced by considering the change in output current (dI) profile along with the traditional P&O MPPT technique. The proposed modified P&O technique is tested with both fixed step size and variable step size. To implement this technique, the dc–dc converter is required between the load and the PV module. Thus, in this article, the traditional boost converter is selected and effectively designed as per the system ratings to meet the objectives of the MPPT.

MPPT algorithm

The algorithms control the voltage to ensure that the system operates at “maximum power point” (or peak voltage) on the power voltage curve. MPPT algorithms are typically used in the controller designs for PV systems. The algorithms account for factors such as variable irradiance (sunlight) and temperature to ensure that the PV system generates maximum power at all times.

Perturbation and Observe(P&O)

This algorithm perturbs the operating voltage to ensure maximum power. While there are several advanced and more optimized variants of this algorithm, a basic P&O MPPT algorithm is shown below.

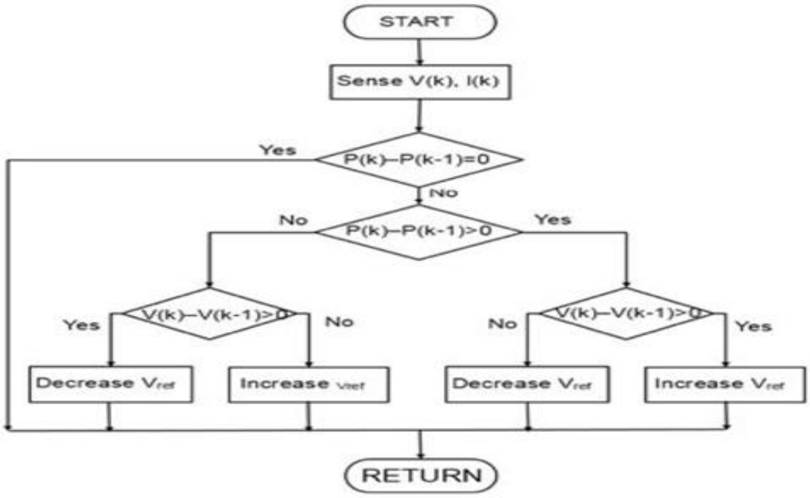


Fig 1 : Basic P&O Algorithm

Adaptive P&O Algorithm

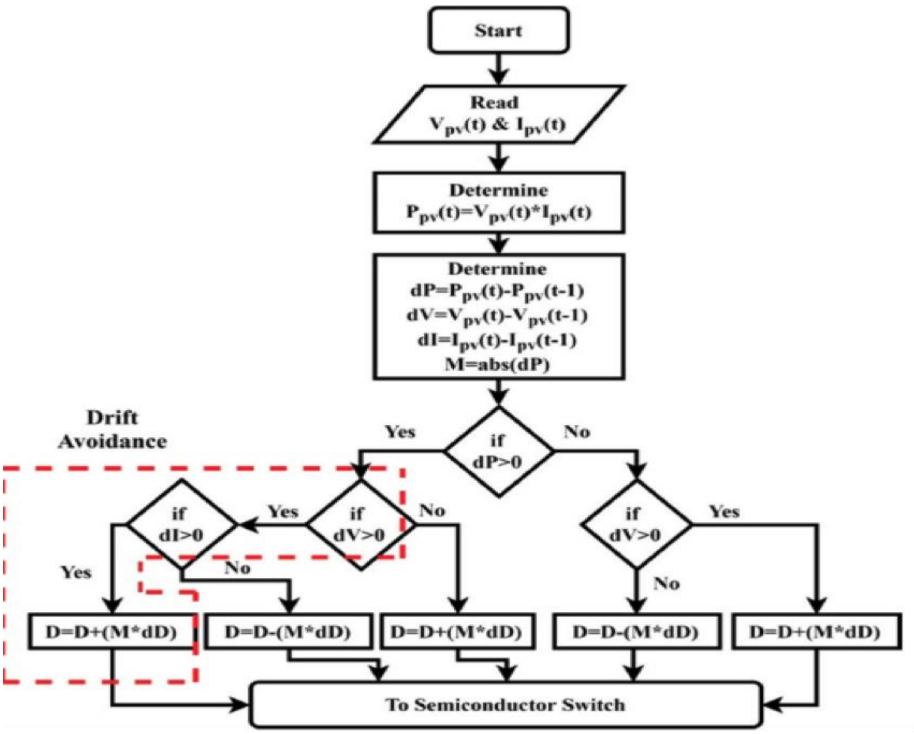


Fig 2 : Algorithm of Adaptive P&O Technique

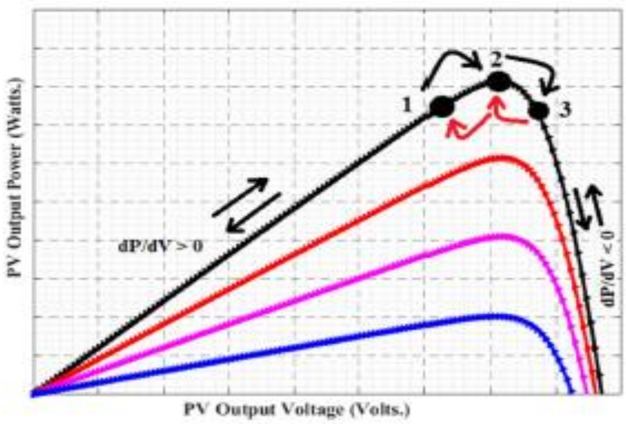
Selection of Perturbation Time (Tp)

The time, Tp, should be less than the settling time of the converter to reduce the power oscillations in the conventional P&O technique for a change in duty ratio of the converter. The perturbation size (dD) and the settling time of the converter are directly proportional to each other. However, for an adaptive method, the perturbation time is larger than the settling time of the converter for a maximum variation in duty ratio (dD max).

Selection of Perturbation Size (dD)

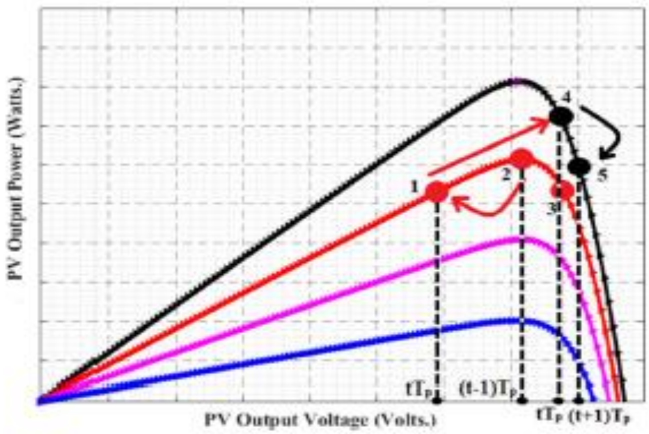
By considering the performance under steady-state and transient state conditions, the perturbation size is selected. If the size of the perturbation is less, then the performance under steady-state is improved, whereas if the perturbation size is maximum, then the performance under the transient state is improved. The minimum step size can be selected based on the analog-digital converter resolution, microcontroller, and tracking accuracy of the system. Due to the switching ripple of the semiconductor on the PV voltage, the optimal perturbation size can be selected, such that the PV voltage deviation due to the size of the perturbation should be higher than the swell of PV output voltage.

Steady-State Behavior of P&O Algorithm



Consider that the operating point on the P–V curve has been relocated from point-1 to point-2, and the algorithm takes a decision at point-2 by considering dV and dP. As dV > 0 and dP > 0 at point-2, the algorithm decreases the converter duty ratio. Now, the operative point is moved to point-3. As dP < 0 and dV > 0 at point-3, the method raises theconverter duty ratio, and now, the operative point is moved to point-2. As dV < 0 and dP > 0 at point-2, it raises the converter duty ratio further, and now, the operating point is moved to point-1. As dV<0 and dP<0 at point-1, the algorithm decreasesthe converter duty ratio, and now, the operative point is moved to point-2. As discussed, the operating point oscillates between three locations around the MPP.

Drift Occurrence in the P&O Technique



During rapid variations in solar irradiation, which happen typically in cloudy seasons, the chances of getting drift problems are high. Usually, the drift occurrence happens at any of the three operating points. It depends on the change in solar irradiation instant in between the perturbation duration. The drifting issue is due to the absence of information in knowing whether the rise in PV power in the module is because of the increase in solar insolation or an increase in perturbation. As depicted in Fig. 6, assume that the solar insolation is changed at point-1, and at the same instant, the operating point on the characteristic settles at point-4 during the same perturbation duration (tTp) as that of point-1. As dV (V4(tTp) − V2((t −1)Tp) > 0 and dP (P4(tTp) − P2((t − 1)Tp) > 0 at point-4, it decreases the converter duty ratio, and the operative point moves away from the MPP, i.e., toward the point-5. Similar to this, the problem due to drift occurs at the point-3 and point-2 as well.

Block Diagram

The adaptive P&O technique is tested with both fixed step size and variable step size to avoid failure in tracking the MPP under a fast change in solar insolation.
To implement this technique, the dc–dc converter is required between the load and the PV module as you can see it in the block diagram.

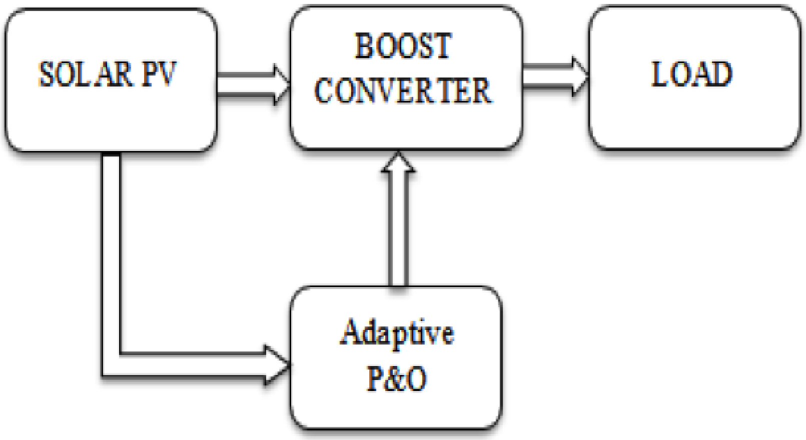


Fig 3 : Basic Block Diagram of Adaptive P&O MPPT Technique

Circuit Diagram

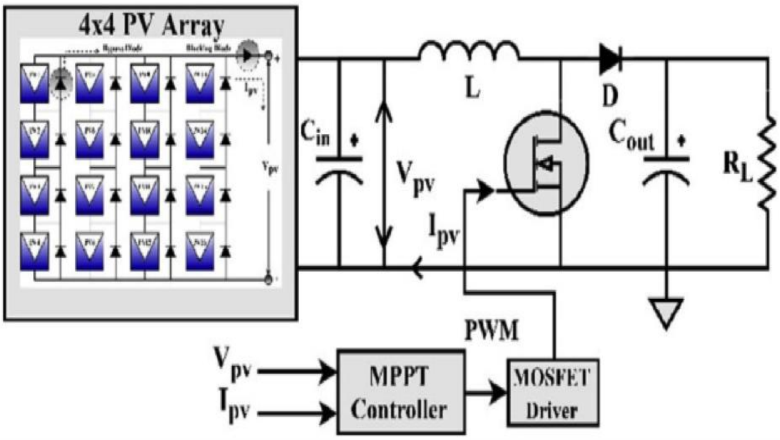


Fig 4 : Basic Circuit Diagram of Adaptive P&O MPPT Technique

Circuit Explanation

The solar PV array is formed by connecting the PV modules in series and parallel combinations to acquire the required current and voltage rating. The sum of the individual power rating of the module is equal to the rating of the PV array. The PV array has four panels in a string, and four PV strings are attached in parallel (4×4). If cells/panels are shaded due to various reasons, then the shaded cell/panel acts as a load instead of the source. In due effect, the shaded panels will be damaged if the hotspot increases. To reduce the hotspots in the panel, the bypass diode is connected across each panel during shading conditions. The reverse current to the PV module is restricted by connecting the blocking diode. During the normal condition, the PV panel exhibits a single peak on P–V characteristic. On the other hand, during shaded conditions, the panel has multiple peaks, such as two or more local peaks (LPs) and one GP. It is essential to drive the PV module at GP to generate the maximum output power, instead of operating at LP. So, it is essential to find an effective MPPT method to produce the maximum output power with good tracking time and accuracy.

Simulation

A simulation design of the proposed model is implemented in the MATLAB SIMULINK. The obtained waveforms were shown in the following figures.

Simulation Circuit

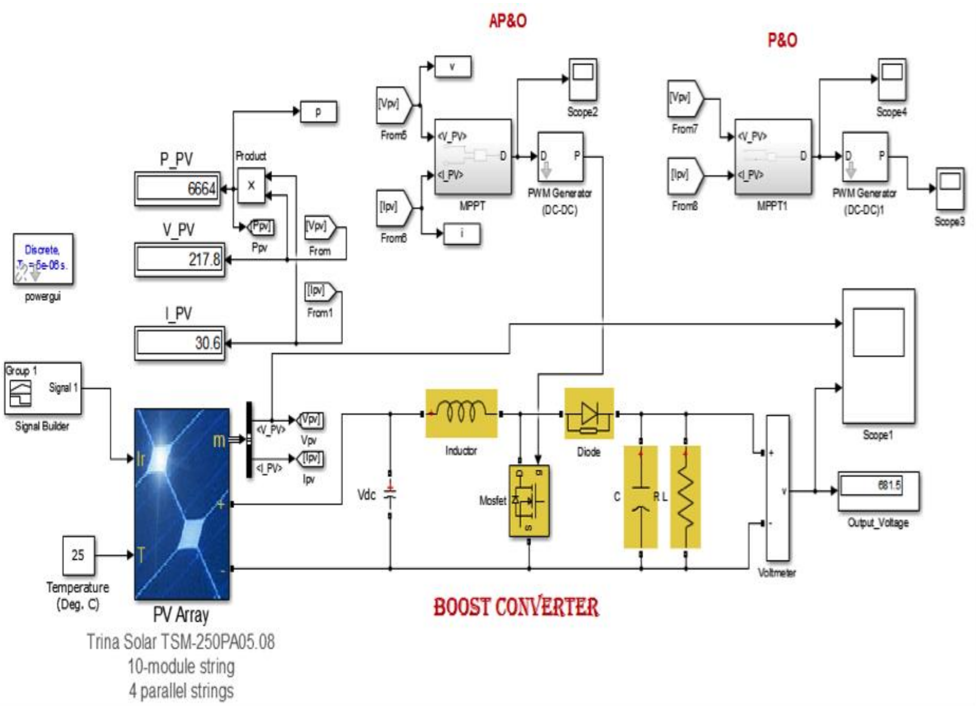


Fig 5 : Simulation Circuit of P&O and Adaptive P&O

Simulation Output

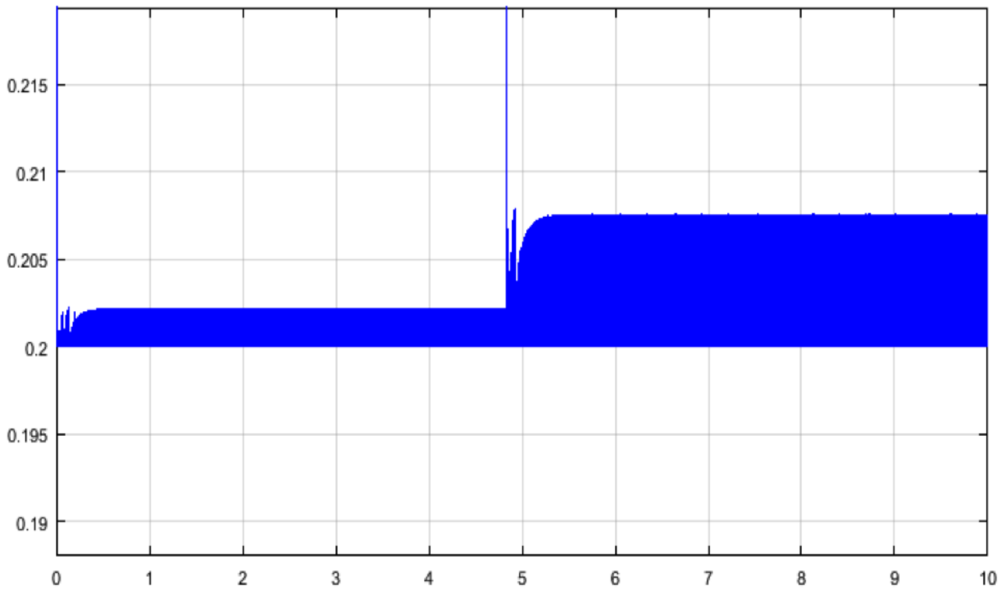


Fig 6 : Duty Cycle waveform of P&O and Adaptive P&O

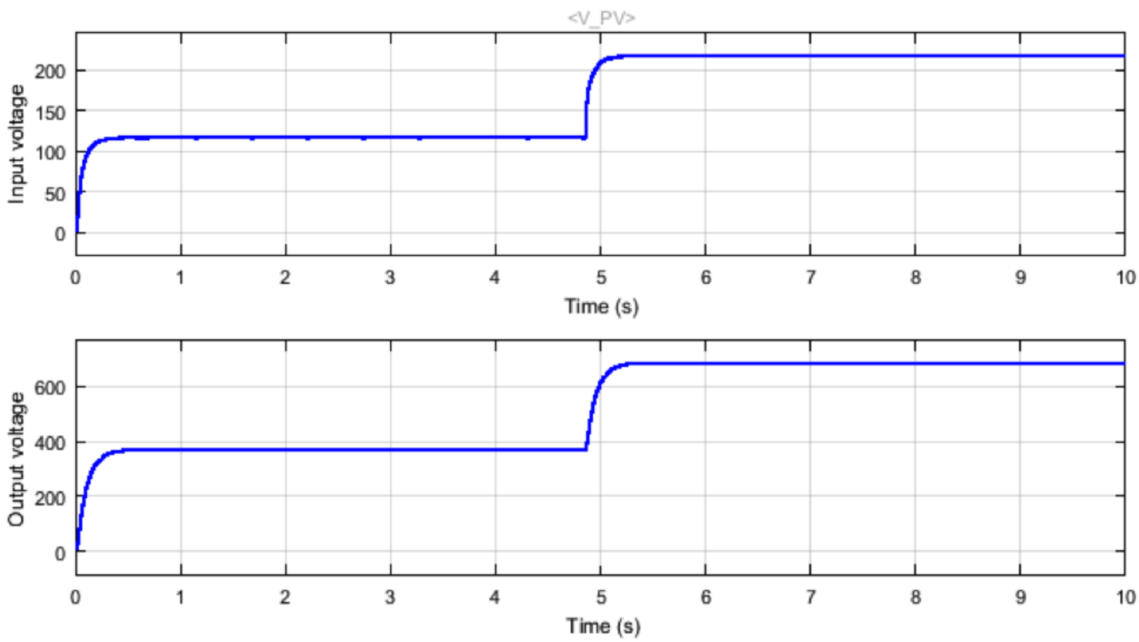


Fig 7 : PV Voltage and Boosted Output Voltage waveforms

Conclusion

This article investigates and outlines the problem in the traditional P&O MPPT technique and presents new MPPT technique called AMP&O, which can significantly reduce the computational problem. The drift-free condition is achieved by including the change in current (dI), profile with the existing change in voltage (dV) and power (dP) profile. The mathematical analysis justifies the advantage of the proposed techniques.

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