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Maximum Power Extraction by Introducing P&O Technique in PV Grid

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Abstract - *The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems. This paper elaborates overview of a photovoltaic (PV) system model, and compares the attributes of different conventional and improved incremental conductance algorithms, perturbation and observation techniques, and other maximum power point tracking (MPPT) algorithms in normal and partial shading conditions. One of the most widely used techniques is the perturb & observe algorithm, which periodically perturbs the operating point of the PV array, sometime with an adaptive perturbation step, and compares the PV power before and after the perturbation.*

Key Words: MPPT, Photo Voltaic Cell, Perturb & Observe, partial shading conditions, performance evaluation etc.

1. INTRODUCTION

Fossil fuels like gas and oil are not renewable, unclean and non eco-friendly source of energy. Solar energy is one of the most important renewable energy sources. PV system is divided into two categories: Stand-alone and Grid connected PV system. For places that are away from the utility grid, stand-alone PV systems are used at those places. In these systems, the performance of a PV system relies on the operating conditions. The maximum power extracted from the PV source depends strongly on three factors such as irradiation, load profile and temperature [Salas, 2006]. A place where utility grid is easily available, grid-connected PV system is used there. Amongst all RES, solar energy is well-thought-out one of the probable sources to resolve the crunch as it is accessible in plenty and free of cost [1].

Photovoltaic (PV) power generation has acknowledged major attention from scientists over the last few years to reduce the environmental pollution inherently associated with traditional electric generators. The economic convenience of PV generation is directly connected to the cost of the cells and the amount of energy that the arrays are capable of supplying over their life. The former is influenced mainly by the price of the feedstock for the PV industry and the improvement of fabrication technologies. PV systems have the main drawback that the power output is dependent on direct sunlight, about 10-25% is lost if a tracking system is not used, since the cell will not be directly facing the sun at all times [2]. Dust, clouds, and other hindrances in the atmosphere also reduce the power output. [3][4] The latter is connected to the efficiency of the power conversion system, which is normally necessary when PV arrays are used for power generation. At the present state of the art, the control algorithms used for the maximization of the power extracted from PV arrays are widely known as maximum power point tracking (MPPT) algorithms. These power conditioners guarantee that PV arrays operate close to their point of maximum efficiency under any weather conditions. This is particularly important for variable irradiation levels, because the efficiency of the PV modules is very small when the operating point is far from the maximum power point.

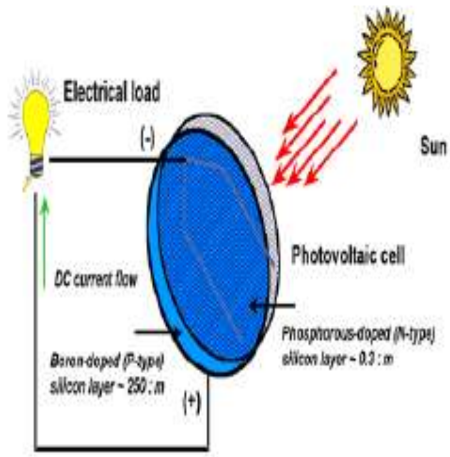

Figure 1: Working of Photovoltaic cell

Maximum power point tracking (MPPT) scheme is used to extract maximum power from solar PV cells. various types of MPPT schemes are projected by researchers [5] namely open circuit, short circuit, perturb and observe (P&O)/hill climbing, incremental conductance, and so forth.

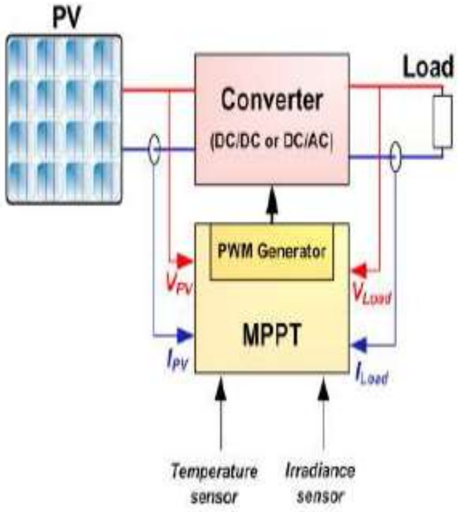

Figure 2: Block diagram of Typical MPPT system.

This paper proposes a limited search space based on improved P&O algorithm integrated with a solar tracker. Solar tracker makes sure the maximum coupling of the irradiance with the solar panel by keeping the panel always normal to the sun. The proposed algorithm first divides the power curve into three regions: Area 1 and area 3 are the left and right regions to the MPP respectively. Area 2 is the intermediate region of the power curve containing 10% area of the power curve and MPP lies in this area 2. This reduction in the search space reduces the step response time to reach the maximum power and the steady-state oscillations at the maximum power point.

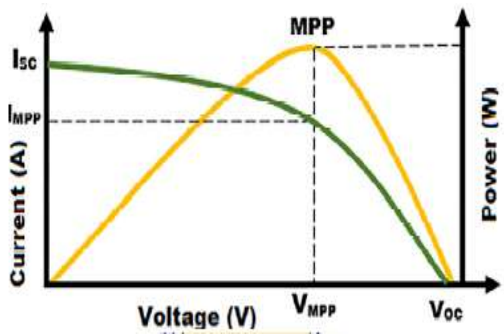

Figure 3: I-V and P-V characteristics of solar PV cell

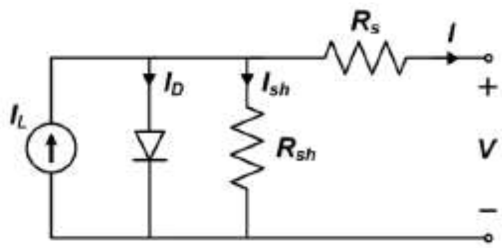

Figure 4: Standard equivalent circuit of the PV cell

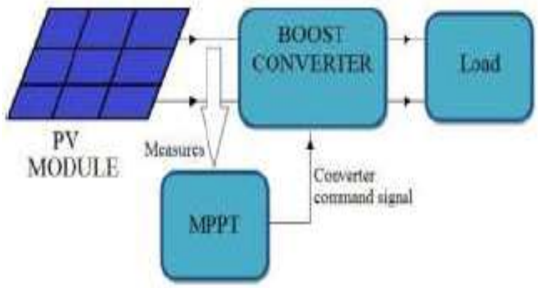

Figure 5: Block diagram of the MPPT system

There are different techniques used to track the maximum power point are:
1) Perturb and observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

1.1 Methodology (Perturb-and-Observe):

Doubly The most commonly used and modest MPPT algorithm is Perturb-and-Observe (P&O) method. Both Hill climbing (HC) and P&O methods have same logic and can be said to be two dissimilar means of visualizing the same method. In HC method duty ratio of the power converter used is perturbed and in P&O method the working voltage of the PV array is perturbed. Since a power converter is generally used with a PV array, so perturbing its duty ratio will automatically perturb the working voltage and thus both the methods are almost same. The logical flowchart of P&O method is shown in figure 6.

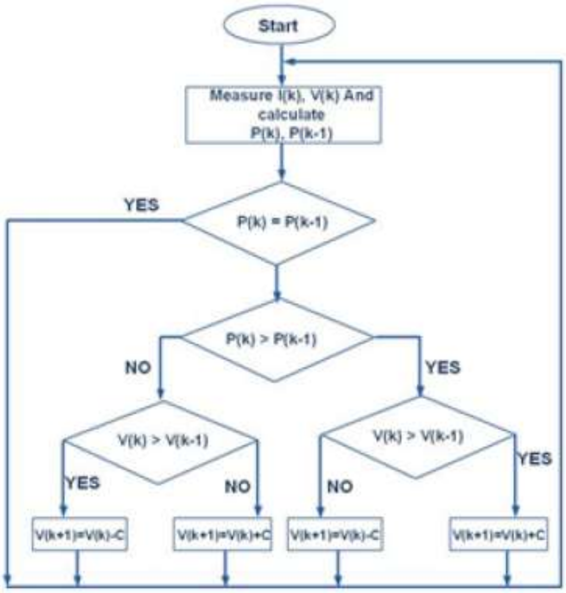

Figure 6: Flowchart of P&O MPPT technique

V(k) and I(k) is the PV panel voltage and current at k_{th} iteration. C is the length of voltage perturbation and choice of its value is very important. Small C results in slow tracking and large C gives fast tracking but the oscillation near the peak is large. The solution for this problem is the use of varying value of C, such that its value is large when the system is far from the MPP and its value approaches zero as the system reaches MPP. Here, it is shown that a fast convergence speed and almost no oscillation around the MPP can be attained by taking the value of C at k_{th} iteration i.e. C (k) according to following equation.

$$C(K) = N \log10(\text{abs}(\Delta P/\Delta V))$$

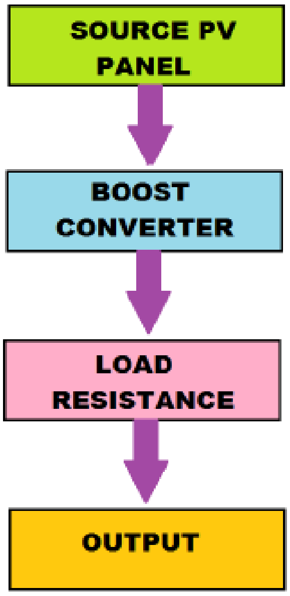

Figure 7: Basics of MPPT Technique

As shown in Figure 7 the first block is sourcing i.e. Solar Panel. There are some materials, which are photo sensitive and they find a place in photo voltaic conversion. A junction of materials, which have dissimilar electrical properties semiconductors are used in solar cells, provides the electrical field in most solar cells. Semiconductors are a class of materials with conductivity somewhere between metals and insulators. Solar cells are manufactured from monocrystalline materials. Low cost cells are round because they are made from sheets, which are cut from monocrystalline rods as they are pulled from the melt. Joining p and n type material in to a single crystal makes the cross section of a silicon solar cell.

1.1.1 Oscillation near MPP:

In most online MPPT schemes, power losses are mainly due to steady-state oscillations in the vicinity of the MPP [6]. The use of a large step size in a fixed duty cycle to increase tracking speed causes many oscillations around the MPP of PV panels [7]. These power oscillations can be extreme if the conventional algorithm (P&O) continues to search for the operating point on the P-V curve, although the MPP is tracked in advance [6]. A function-based modified MPPT method is implemented to track a current MPP with less steady-state oscillations to remain close to the MPP compared with the variable step size INC algorithm [8]. All improved and hybrid MPPT algorithms are employed to curb the oscillations adjacent the maximum power point in the dynamics.

1.1.2 Tracking Performance:

In conventional algorithms, the tracking accuracy is found to be higher when using soft computing, moderate with P&O algorithms and lower when used with constant voltage or current methods. In the P&O technique, tracking accuracy is reduced if the tracking speed and perturbation size are increased to track the MPP [9]. In the conventional INC MPPT method, the fixed step size is the main constraint in achieving high tracking performance for the PV system. Thus, the variable INC algorithm is introduced to improve the tracking efficiency, but it has an inversely proportional effect on steady-state oscillations and tracking speed. Fast and accurate tracking speed is attainable by calculating the distance from the operating point to MPP in combination with an automated tuning of the duty cycle step size [10].

MPPT Technique	Speed	Complexity	Reliability	Implementation
Fractional Voc	Medium	Low	Low	Digital/Analog
Incremental Conductance	Varies	Medium	Medium	Digital
Hill Climbing(P & O)	Varies	Low	Medium	Digital/Analog
Fuzzy Logic	Fast	High	Medium	Digital
Neural Network	Fast	High	Medium	Digital

Table I: Comparison of common MPPT methods

1.2 Perturb and observe:

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

1.2.1 Modified Perturb and Observe method:

This method is an improved method of perturb and observe (P&O) method. P&O is unable to track the power during load changes and rapid variation of environmental condition. MP&O method can meet the desired shape which is ineffective in case of P&O method. Although response time is improved, but power oscillation still pertains in case of MP&O algorithm.

That presents the idea to focus on ANN and fuzzy logic controller.

Advantages:

1. Simplicity: This algorithm solves one linear equation. Therefore, it does not consume much computational power.
2. It can be implemented as analog or digital circuits.
3. Since temperature varies slowly with time, there are no steady-state oscillation and instability.
4. Low cost: temperature sensors are usually very cheap.
5. Robust against noise.

Disadvantages:

1. Estimation error might not be negligible for low irradiation levels (e.g. below 200 W/m)

3. Conclusions:

This paper analyses the most suitable perturbation step to optimize maximum power point tracking performance and suggests a design criterion to select the parameters of the controller. Using this proposed adaptive step, the MPPT perturb & observe algorithm achieves an excellent dynamic response by adapting the perturbation step to the actual operating conditions of the PV array. The proposed algorithm has been validated and tested in a laboratory using a dual input inductor push-pull converter. This particular converter topology is an efficient interface to boost the low voltage of PV arrays and effectively control the power flow when input or output voltages are variable. [11]

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