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ANALYIS OF SEPIC CONVERTER OF MAXIMUM POWER POINT TRACKING OF PV ARRAYS

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ABSTRACT

There exists a variety of maximum power point tracking (MPPT) techniques, each having its own merits and demerits. Under partial-shading conditions, the conventional tracking techniques fail to guarantee successful tracking of the global maximum power, ie the conventional MPPT methods such as perturb and observe and incremental conductance may converge on local maximum power point resulting in significant reduction of power generated. This paper discusses about an improved technique for tracking global maximum power point of photovoltaic arrays that has better performance under partial shading conditions. The first stage in this method is to find out global maximum power point among the local maxima. Once the global maximum power point is found then by adjusting the duty ratio, the voltage corresponding to maximum power can be found out. The control is then transferred to perturb and observe algorithm stage. This technique could be applied for both stand alone and grid connected PV system. A comparison study between a SEPIC converter and a buck boost converter with the above mentioned algorithm has also been carried out in order to verify the performance of both the converters. The above mentioned converters have been designed for 150W at a switching frequency of 10 KHz. Modified algorithm has been simulated using MATLAB/Simulink and results are obtained. Partial shading condition was modelled in MATLAB/Simscape and analysed the solar array characteristics under various shading conditions. From the simulation results it was found that the SEPIC converter is much more efficient and is highly suitable for photo voltaic applications.

1. INTRODUCTION

Research in renewable energy has recently received great attention. Especially for photovoltaic (PV) technology, renewable energy has gained popularity as one of the potential avenues due to unlimited power resources and unpolluted operation [1]. To enhance the efficiency of PV, the effect of weather conditions must be considered. According to research by Patel and Agarwal [2], there are two main parameters which affect the PV-generated power, irradiation and temperature; where PV technology is installed, the generated power varies from location to location. It is apparent that we cannot control the two aforementioned parameters; therefore, the problem of "PV mismatch" can occur. PV mismatch is defined as the difference between the expected and actual output power from

a PV module, causing difficulties in PV technology generating power. Classified according to its source, mismatch can be internal or external. If PV power degradation occurs due to the quality of the panel, such as aging and impurities in the Silicon crystal, the mismatch is considered internal as it stems from the material's properties, and product replacement can solve the issue. However, if degradation occurs due to an environmental factor, mainly shading from PV alignment and the surroundings, the mismatch is considered external. The effect from shading has also been pointed out by Femia et al. [3] and Gao et al. [4] who considered shaded PV panel a significant obstacle in the rapid growth of solar PV systems. The study by Eftichios et al. [5] offers a practical case study through PV rooftop systems in Germany, where 41% of the installed panels had been affected by shading, with energy losses up to 10%. Hence, remarkable reduction of power generated was observed. In the same manner, Daraban et al. [6] presented a case study of 13 different PV power tracking systems operating under a shading condition, where the result showed up to 70% of power was a loss due to not detecting the actual maximum power.

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In electrical engineering, PV operating current and voltage form a non-linear relationship, demonstrated as the current-voltage (I-V) and power-voltage (P-V) characteristic curve. Figure 1a,b presents the series-connected PV array operated at a normal condition and with partial shading. Here, the bypass diodes were installed on each panel and a blocking diode was installed on each PV branch to reduce the effect of shading [2,7,8]. The I-V and P-V characteristic curves corresponding to each condition are shown in Figure 1c. Here, we can observe the significant difference between the two conditions is that shading exhibits multiple local peaks, while the normal condition shows only a single peak. Naming each peak as the local power peak with the highest among all points as the global power peak increases the challenge for the maximum power point tracking (MPPT) system to locate the correct global power peak point.

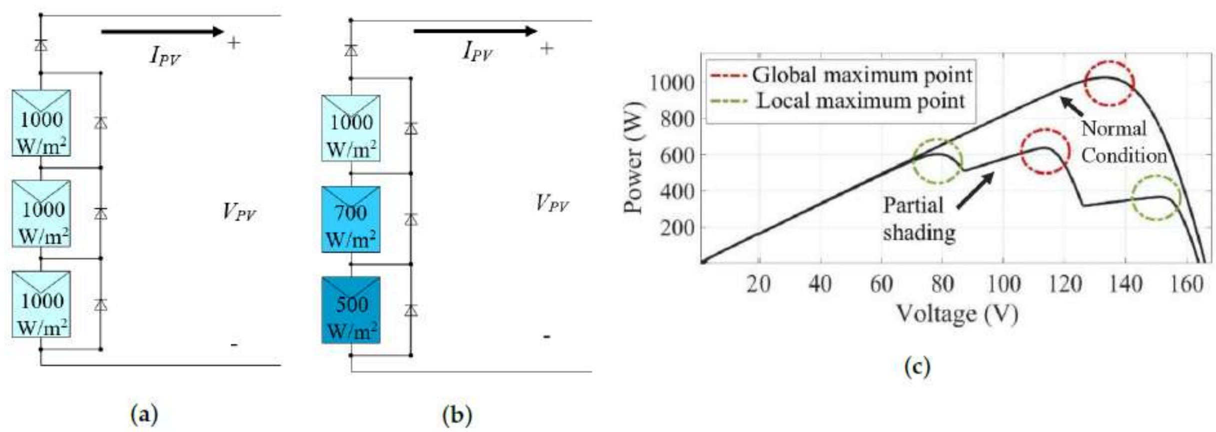

Figure 1. (a) Normal condition at 25 C, (b) partial shading condition at 25 C, (c) power-voltage (P-V) characteristic curves for both conditions.

Under shading conditions, it has been confirmed by previous research that conventional MPPT methods fail to ensure successful and precise tracking of the global power peak [6]. Consequently, the difficulties in implementing MPPT include the complexity of the algorithm, cost, and failure while operating in shading conditions [5]. Studies of global power peak identification under shading conditions have been done, especially in the past five years; each study presented a tracking method with a variation of complexity, cost, operating speed, and range of effectiveness. These variations should be taken into consideration when designing an effective MPPT system [4]. The demand for energy is increasing day by day with the growth of world population. However, the natural energy resources don't grow with time instead gets depleted due to over usage. This has lead to a hike in energy cost and an increase in the emission of greenhouse gases. Solar energy has been identified as the most abundant resource of future energy and is becoming a strong competent to fossil fuel. Recent advancements in photovoltaic (PV) technology made access to solar energy more economical [1] than in the past. The future of Indian energy sector is expected to be dominated by solar energy.

Photovoltaic cells when connected together form a panel and a number of panels contribute to form a solar array. The PV array consists of a number of panels connected in series and parallel topologies. With varying levels of irradiation during the day, the array output can

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vary in a wide range. This effect is expected. But unexpected shading effects due to dusts, clouds, leafs, branches of trees and buildings causing shading on cells or part of modules or panels. Under these partial shading conditions, the Power versus voltage characteristics of the solar array will contain one global maximum along with many local maxima. The global maxima correspond to maximum power while the others correspond to much lower powers [2]. Around 30% power loss will take place even though only one cell in the PV module is shaded. As the number of shaded cells increases, the amount of power loss also will be increases (nearly 80%). Under partial shading conditions, conventional MPPT methods may not be able to track maximum power irrespective of the change in irradiance conditions. At the local maximum power point it may converge resulting in reduction of PV panel output. Due to this reason the overall PV system efficiency gets degraded [3]-[4]. An efficient MPPT system which can be used even under partial shading conditions efficiently is discussed in this paper.

2. SYSTEM DESCRIPTION

Basic block diagram of photovoltaic maximum power point tracking system implemented using SEPIC converter is shown in Fig.2. System load is supplied from solar panel with the help of SEPIC converter. The array voltage VPV and current IPV is sensed by suitable sensors and is given as input to the MPPT controller. The basic idea of MPPT technique is to adjust the load impedance of the panel there by forcing the panel to operate at the maximum power point of the P-V curve. Load impedance is adjusted by changing the duty ratio of the converter which is connected as an interface between the panel and the load. In this work, SEPIC serves as the dc-dc converter and its duty ratio is adjusted to track maximum power transfer from PV array to the load.

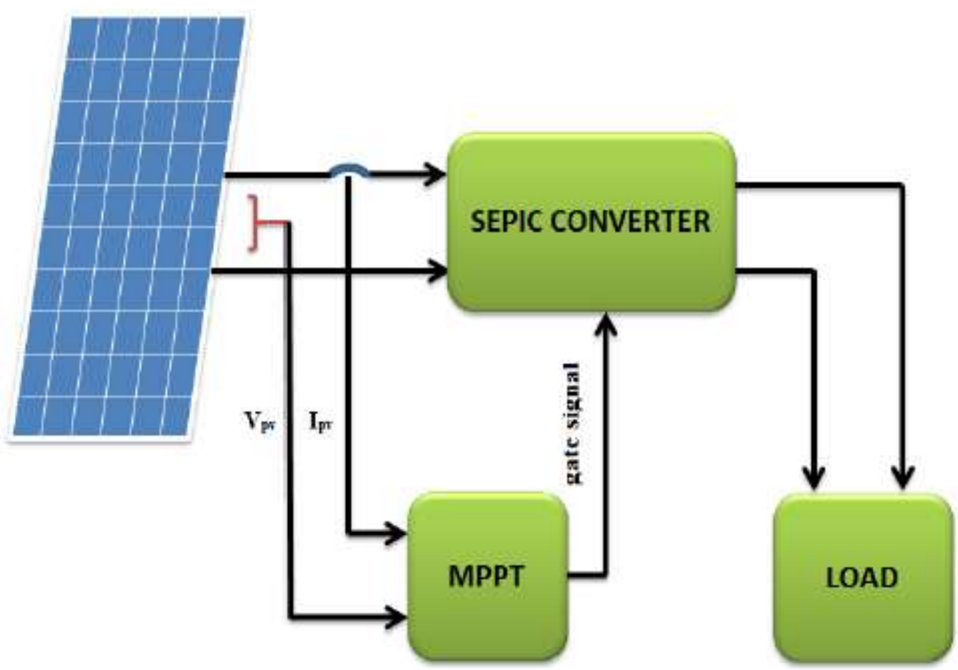

Fig.-2: General block diagram of an MPPT system

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Under partial shading conditions multiple local maxima will appear on the power-voltage characteristics of solar PV system in that only one will be global maximum power point. The above mentioned situation is shown in the power-voltage curve of partially shaded array in Fig.3. The conventional MPPT methods converge at local maximum power points and the efficiency of the solar PV system reduces considerably.

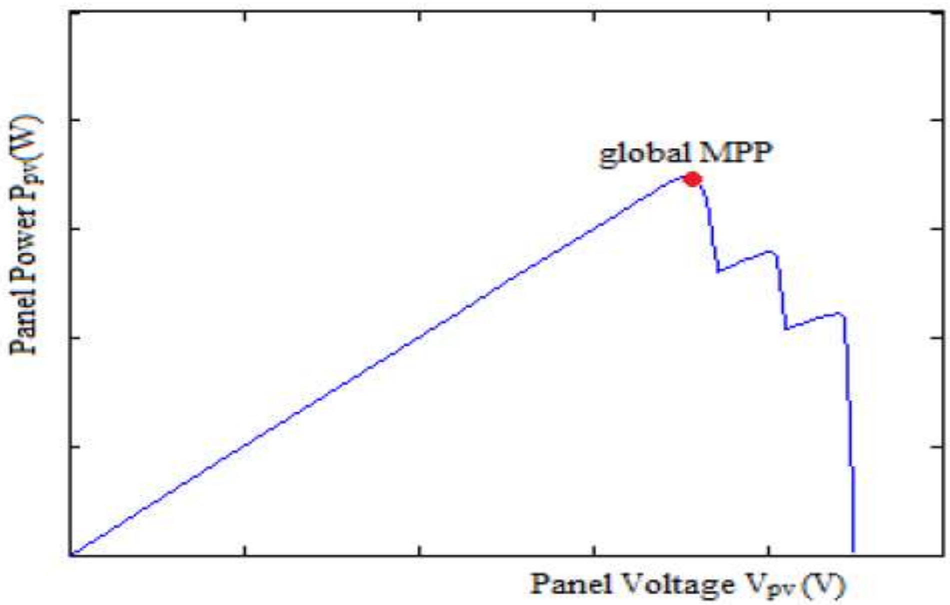

Fig-3: Power vs Voltage for a partially shaded PV array

The above mentioned MPPT system can be applied to either grid connected solar PV applications or standalone applications. Here Single Ended Primary Inductor (SEPIC) converter is used as DC-DC power converter so that the output voltage can be made constant irrespective of the input voltage variations.
The global MPPT technique used here is performed in three consecutive steps, a) Constant input power mode b) PV array voltage regulation c) Perturb and observe (P&O) stage The switch is controlled by either PWM1 or PWM2 control signals provided from the MPPT controller. This aspect is explained in the following section.

3. System Description and Proposed Global MPPT Algorithm
3.1. System Description

Generally, for the PV system, a DC-DC converter is implemented together with the MPPT controller to control the input voltage and current from PV to reach its maximum power point. In this case, it is assumed that the PV system connects to the constant DC load voltage. For this paper, the DC-DC boost converter is used to test the proposed method due to its robustness and simple switching control with only one duty cycle value (d). As for other converter topology (i.e., a buck-boost converter, single-ended primary-inductor converter (SEPIC)), the proposed algorithm can also be integrated; however, additional switching control is required since the number of switches adds and the converter operates in both buck and boost mode. Figure 4 shows the basic block diagram of the PV system integrated with the boost converter.

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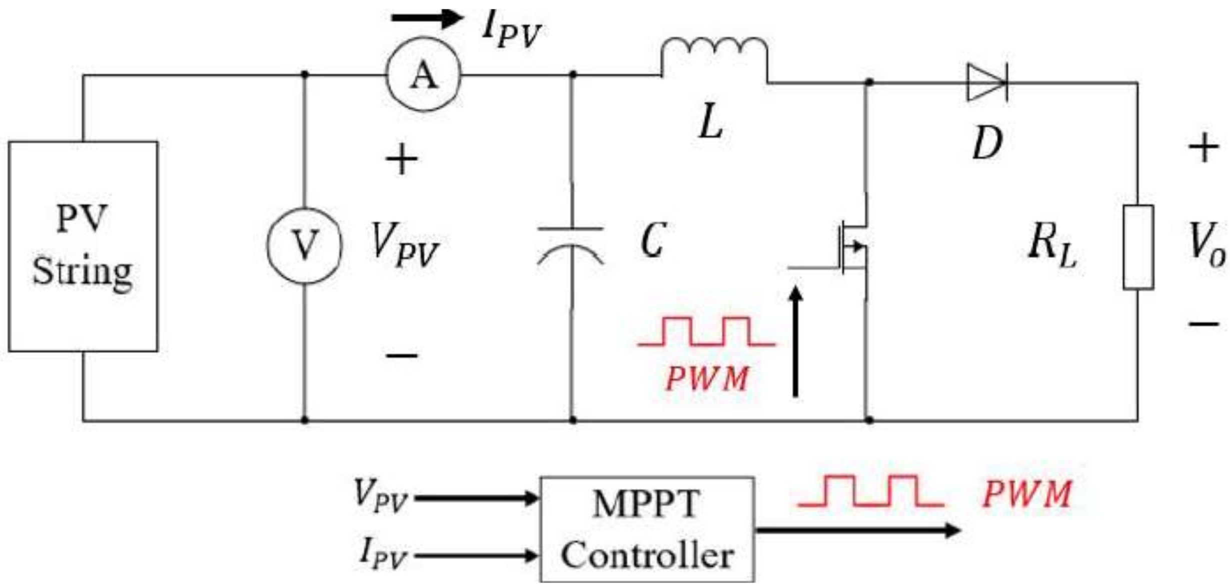

Figure 4. Basic PV system with the DC-DC boost converter.

After measuring the PV's voltage and current, the MPPT controller determines the maximum power point according to the level of irradiation and temperature. By tracking, the controller outputs the duty cycle to control the PV system to operate at its maximum power. Below Equation demonstrates the mathematical relations between PV voltage VPV, load voltage VO, and duty cycle d.

$$V_{PV} = (1 - d)V_O$$

d is used to generate the pulse width modulation (PWM) switching signal to control the metal-oxide semiconductor field-effect transistor MOSFET. The challenge for this model is the accuracy. In order to achieve an accurate VPV, at maximum power, the tracking system is necessary.

3.2. Proposed Global MPPT Algorithm

Figure 6 shows how the proposed global MPPT algorithm works. It mainly divides into three parts, which include the main program, shading detection, and global MPPT tracking using slope calculation, as presented.

3.2.1. Main Program

The first step is to input the necessary parameters of the PV module. These include a single PV module's open-circuit voltage (VOC), short-circuit current (ISC), and PV current at maximum power point (IMPP) given from the manufacturer. Additionally, the number of modules connected in series (N) and the number of PV stings connected in the system (M) are inputted in the main program. When the program starts its operation, first time scanning is performed in order to determine the first maximum power point and maintains tracking with the conventional Incremental and conductance method (InC), where the tracked power is assigned as the reference point PREF[k] at the duty cycle DREF. The system keeps tracking at DREF, and after one second, the value of the maximum power point is updated as PREF[k+1], which is the next sample.

Conclusions

This research proposes the studies of P-V characteristic curves, partial shading detection, and a global maximum power point tracking algorithm. As irradiation and temperature affect generated power, the work presents an analysis using mathematical equations. The simulation result shows the tracking process is successful, with accuracy and requiring less tracking time compared to conventional scanning. More energy is achieved by 8.55% from the long-term study, which also increases revenue. The

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experimental result shows successful tracking when the change of irradiation happens. This paper's proposed algorithm is advantageous because it requires fewer samples and less power loss, while tracking increases the energy achieved.

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