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HILL CLIMBING MPPT PERFORMANCE ANALYSIS FOR PHOTOVOLTAIC SYSTEM UNDER PARTIAL SHADING

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ABSTRACT

The HC approach is developed in this work with the intention of tracking maximum power from the PV array. Multiple local maximum power points are displayed on the power–voltage characteristic of photovoltaic (PV) arrays when all of the modules are not receiving uniform solar irradiation, which is another way of saying that they are operating under partial shading conditions (PSCs). Under conditions of consistent sun irradiation, it has been demonstrated that conventional maximum power point tracking (MPPT) approaches are effective. On the other hand, it is possible that these may miss the worldwide peak caused by PSCs. In this thesis, a new approach for maximum power point tracking (MPPT) of photovoltaic arrays is proposed for use under both PSCs and uniform circumstances. The proposed method locates all of the regional maximum power locations by doing an analysis of the sun irradiance pattern and then applying the well-known Hill Climbing method. Simulations run in a MATLAB/SIMULINK environment are used to assess how well the suggested approach performs.

Keywords:

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1. INTRODUCTION

Photovoltaic systems have developed into a source of energy that may be utilized in a broad variety of contexts. The applications may involve stand-alone PV systems or PV systems that are connected to the grid. In isolated applications, where PV is connected directly to the load and storage system, a standalone PV system is employed. When using a solar system that operates on its own, having energy storage can be advantageous when the PV source of energy is quite large. On the other hand, when a PV system injects the current directly into the grid itself, it is referred to as a PV system that is connected through a grid. The opportunity to sell any excess energy is one benefit of utilizing a system that is connected to the grid. There is a growing interest in the usage of non-conventional energy sources such as solar energy as a result of the ever-increasing need for energy that is available at a low cost and the growing concern about environmental issues. Using photovoltaic (PV) cells, the easy conversion of solar energy into usable electrical energy can be accomplished. Solar energy is both abundant and readily available. A PV source offers a number of benefits, including low maintenance costs, no moving or rotating parts, and an energy conversion process that does not produce pollutants. However, one of the most significant drawbacks of the PV source is that it cannot be used effectively during the night, during seasons of low insulation, or in settings when there is partial shading. Another factor that has contributed to the decline in PV system adoption rates is the high initial capital cost [1].

The fact that photovoltaic cells have nonlinear current-voltage (I-V) characteristics, which produce a one-of-a-kind maximum power point (MPP) on their power-voltage (P-V) curves, presents a significant difficulty in their application. The fact that these features are dependent on the amount of sunlight and the temperature adds another layer of complication to the situation. MPP is subject to continual change because these factors are always shifting. Because of the high initial cost of a PV source's capital investment and the low efficiency with which it converts energy, it is absolutely necessary to run the PV source at its maximum power point (MPP) in order to derive the most amount of power from it. In most cases, a photovoltaic (PV) source is used in conjunction with a direct current to direct current (dc-dc) power converter. The duty cycle of the dc-dc power converter is modulated in order to follow the instantaneous maximum power point (MPP) of the PV source. There have been a number of different tracking techniques suggested [2-12]. The perturb and observe (P&O) or hill climbing [4], [5], incremental conductance [8], short circuit current [2], open-circuit voltage [7], and ripple correlation techniques [6] are some of the most used tracking systems. [4], [5]; [4], [5]; [8]; [6]; [8]; [4], [5]; [8]; [Some modified strategies have also been developed, with the goal of either reducing the amount of hardware required or increasing the overall performance [7], [9]-[12]. Under conditions of uniform solar insulation, where the P-V curve of a PV module exhibits only one maximum power point (MPP) for a given temperature and insulation, the above-mentioned tracking techniques have been shown to be effective and have stood the test of time. When testing a variety of commercially available inverters in partially shaded settings, Bruendlinger et al. discovered that the power loss caused by shading can be as high as 70% [13]. Under conditions of partial shading, when the entire array does not get the same amount of insulation, the P-V characteristics become more complicated and display many peaks, of which only one is the global peak (GP);

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the others are local peaks. [14]. There has been the presentation of an analytical model [15] that is based on the Lambert function and the features of that function. It is able to simulate the presence of many peaks under a wide variety of situations, including varying degrees of insulation and temperature, a variety of shading patterns, mismatch, and other variables. This model requires less time spent in computing as well as less memory to function.

The assumption that there is only one peak power point on the P-V characteristic makes existing MPP tracking (MPPT) techniques less effective. This is because the occurrence of many peaks complicates the situation. Due to the frequency with which partially shaded conditions arise (for example, as a result of clouds, trees, or other factors), there is a pressing need to design specialized MPPT schemes that are capable of tracking the GP when operating in such environments. The utilization of intelligent PV modules [16] or alternating current modules constitutes the second alternative.

2. SOLAR PHOTOVOLTAIC SYSTEM

The PV system is designed to offer the electric supply to load, which might be of the alternating current type or the direct current type. It's possible that supply will be required in the morning, the evening, or both. PV systems are only able to provide a supply during the day; in order to meet our supply needs throughout the evening and overnight, we have batteries that can store and release energy [13].When a PV system is connected to the grid, this configuration is referred to as a grid-connected PV system. The photovoltaic array and the inverter make up this kind of system. Figure-.2.5 depicts a PV system that is connected to the grid. A system that is connected to the grid deals with AC. Because grid-connected systems deal with applications that require very high amounts of power, it is difficult to store this much power in batteries [13]. The example of grid integrated PV system is presented in Figure-1.

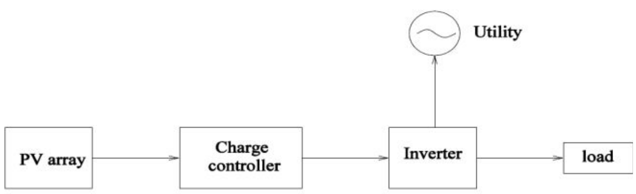

Figure-1. Grid interactive PV system.

In the available research, we came across models with one diode, two diodes, and three diodes. The single-diode model strikes an excellent balance between ease of use and precision in its predictions. When taking into account the many different effects, more diodes should be considered. The single-diode model provides an accurate and straightforward method for practitioners of power electronics to conduct analysis.

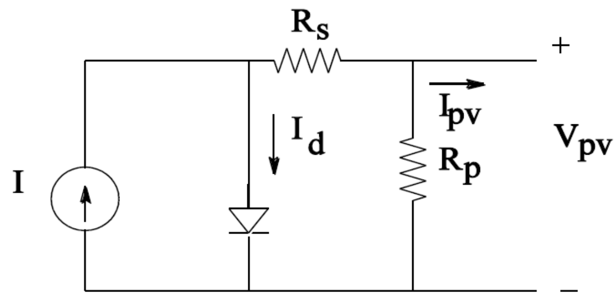

Figure-2. Equivalent circuit of practical PV device.

An equivalent circuit of practical PV device is illustrated in Figure-2. The Maximum Power Point Tracking (MPPT) algorithm determines the efficiency of a PV system. In a PV system, the MPPT is the most critical component; effective tracking is the primary concern. We have already described the effect of temperature and irradiation on the parameters of the current equation. Roughly speaking, we can say that temperature is inversely proportional to output power, and irradiation is directly proportional to output power. It is found many literatures that took care of irradiation and temperature changes because these are key factors of shifting of MPP. It is difficult to track the global maxima through one MPPT in a partial shade condition since we have several local maxima and only one global maximum. This makes it necessary to use the MPPT in a distributed manner. The fast tracking of MPPT is another significant challenge.

The most urgent problem at hand is the conservation of energy. Wind and solar power are two of the most common forms of renewable energy, and their contribution to the generation of electricity has become increasingly significant in recent years. The fast tracking of the global maximum power point, often known as the MPP, is an issue that is now the subject of a significant amount of research. Our maximum power point tracking (MPPT) method should be sufficient for monitoring MPP under dynamic atmospheric settings because MPP is highly influenced by the conditions of the atmosphere. We simulated a solar photovoltaic system operating in dynamic atmospheric circumstances by making use of the INC approach. The majority of conventional MPPTs are unable to track global MPP. To solve this issue, the literature presents two control strategies: one modular MPPT and one two controller structure. Partial shading produces local MPPs in addition to one global MPP. Power loss occurs in a shaded module, which causes an efficiency decrease. The load has a significant impact on MPP, and vice versa: as the load shifts, so does MPP. The need to store additional power arises from the fact that the load requirement may at times be lower than the generation. A battery is required in this scenario because the power can be drawn from the battery throughout the night, when the PV module is unable to create electricity.

The hill climbing approach is comparable to the perturb and observe, or P&O, method. The key distinction between the two lies in the fact that the hill climbing method addresses fluctuations in duty cycle, while the P&O method addresses fluctuations in voltage. The inability of this technology to accurately track MPP in settings of variable weather is a drawback of using it.

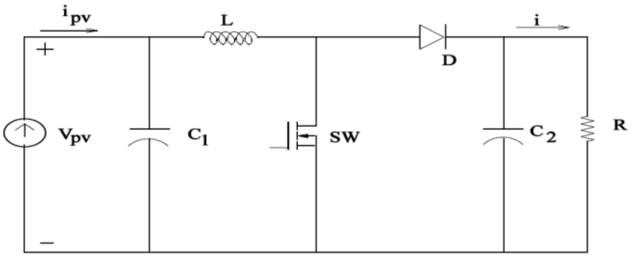

Figure-3. Boost converter interface with PV system.

DC to DC converters are used to convert one level of input voltage to another level of DC output voltage. This conversion can take place in either direction. The DC-DC converter is made up of an inductor, capacitors, and switches. The DC-DC converter's interface with the PV system is highly important, and because of this, we need a reliable converter. These converters serve multiple purposes, including those of charge controller, MPP tracker, and PV load interface. Buck and boost non-isolated DC-DC converters are often used in the literature due to the fact that their construction is simple and they have less components than isolated DC-DC converters. We have several varieties of isolated and non-isolated converters. The boost DC-DC converter along with their PV interface is depicted in Figure-3 [3]. The boost converter offers the most benefits out of these two [3], [9].

3. HILL CLIMBING ALGORITHM

A photovoltaic system that is both effective and easy to install may be set up virtually anywhere with just minor adjustments. This chapter provides an explanation of the photovoltaic energy conversion system that uses the Hill Climbing MPPT method. The hill climbing approach of MPPT was developed by Maheshappa *et al*. (1998). This method involved adjusting the array's operating voltage by either increasing or reducing it, and then monitoring how this adjustment affected the array's output power. This algorithm does not require any preliminary research or analysis of the geographical data and is not dependent on the location where it is installed. It is generally agreed that the hill climbing algorithm is the most efficient way to implement a system, hence that label applies to any system that uses it.

The hill climbing algorithm determines the position of the greatest power point by establishing a correlation between variations in the power and shifts in the control variable that is employed in the management of the array. The perturb and absorb algorithm, which was suggested by Xiao *et al.*, is incorporated into this system (2004). The hill-climbing algorithm calls for a disturbance to be introduced into the duty ratio of the power inverter. When a PV array is linked to a system, causing a disturbance in the duty ratio of the power inverter will cause a disturbance in the current flowing through the PV array, which will cause a disturbance in the PV array's voltage. The characteristic curve of the PV array is displayed in Figure-4. If the method is used on the left side of the MPP, the power is increased whenever the voltage is increased, but the power is decreased whenever the method is used on the right side of the MPP. Therefore, in the event that there is a rise in power, the subsequent perturbation is maintained at the same place in order to arrive at the MPP, and in the event that there is a fall in power, the perturbation is turned around. This algorithm is broken down into its component parts in Table-1. The procedure is carried out on a regular basis till the MPP has been attained. Following that, the system begins to fluctuate about the MPP. By reducing the size of the perturbation step, the oscillation can be made to be as small as possible.

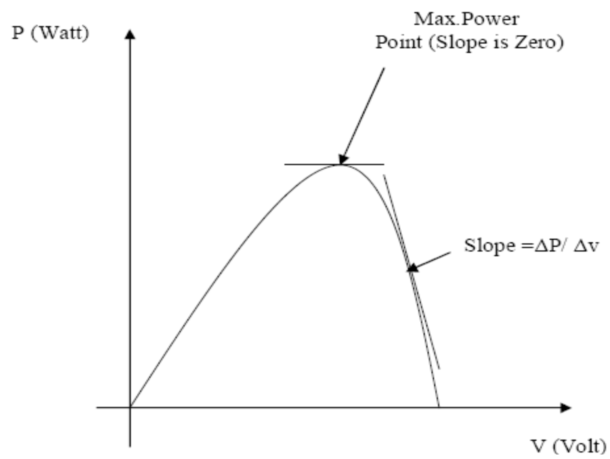

Figure-4. Characteristic PV Array Power Curve.

Table-1. Summary of Hill climbing algorithm.

Perturbation	Change in Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

4. SIMULATION RESULTS

In the next paragraphs, the results of numerous simulations will be discussed. The simulated photovoltaic system is a PV array that is 3 by 2. The photovoltaic array is linked to a boost DC-DC converter, which monitors and maintains the maximum power point. A battery with a voltage of 12 V is attached to the output side. The functionality of the algorithm is examined under four different situations of sun irradiation in rapid succession. All of the modules receive an irradiance level of 1000 W/m2 from 0 to 0.3 seconds when the sun is shining directly on them. Last but not least, the solar irradiance remains constant at 1000 W/m2 throughout all of the modules from 0.9 to 1.2 seconds. The waveforms of the array's associated voltage, current, power, and duty cycle are depicted in Figure 5 (a)-(d), respectively. In addition, a zoomed view of the voltage, current, power, and duty

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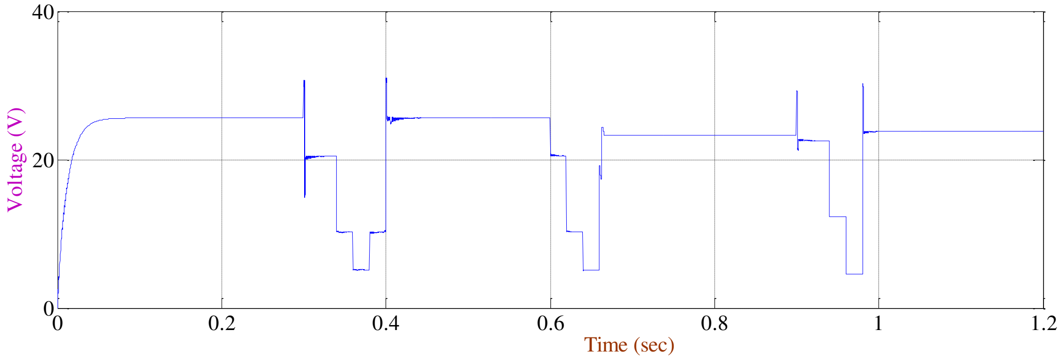
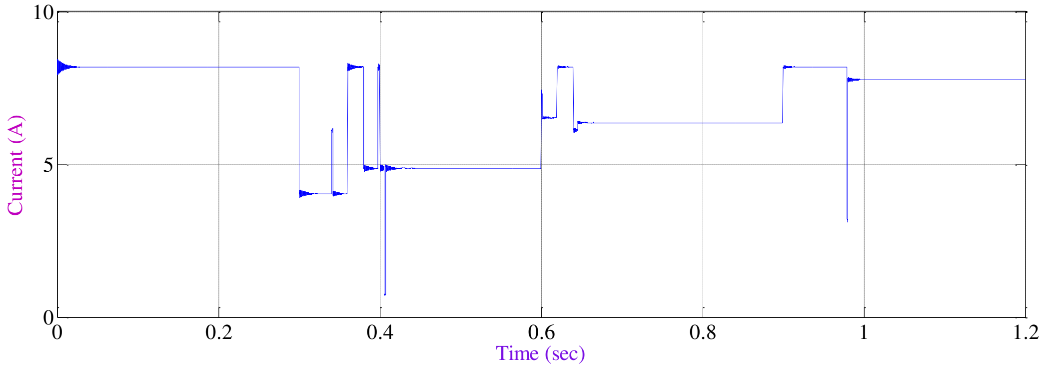
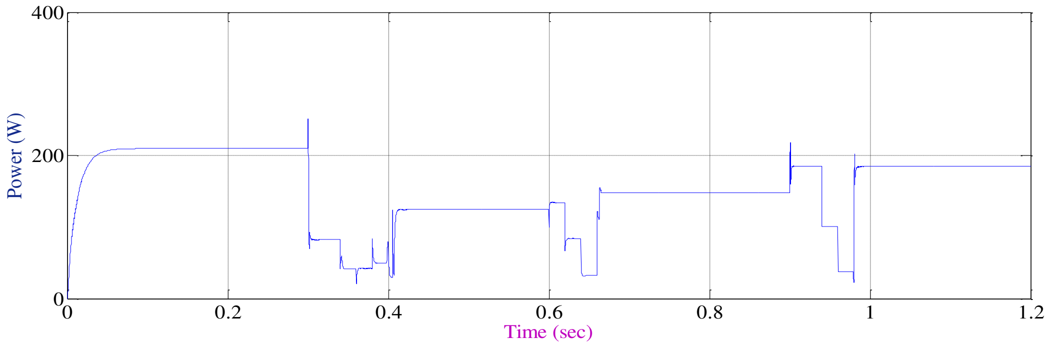
cycle waveforms of the per unit array are given at Figure-6(a)-(c), respectively, in time periods of 0.3 to 0.5 s, 0.6 to 0.8 s, and 0.9 to 1.1 s, respectively.



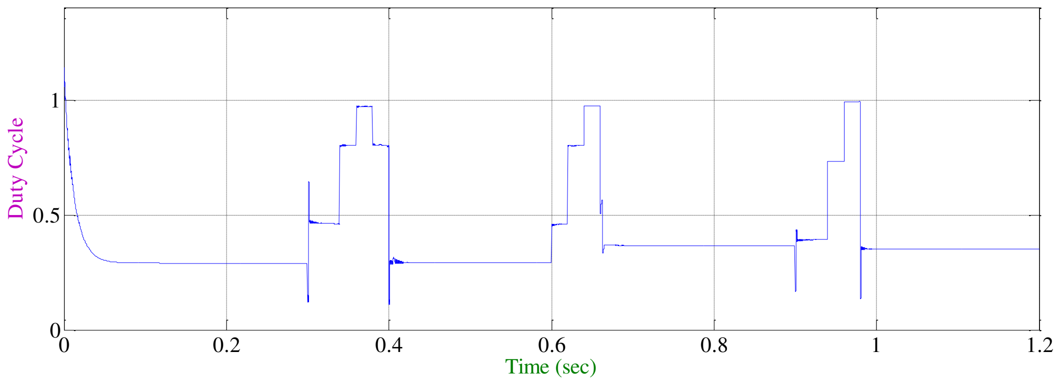
(a) Voltage



(b) Current



(c) Power



(d) Duty cycle

Figure-5. Curves of the corresponding arrays when running the first simulation.

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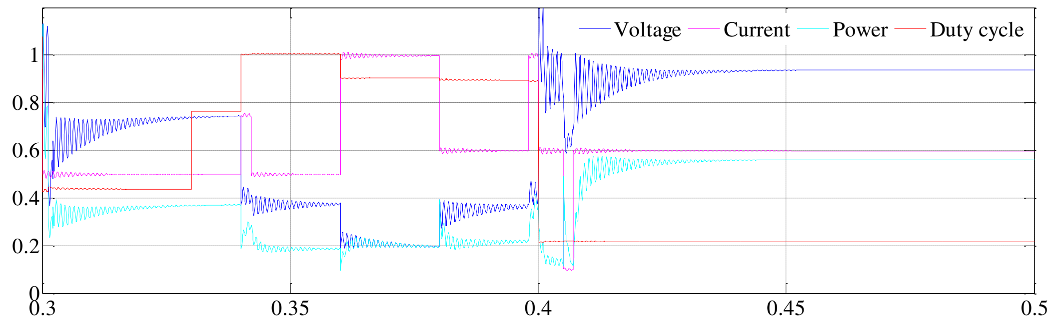
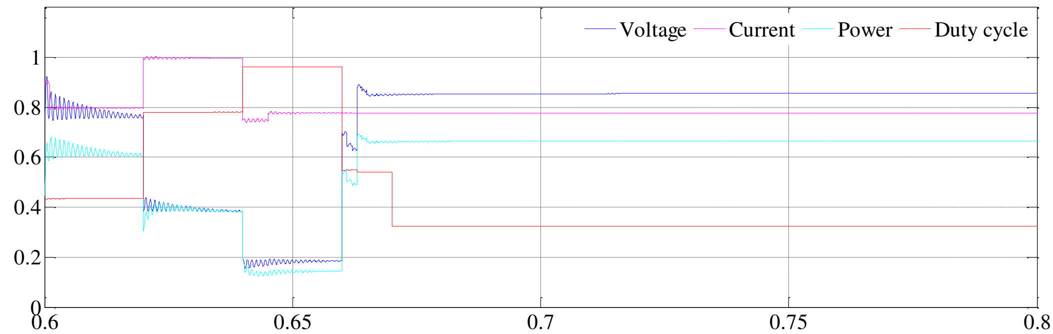
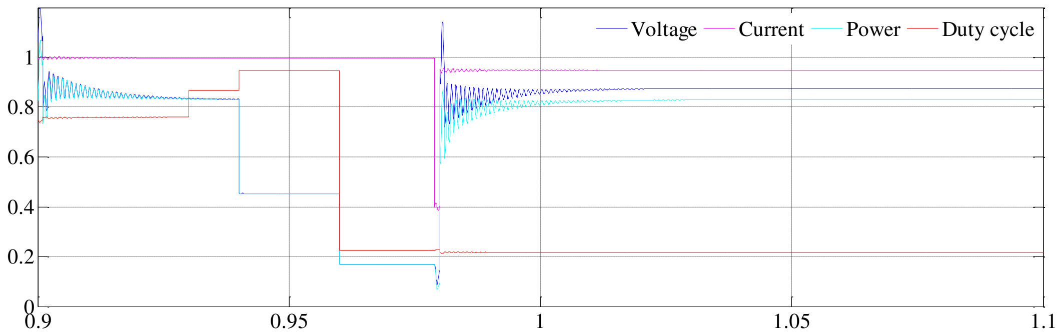


(a) 0.3-0.5 s



(b) 0.6-0.8 s



(c) 0.9-1.1 s

Figure-6. In the first simulation, a zoomed-in view of per unit arrays of voltage, current, power, and duty cycle waveforms are displayed.

Simulations are run to evaluate the new approach in comparison to two other widely used approaches, with the goal of demonstrating the advantages of the new approach. It should be taken into consideration that previous works such as [23] have proven that some of the fundamental hypotheses in [13] are not valid, and that it may fail to monitor the GP in certain scenarios. This is something that should be taken into consideration. Despite this, [13] has become an established approach that is frequently used, and it serves as a point of reference for the majority of algorithms. In addition, the corresponding power waveforms of the suggested approach [13] and [17] are depicted in Figure-7 (a)-(c), respectively, for your viewing convenience. It can be seen in Figure-7 (a) that the proposed technique follows the GP with equivalent powers of 97 W within 0.093 seconds. The strategy that is proposed in reference number [13] follows the same peak.

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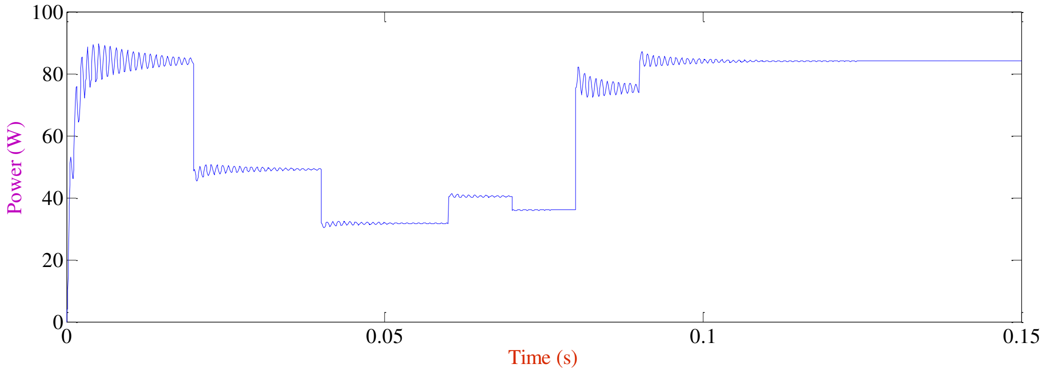
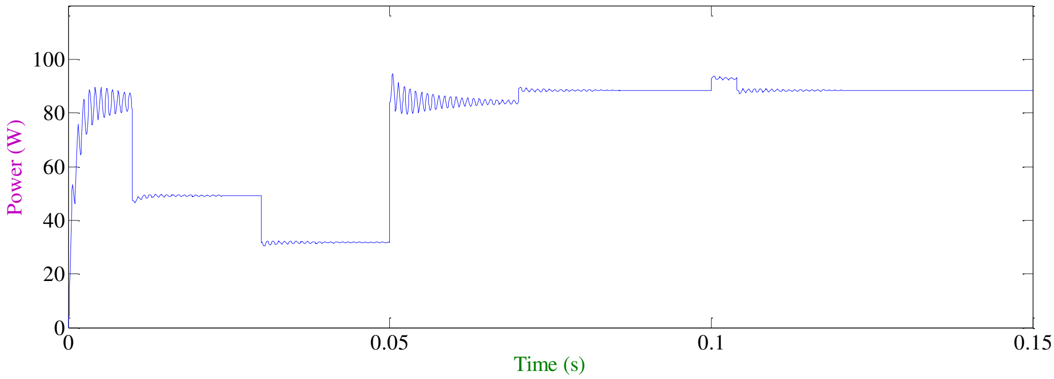
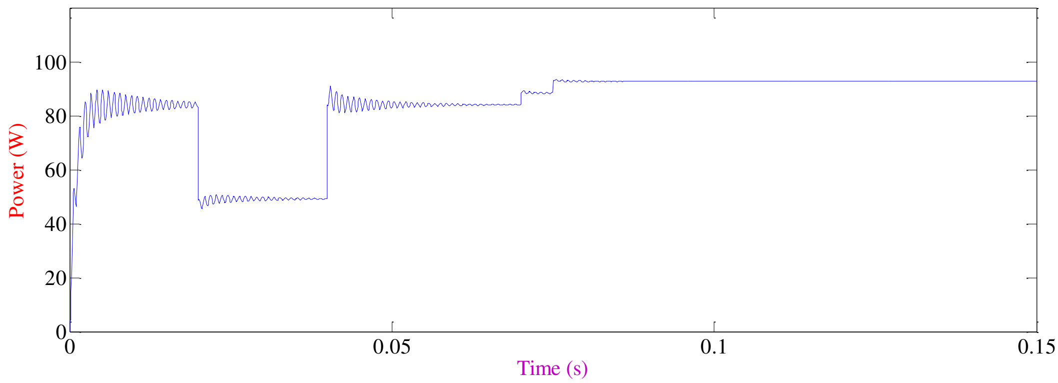


(a) Proposed Method



(b) Proposed method in [13]



(c) Proposed method in [17]

Figure-7. Efficacy comparison with conventional techniques.

5. CONCLUSIONS

This study proposes the Hill Climbed MPPT algorithm, which has excellent performance under PSC. On the basis of simulation findings, it was determined that the current in each step of the I-V characteristic is nearly constant until the start of the following phase. In addition, it was demonstrated that the beginning locations of each step on the I-V curve are close to the left side multiples of Voc, m. The proposed approach is a modified version of the HC method that efficiently tracks the GP under various scenarios. This method's implementation is very straightforward. Upon the appearance of PSCs, the number and length of I-V characteristic steps are determined by measuring the current value in multiples of Voc, m. The GP is ultimately identified by comparing the LPs. Simulation findings have proven this method's accuracy and speed improvements over two prominent existing approaches.

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