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Global Maximum Power Point Tracking Using the Hill Climbing Approach: An Analysis of Its Performance for Photovoltaic Arrays under Partial Shading

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ABSTRACT: Under partial shading circumstances (PSCs), when not all of the modules are receiving the same amount of solar irradiation, the power-voltage characteristic of PV arrays exhibits many local maximum power points. Maximum power point tracking (MPPT) techniques have been shown successful under settings of constant sun irradiation. However, they may not capture the worldwide maximum under PSCs. A novel approach to maximum power point tracking (MPPT) of PV arrays is proposed in this research. The suggested approach finds all local maximum power locations by studying the sun irradiance pattern using the well-known Hill Climbing technique. Simulations in the MATLAB/SIMULINK environment are used to test the efficacy of the suggested technique.

Keywords: maximum power point tracking (MPPT), photovoltaics (PV), hill climbing, partial shade conditions (PSCs).

I. INTRODUCTION

II. In order to lessen our reliance on traditional energy sources, solar power, which is both renewable and free, has become more significant in recent years. Photovoltaic (PV) systems convert the limitless solar energy into electricity in a straightforward process. However, the main difficulties in using PV arrays are their high price, low conversion efficiency of electric power generation, dependence on environmental conditions (such as solar irradiance and temperature), and the nonlinearity of the power-voltage (P-V) and current-voltage (I-V) characteristic.

III. Monitoring the global peak (GP) of a PV array under all environmental circumstances is crucial for ensuring the highest possible output. In order to find the maximum power point, many MPPT techniques have been developed [1–3]. When the solar irradiation situation is consistent across all PV modules, popular MPPT approaches including the perturbation and observation (P&O), hill climbing (HC), and incremental conductance (IC) methods have shown to be efficient. These simple approaches fail to follow the GP because of the complexity introduced by partial shading conditions (PSCs), in which not all modules get the same amount of sunlight. Although there is just one peak in the P-V characteristic of a PV array when operating under uniform solar irradiation, with PSCs, there are several peaks. Therefore, many MPPT strategies are given that may be used in PSCs. You may classify these techniques as either hardware-based or software-based [4].

IV. Each module has its own controller according to [5] and [6]. Since the P-V characteristic of a module (with a single bypass diode) always has a single peak, these hardware-based approaches may fix the issue. However, in compared to software-based techniques, these approaches are quite expensive and need a large number of additional equipment.

V. Particle swarm optimization (PSO) is the basis for the maximum power point tracking (MPPT) approach introduced by Ishaque et al. [7]. Because of the need for human input, this approach is too complicated to be used with mass-produced machines. Artificial neural networks (ANN) are used as the chosen algorithm in [8]. One major drawback of ANN-based approaches is that the quality of the training data greatly affects the ANN's performance in diverse environments. When the PV array is updated, they also need to be retrained. Applications of genetic algorithms, fireflies, and simulated annealing are described in [9] through [12] for PV systems. These techniques have high performances, but their implementation complexity is their biggest drawback, since it involves complicated calculations and various parameters have to be adjusted by user, much as the PSO and ANN methods.

VI. The HC strategy has been refined in [4]. It is sensitive enough to detect the presence of shadows. Then, the HC is conducted centered on the location with the greatest power reading. Since it only considers the strength of points in close proximity to the LPs, its precision is inadequate for GP monitoring.

VII. opposed to the LPs in question. In [13], a novel P&O technique is presented that takes use of a special feature of the P-V curves. Great performance is achieved, however tracking speed is slow due to practically two measurements being taken for each LP. The GP is said to be around the point where the I-V characteristic of PV arrays and another line cross in [14]. The array's short circuit current is a limiting factor [1]. Changing this to account for sun irradiance will very certainly fix the issue. However, sun irradiance sensors are somewhat hard to come by [1]. In order to follow the P-V curve and determine the GP, a relationship is established between the PV power and a control signal in [15]. It's quite precise, but time-consuming to use since it examines a large portion of the P-V curve. In [16], a strategy is given that makes advantage of the key insights detailed in

VIII. [13] in a new manner, but it lacks a method for determining whether an LP is present in the area around the target. Therefore, it may not work in all PSCs. Furthermore, the technique in [16] is not as straightforward as other comparable approaches for experimental implementation since it requires sophisticated calculations (such as the computation of square root) in comparison to other similar methods. By setting minimum and maximum voltage thresholds, [17] is able to rapidly follow the GP. However, when the power of two LPs is very close to being the same, the approach may fail, as acknowledged by the authors.

IX. Based on the voltage of the modules, the approach provided in [18] plots out the solar irradiance pattern and selects a suitable voltage to center the GP's tracking around.

X. it. Using a single voltage sensor for every module is both impractical and expensive. Two approaches are presented in [19]. The first one uses IC to scan the P-V curve for MPPs. However, it does not cover the whole region because of the maximum local power and the short circuit current of the modules. Scanning almost the whole P-V curve would make this approach painfully slow. The second technique is more efficient at tracking, but it is still inefficient since it requires one current sensor for each bypass diode.

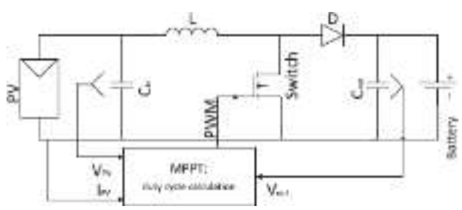
XI. In [20], a solution is suggested that uses a ramp voltage instruction on the converter. As a result, the system's voltage and current won't fluctuate during brief periods of instability. As a result, the traditionally large delays required for accurate voltage and current sampling are no longer necessary. However, its tracking speed is subpar since it examines almost the whole P-V curve. It is still very crucial to provide a technique that is accurate, has fast convergence, is simple, has few parameters, is inexpensive, and fulfills other critical criteria [1]. In this research, we suggest a new approach to maximum power point tracking (MPPT) of PV arrays that is both efficient in PSCs and very successful in the other areas we've highlighted. The approach plots the distribution of solar radiation by measuring PV current at specific locations. It selects points for LP tracking based on the mapping. After that, it keeps tabs on all the LPs while performing HC at these nodes. At last, it selects the GP based on how similar it is to the obtained LPs.

XII. SOLAR PV ARRAY UNDER PARTIAL SHADING CONDITION:

When we look at the features of a PV system, we see that partial shading is one of the main reasons why power is lost. Multiple maxima appear in the SPV system's non-linear Power-Voltage characteristics when it is partially shaded.

A. Solar Pv Array Uniqueness and Its Non-Linearity Under Psc

Solar Pv Array Uniqueness and Its Non-Linearity Under Psc: Multiple PV modules are used to create an array, which is then linked in series and parallel to get the desired voltage and current. To protect PV modules from the hot-spot issue, bypass diodes are connected in parallel with each module. To shield the PV modules from the influence of potential difference between series connected strings, a blocking diode is connected in series with each string, which is a group of PV modules in series connection. There is only one maximum power point (MPP) on the P-V characteristic curve of a PV array when the sun irradiation on each panel is the same. On the other



hand, in partly darkened conditions, there might be several local maximum power locations (many local maxima) due to the diodes that both bypass and block the light.

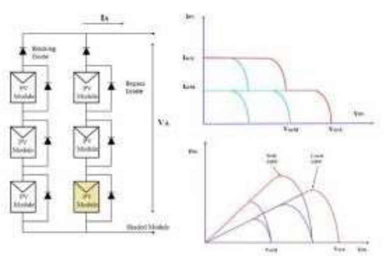
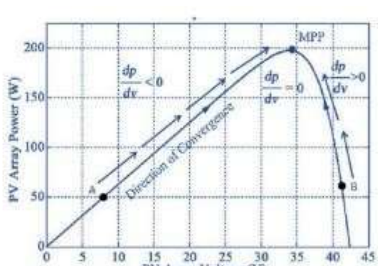


Fig.1 Nonlinearity of Solar PV Array Characteristics under PSC

XIII. SYSTEM CONFIGARATION:

Maximum power point tracking is an essential part of a photovoltaic system. Photovoltaic systems have a distinct operating point that provides maximum power. An MPPT actively seeks this operating point. Maximum Power Point Tracking, normally known as MPPT, is an electronic arrangement that find the voltage (VMPP) or current (IMPP) routinely at which PV modules should operate to achieve the



maximum power output (PMPP) under rapidly-changing environmental conditions. The penetration of PV systems as distributed power generation systems has been increased dramatically in the last years. In parallel with this, Maximum Power Point Tracking (MPPT) is becoming more and more important as the amount of energy produced by PV systems is increasing. Since the MPP depends on solar irradiation and cell temperature, it is never constant overtime and hence Maximum Power Point Tracking (MPPT) technique should be used to track the maximum power point. Normally, PV module efforts well at cold temperatures and MPPT are operated to extract maximum power presented from them. When battery is totally discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

Fig 2.Schematic of the System

XIV. CONVENTIONAL METHODS:

Figure 5 shows the cause that the tracking disappointment of conventional MPPTs under PSC. The operating point of PV array is on the “point A” before PSC is occurred. After PSC is occurred, the operating point is moved to “point B”. In this case, the real MPP is to be found on “point C”. Nevertheless, because of the conventional methods changes the operating point due to predetermined voltage reference step (△V), the operating point is oscillated on vicinity of “point B”. At the same time, the difference in power capacity between PC and PB is lost due to this MPPT failure. To prevent this power loss, MPPT methods have to move the operating point to “point C”.

Fig 3. PV characteristics showing MPP and operating points A and B

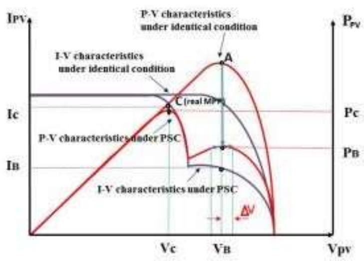
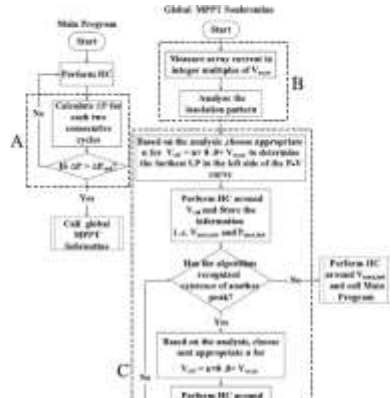


Fig. 4 MPPT Failure in conventional methodunder PSC

XV. PROPOSED METHOD: Usual MPPTs monitoring GMPP has been fraught with failure. In tandem with ADCs and the multifunctional microprocessor, certain improved MPP algorithms are being developed. This paper presents a technique that identifies the GMPP while minimizing the necessary hardware. We've used both a local dithering method and a global search strategy to locate the GMPP. When a global MPP occurs between two local MPPs, as seen in fig., none of the existing global MPPT approaches reaches the global MPP. As a result, the intended algorithm has been tailored to follow MPP on a worldwide scale. Any operation involving less than two phases. (i) A worldwide search with a significant step size (d) (ii) Searching locally with a small step size, d, in the global MPP area The hill climbing technique is the foundation of the proposed MPPT algorithm. To ensure that no maximum power point is missed, the updated hill-climbing algorithm traverses the full P-V curve with a large step size in duty cycle, d, in the search space defined by the Dstart and Dend. There will be a maximum power point in the area corresponding to the duty cycles D(k-1) and D(k) if and only if the sign of the power differential, P(k)=P(k) - P(k-1), changes from positive to negative at any time during the search begun at Dstart. Thus, the comparable duty cycle D(k-1) and equivalent power P(k-1) are recorded to indicate the initial state of the area. The procedure repeats itself until the duty cycle, D, is equal to the density, Dend. After the global search is complete, the global MPP is identified from the stored values of all the maximum power points simply by comparing the powers P of each duty cycle, D. This is possible because the step size d used for the global search is adequately great sufficient, reducing the time required to finish the entire global search. Although the global maximum power point (MPP) determined by the global search is close to the real MPP, it will not transmit the actual maximum power available under the given meteorological circumstances. To get there, we're beginning a local search with a duty cycle of D(k-1) and taking very tiny steps in duty cycle (d). When we get there, we'll experience a two-step oscillation close to the global MPP. The efficiency of the PV system is improved because to the small step size d, which decreases the amplitude of oscillation around the global MPP. This method states that worldwide searching is repeated every five minutes as weather conditions may havechanged.



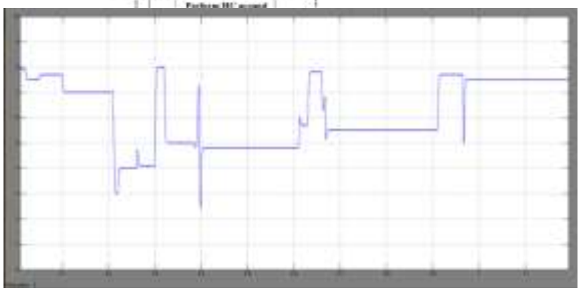
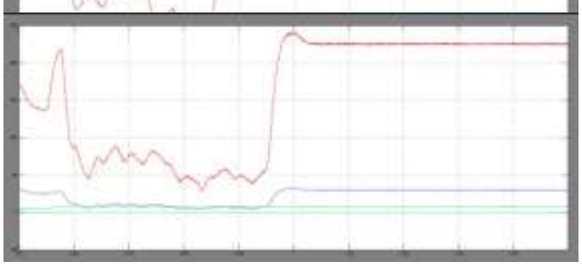


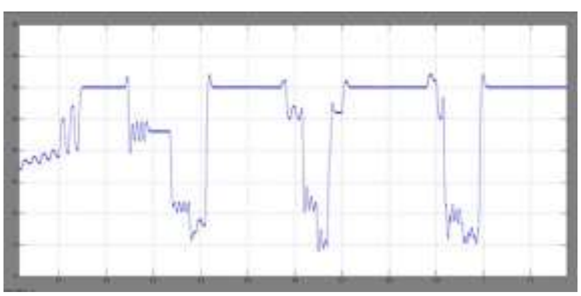
Fig.5 Proposed Algorithm

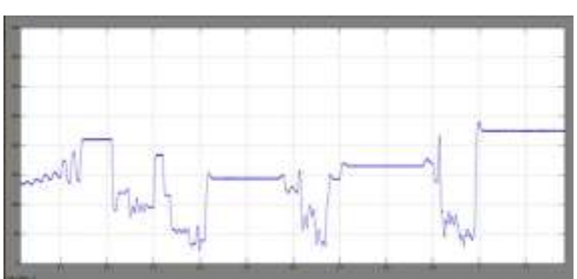
VI SIMULATION RESULTS:

Fig. 6. Corresponding (a) I-V and (b) P-V



characteristics under first simulation.

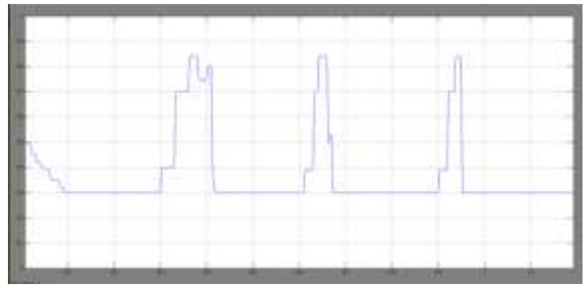




(a)

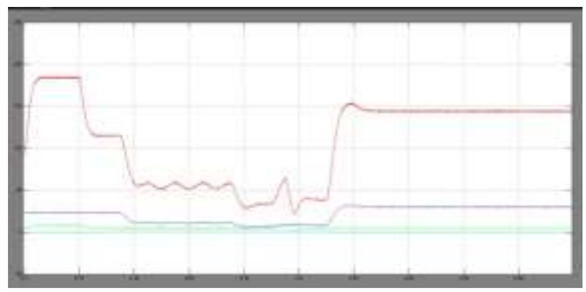
(b)

(c)



(d)

Fig. 7. Corresponding array's (a) voltage, (b) current, (c) power, and (d) duty cycle waveforms in the first simulation.



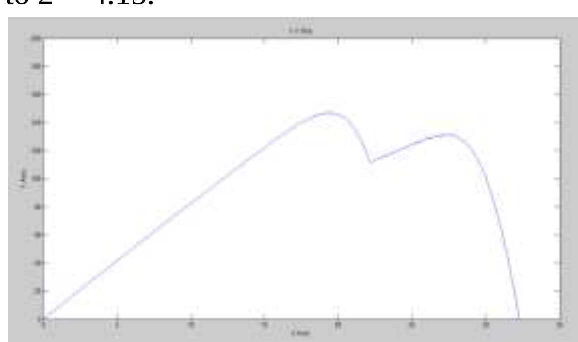
(a)

(b)

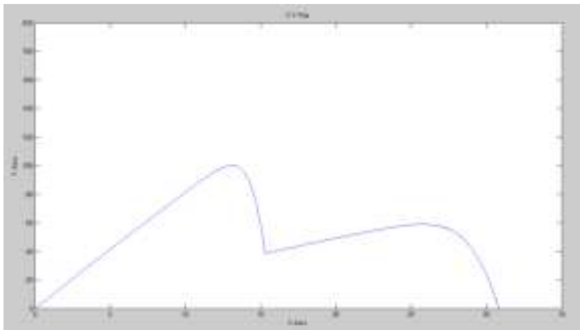
(c)

Fig. 8. Zoomed view of per unit array's voltage, current, power, and duty cycle waveforms in the first simulation during (a) 0.3–0.5 s,(b) 0.6–0.8 s, and (c) 0.9–1.1 s

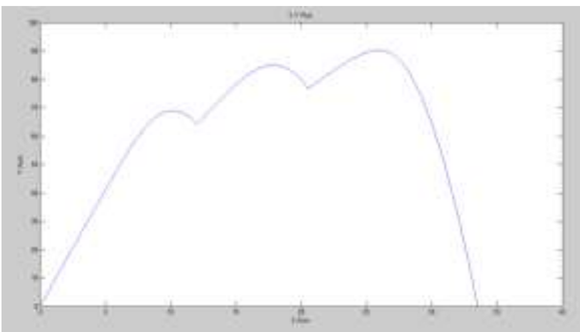
intervals. Power should be multiply to35 × 6, voltage should be multiplied to 3 × 11.15 and current should be multiplied to 2 × 4.15.



(a)



(b)



(c)

Fig. 9. Corresponding (a) PSC pattern and (b) P-V characteristics under second simulation.

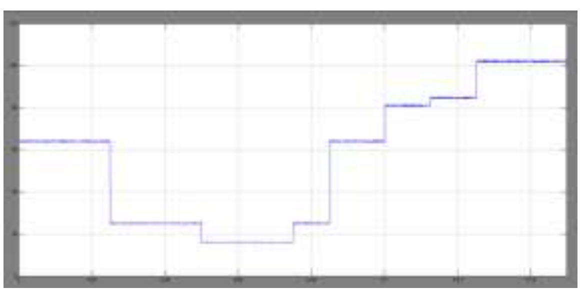


Fig. 10. Proposed method

CONCLUSION: In this study, we present a new MPPT technique that performs very well in PSC. The simulation results demonstrated that the current is essentially constant from the end of one step of the I-V characteristic to the start of the next. It was further shown that the sites of origin for each segment of the I-V curve are located close to the left-hand multiples of Voc,m. In reality, the suggested approach is a tweaked version of HC that successfully follows the GP in a variety of settings. So, it's easy to put this technique into practice. Once PSCs are present, their stepped I-V characteristics may be identified by counting the number and duration of the current's steps as multiples of Voc, m. The HC technique then follows all LPs around certain multiples of 0.8 Voc, m. In the end, the GP is identified using LP comparison. The benefits of this strategy over two well-known current methods have been verified by simulation results.

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