MODIFIED MPPT CONTROLLER FOR SOLAR PHOTOVOLTAIC SYSTEM UNDER PARTIAL SHADING

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Abstract : The I-V characteristic of the Solar Photovoltaic (PV) Panel is depends upon the solar irradiance and the connected load. For extracting maximum power from the PV panel, it is required to operate the solar panel at optimal voltage point known as Maximum Power Point (MPP) and controller used for operating the solar array at MPP is known as Maximum Power Point Tracking (MPPT) Controller. In general, there is only one MPP for solar array and general MPPTs like P&O and INC controller are capable to track the optimal point. In case of partial shading, there is multiple MPP and common MPPT controller is unable to track the actual MPP. In this paper, Global MPPT is purposed which is capable to track optimal power point in any environment conditions. The proposed MPPT controller will increase the efficiency of MPPT controller.

***IndexTerms* - Renewable Energy System, Solar Photovoltaic System, Solar PV Panel, Maximum Power Point (MPP), Maximum Power Point Controller (MPPT), Global MPPT**

I. INTRODUCTION

The fossil fuels are a main source for the generation of electricity. The thermal power plant has a contribution of 70% in total electricity generation. The major issues associated with fossil fuels are environment pollution, global warming, natural resource depletion and fluctuating economy. The renewable energy resources are the alternative option to reduce the dependence on fossil fuels. The renewable energy are uncertain as it is totally depends up on environment condition and reliability of renewable energy system can be improved by operating it along with conventional power plant [1]. The sun is a primary source of all the available energy on earth. The solar energy can be used as a thermal energy or electrical energy. The solar energy is one of the preferable renewable energy resource for India due to its geographical location. After number of research and development, the efficiency of Solar PV panel is still in the range of 20-25% [2]. The final efficiency is further degraded due to temperature, Irradiation, dirt etc. The current (I), voltage (V) and Power (P) are the important electrical parameter of PV panel. The I-V and P-V characteristics are the important criteria for study of PV panel. The output power point is the crossing point between load line and P-V curve. For the given load line there is only one operation point possibility if there is no partial shading. So, it is load which decides the point of operation and for extracting maximum power, optimal load based upon the solar panel must be connected. The controller which operates the solar panel at optimal power point without connecting actual optimal load is known as Maximum Power Point Tracking Controller.

The MPPT controller has a DC-DC converter whose duty cycle is adjusted after monitoring the PV characteristics continuously. The P&O, INC and Fuzzy Controller are the simplest MPPT techniques and capable to track MPP when there is no partial shading [3]. The partial shading is a condition when few solar panels receive uneven solar irradiance and the P-V characteristic has a multiple MPP. Some of the drawbacks of the simple MPPT techniques are as follows:

- Power tracking during rapid change in irradiance [3]
- Higher oscillation near MPP [4]
- Duty step selection is an issue, which causes slow time response and higher oscillation loss [5].

The Partial shading conditions causes degradation in PV array performance and at the same time change I-V characteristics which cause multiple maxima on P-V curve [6]. The performance characteristics of the PV array under uniform and different non-uniform irradiance conditions have been analyzed in [7-8]. Some researchers proposed network topology of array for improvement in PV curve under partial shading. Also, segmented PV system with multiple inverters for PV array is also suggested in research paper, so that effect of shading on each segment of PV array is minimize. In commercial term, the change in network topology and other methods are either unpractical or unviable. The best way to tackle the partial shading of PV array is to use the MPPT with modified algorithm for sensing partial shading and response in accordance with that [9-10].

In this work, the solar photovoltaic model is designed in matlab environment. The same model is used for the implementation of the Global MPPT controller. The proposed MPPT improves the tracking response in all type of partial shading. The paper is divided into five sections. In section II, PV system model and DC-DC converter for implementation of the MPPT is presented. A section III discusses the proposed proposed MPPT controller. The simulation and result are presented in section IV. Brief summary of the system is concluded in section V.

II. PV MODULE MODELLING AND DC-DC CONVERTER

A Photovoltaic cell is a solid state semiconductor device which has capability to convert part of sun radiation energy into electricity. The phenomenon to convert solar energy into electrical energy is known as photovoltaic effect. The smallest unit which is commercially available for the manufacturing of standard PV panel is a PV cell [11]. The rating of PV cell is very low, so multiple PV cells on single frame are connected in series and parallel configuration and in common known as PV panel (module). A PV cell characteristic can be modeled as radiation control current source in parallel with diode [11]. The losses of PV cell can be represented by series and shunt resistance The PV cell model is shown in Fig. 1.

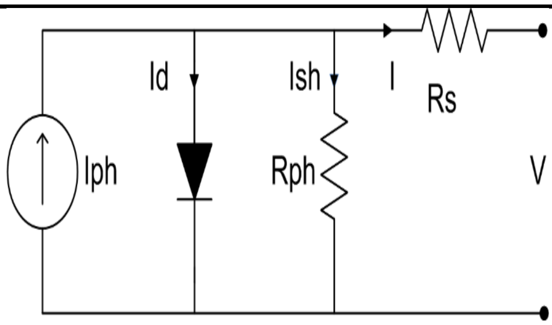


Fig. 1. Single diode model of PV module

Current across the PV cell (I_{cell}) is a sum of photo current ($I_{PV,cell}$), diode current (I_d)and shunt component current ($I_{sh,cell}$)and given by (1)

$$I_{cell} = I_{PV,cell} - I_{o,cell}\left(\exp\left(\frac{q(V_{cell}+R_s I_{cell})}{akT}\right) - 1\right) - \frac{V_{cell}+R_s I_{cell}}{R_p} \quad (1)$$

where $I_{o,cell}$ is dark saturation current of diode, q is the electron charge, k is the Boltzmann constant $1.38 * 10^{-23}\ J/K$), T is an absolute temperature of PV cell and a is the ideality factor of diode. Equation (1) represents a PV cell. For PV module, many PV cells are arranged in series and parallel fashion to increase the current and voltage rating. The mathematical I-V characteristics of PV module is

$$I = I_{PV} - I_o\left(\exp\left(\frac{q(V+R_s I)}{aN_s kT}\right) - 1\right) - \frac{V+R_s I}{R_p} \quad (2)$$

where I_{PV} is the photovoltaic current and I_o is the saturation current of the diode. In (2), $aN_s kT/q$ is the thermal voltage (V_t) of the module with N_s cells connected in series. For the module with N_p strings in parallel and each string have N_s PV cells, I_{PV} and I_o is expressed as $I_{PV} = N_p I_{PV,cell}, I_o = N_p I_{o,cell}, R_s$ and R_p are the equivalent series and shunt resistance of PV module.
The single diode model of PV module is represented in Equation (2). Some authors proposed two-diode or three diode model for more accurate mathematical modelling. . In this paper, single diode modelling is used as it is good enough to study system performance. For any PV module, there are three important points on I-V curve; which is short circuit point ($I_{sc}, 0$), open circuit point ($0, V_{oc}$) and maximum power point (I_{mp}, V_{mp}).

Generally PV module datasheet provides the information of short circuit current (I_{scn}), open circuit voltage (V_{ocn}), maximum current and voltage (I_{mpn}, V_{mpn}), maximum power (P_m), temperature coefficient of open voltage (K_V) and temperature coefficient of short circuit current (K_I) under standard test condition (STC, AM1.5, 1000 W/m2, 25℃) [8]. The P-V curve of PV panel is shown in Fig. 2.

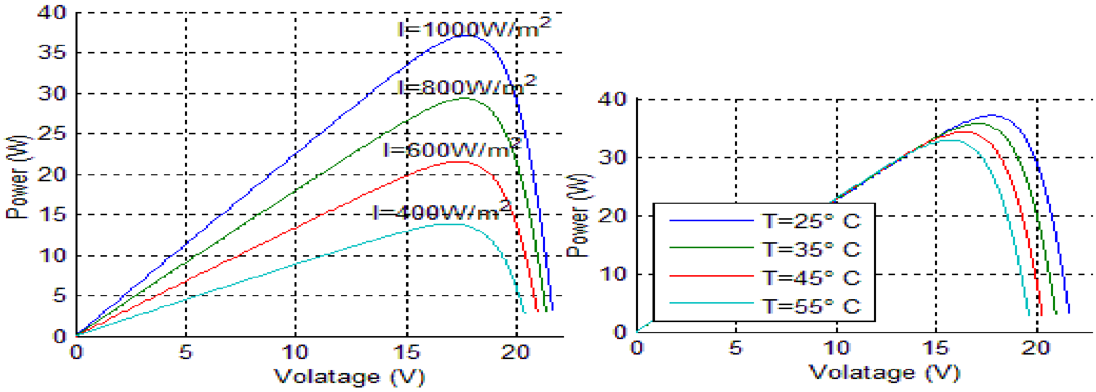
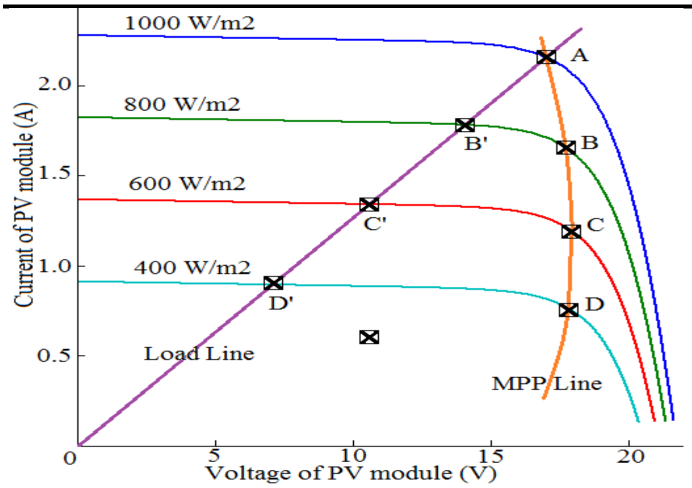


Fig. 2. The P-V characteristic of PV panel for different Irradiance and Temperature

III. STUDY OF MPPT AND PARTIAL SHADING

The MPPs at different irradiance are A`, B`, C` and D` as shown in Fig. 3. The blue line represents the resistive load line. It shows that if fixed resistance is connected across the PV module than point of operation is depends on the resistance of load and Irradiance level. For MPP operation, the optimal load needs to connect across the PV module. Generally, the load or battery rating is fixed, and radiation and temperature varies rapidly. The MPPT is used to operate PV system at points A, B, C and D. The MPPT techniques make use of algorithm and electronic circuit [6]. The MPPT works to adjust the impedance of load. The impedance matching is performed by using DC-DC converter whose duty cycle is adjusted by controller after sensing the current and voltage. The PV array is a combination of series and parallel connected PV modules and the performance of the array is purely depends up on the individual cell characteristics. It is observed that there is a variation in individual cells characteristics due to mismatch loss (chemical ageing, radiation, dust and partial shading). The maximum current flow of the string is depends up on the minimum radiation receiving cell. The partial shaded cells absorb the extra power generated by the unshaded cells and convert it into heat. It causes drop in actual output power of PV array and it also reduces the overall life of PV panel [10].



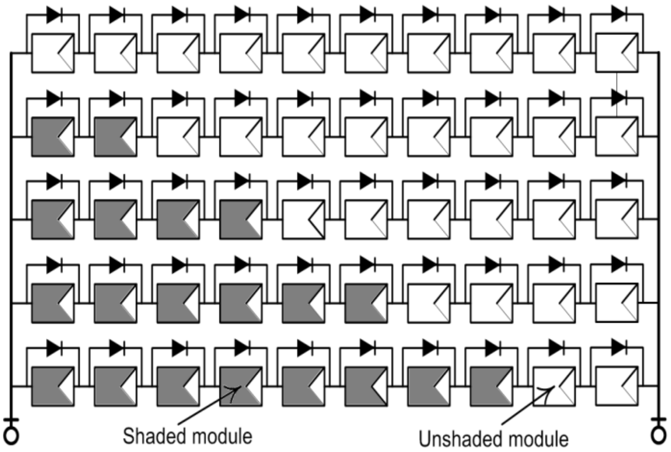
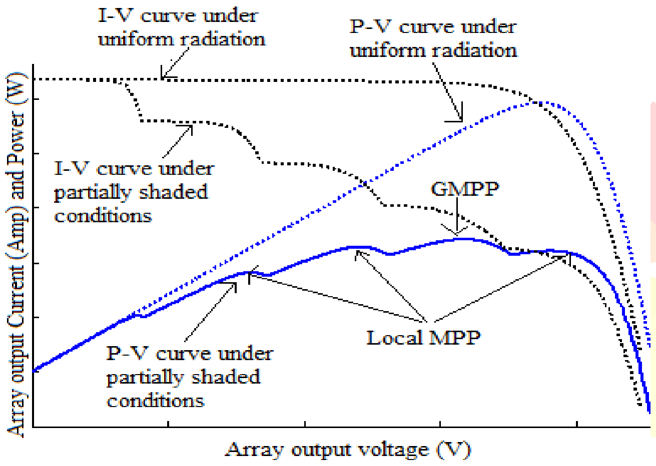


Fig. 3. Demonstration of MPP and Load Line on PV curve, Fig. 4. The PV array configuration for partial shading study

The effect of partial shading can be reduced by connecting a bypass diode across each module. But the PV array with bypass diode has a typical I-V and P-V characteristics with multiple power peaks under partial shading condition [9]. The 10x5 PV array with partial shading pattern is shown in Fig. 4. The plotted I-V and P-V characteristics of the PV array are shown in Fig. 5. It is clear from the Fig. 5 that under partial shading, there are multiple maximum power points and the prediction of global maximum power point location is a typical task. Some of the important findings from the Fig. 5 are as follow:

- I-V curve has a multiple steps.
- The location of GMPP is dependent upon the shading pattern, array configuration and irradiation.
- The MPPs are at multiple of 80% of $V_{oc,module}$.
- The minimum displacement between two successive MPPs is approximately 80% of $V_{oc,module}$.



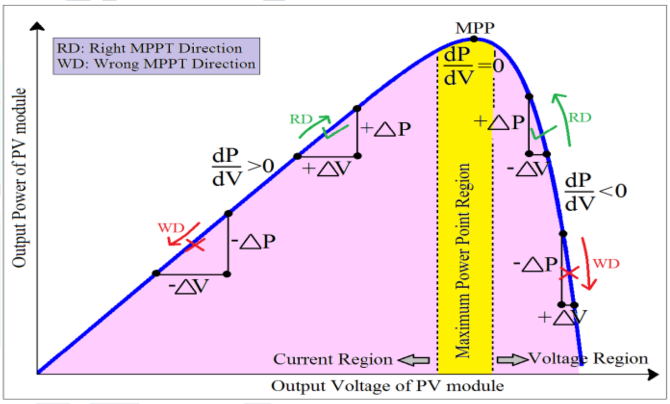


Fig. 5. P-V and I-V characteristics of PV array under partial shading, Fig. 6. The pictorial view of P&O MPPT

IV. THE PROPOSED GLOBAL MPPT CONTROLLER

The MPPT controller regulates the duty cycle of the converter and adjusts the apparent output resistance of PV module. The P&O MPPT detects the slope of dP/dV and accordingly adjusts the duty cycle [9]. The working principle of P&O is demonstrated in Fig. 6.As per the study of partial shading I-V characteristic, it is observed that simple P&O MPPT struct at one local MPP and unable to detect actual MPP. The simpleset method for detecting the GMPPT is the power curve scanning [12]. In this technique, the I-V characteristic is scan in regular interval for detecting GMPPT and then P&O uses to update the MPP at that point. The scanning of Power curve takes considerable time, the response time of this method is slow. The Power Slope technique is a modified form of the continuous search scheme. In this method, the dP/dV value is observed at different location and it is used to find the Local MPP. In [13], the simple P&O method is act to findout Local MPP and GMPP under partial shading is detected by Power curve slope subroutine. As shown in Fig. 7, the LMPP on the left side of the current Maximum is decided by detecting the change in slope (dP/dV) sign at two consecutive points, from positive to negative. Similarly, the right side LMPP can be detected by observing the change in slope sign from negative to positive. It is also observed that if the power available at two LMPP is less than the power at existing MPP, than existing MPP is a Global MPP. The duty step size (ΔV) and scanning time interval are the important parameter for improving the reliability of the controller.

The Fig. 8 shows the algorithm of the proposed GMPPT algorithm to track the GMPP under partially shaded conditions. The execution of the algorithm always starts with a reference voltage (Vref) value set equal to 85% of Voc (block 1). The Main block with P&O continuously update the Vref and operates the PV array near the MPP (block 2 to 6). When any sudden disturbance (like partial shading) or timer interrupt occurs, then the main program identifies the requirement of Global tracking and calls the Global track subroutine (block 7a).

From the characteristics of the P-V curve for different shading pattern, it is observed that:

1. The local MPPs power on the both side of global MPP is less than the GMPP power.
2. For the left side tracking, if the current LMPP power is less than the previous one, then the previous LMPP is the current GMPP.
3. Similarly, for the right side tracking, if the current LMPP power is less than the previous MPP power, then the previous MPP is the current GMPP.

4. During the left side tracking, if the current LMPP power is more than the previous MPP, then it is definite that there is no GMPP in the right side window.

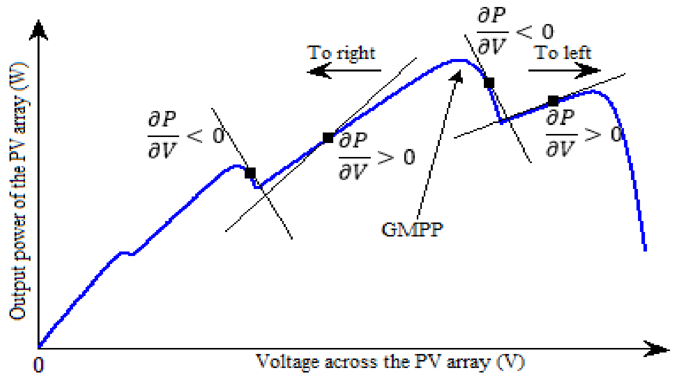


Fig. 7. Demonstration of Power slope GMPPT technique

During the subroutine operation, if the current LMPP (left side tracking) power is more than the previous MPP, then the condition RightSideTrack is set. After the left side tracking, the right side tracking is started in case of RightSideTrack==0 (block 23). This modification helps to reduce the tracking time for most of the shading conditions.

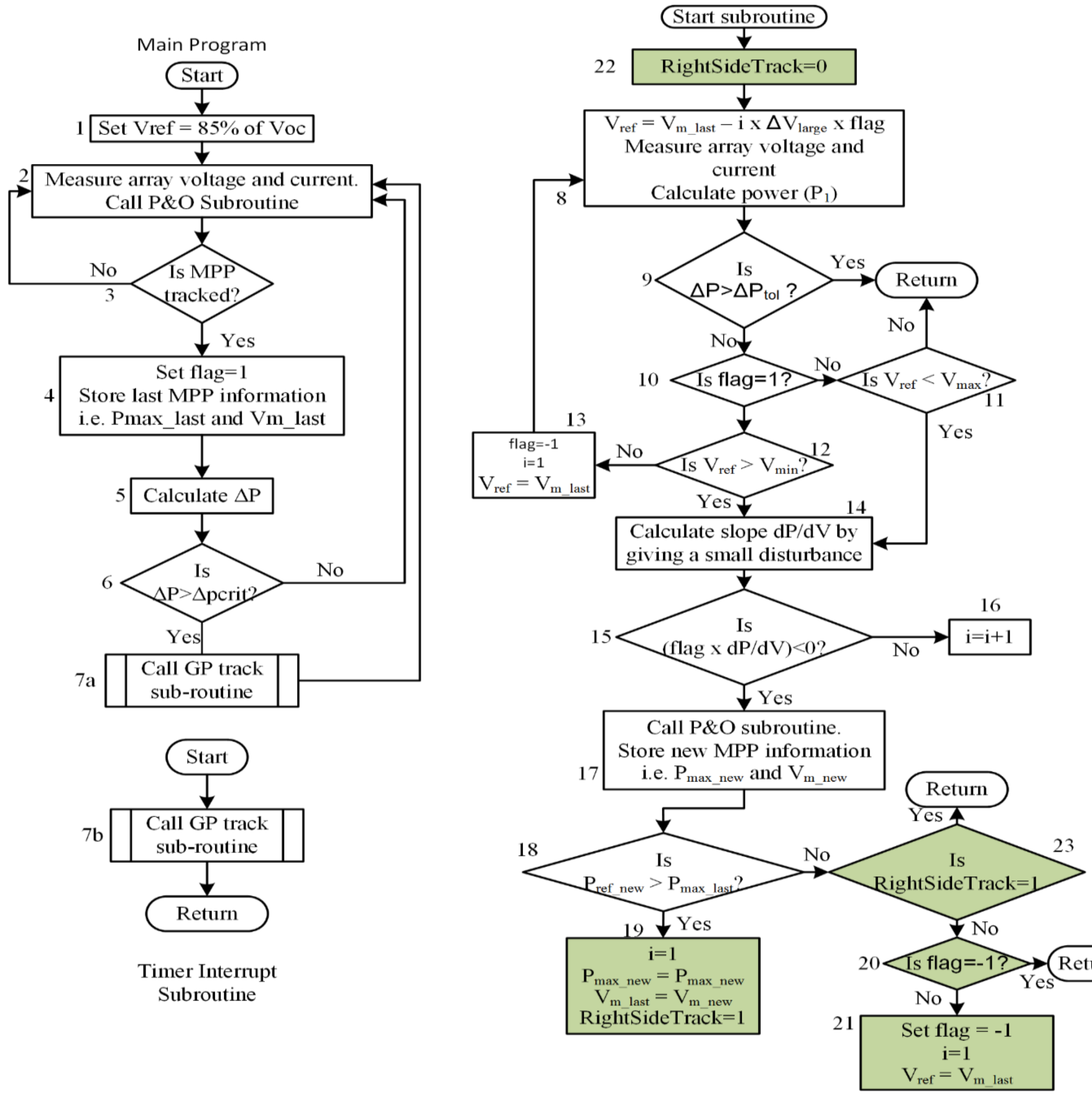


Fig. 8. The algorithm of the modified power slope detection GMPPT technique

V. SIMULATION RESULT AND ANALYSIS

The proposed GMPPT is implemented in matlab Simulink (state flow technique). For the same given condition, the output power for the existing and proposed GMPPT is analyzed. The output power curves are shown in Fig. 9, Fig. 10 and Fig. 11. The comparison of tracking time for proposed MPPT and the existing GMPPT is listed in Table I. It shows that the proposed GMPPT improves the tracking time and at the same time, reduces the scanning window.

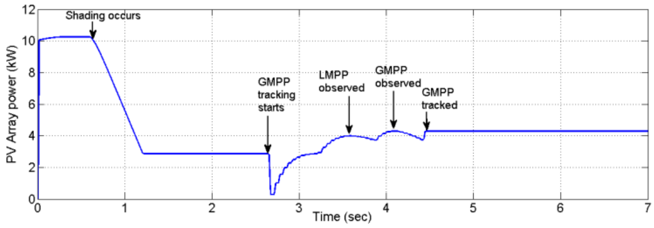


Fig. 9. The output power of PV array for the power curve scanning technique

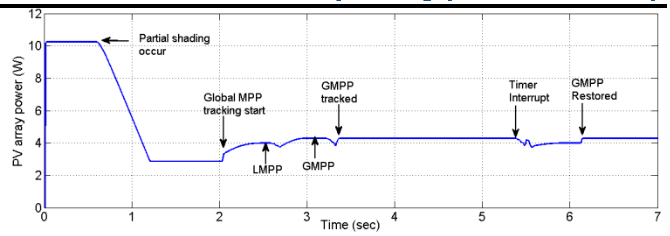


Fig. 10. The out power of PV array for the modified GMPPT

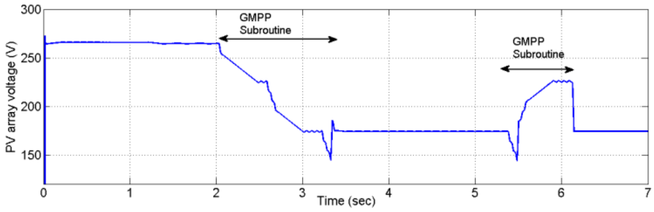


Fig. 11. The output voltage of PV array for the modified GMPPT

Table5.1: The tracking time analysis of different technique

Technique	Tracking Time	Remarks
Power Curve Scanning	1.77 Sec	Simulated Result
Power Slope Detection	3 Sec	Observed by Hiren et. al. [13]
Power Slope Detection	2.1 Sec	Simulated Result
Proposed GMPPT	1.29 Sec	Simulated Result

VI. ACKNOWLEDGMENT

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