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VARIABLE STEP-SIZE BASED P&O ALGORITHM FOR PV SYSTEMS UNDER VARYING IRRADIANCE LEVELS

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Abstract - *PV systems aren't linear in nature, to achieve maximum amount of power several methods are used. In solar system, Maximum Power Point Tracking (MPPT) technique is commonly used for achieving maximum power out of photovoltaic generators. Study of P&O MPPT techniques, commonly used in photovoltaic (PV) systems is presented in this paper. In addition, in this paper, the proposal of method for reducing steady state oscillation in MPPT using P&O method is made. Traditional P&O structure but with methodology to progressively change the amount of the perturbation is implemented in proposed technique. To make sure algorithm will not deviate from tracking locus, constraint of dynamic boundary is introduced. Proposed approach can considerably increase the precision MPPT steady state. Increase in average ηMPPT of almost 2.99% was achieved, compared to conventional P&O under variable irradiance, using proposed MPPT technique. The proposed method was simulated in the MATLAB/Simulink, findings shows, as compared to traditional P&O method new algorithm is faster and accurate.*

Key Words: *Solar Photovoltaic, modeling and simulation, P&O, MPPT.*

1.INTRODUCTION

With the scarcity of traditional fuels, importance of renewable energy is increased. Various sources of renewable energy are available, most well-known of which are wind and solar PV production. These sources of renewable energy have an advantage over conventional fuel-based energy generating since it is endless and has no impact on environment. Because of the relatively efficient and inexpensive PV modules available, solar PV has witnessed phenomenal growth among all renewable energy sources. PV cells are components that use the "photovoltaic effect" to transform solar energy directly into electricity [1]. They take up less space and have a lower balance of system (BoS), making them ideal for distant locations. Series/parallel connections of PV module are done for power requirements to be met. IV curves of PV module non-linear making extraction of energy efficiently difficult. One single point exists where power is maximum. One major issue with PV systems is the potential of making difference with the load's operating characteristics and the PV array's operating characteristics.

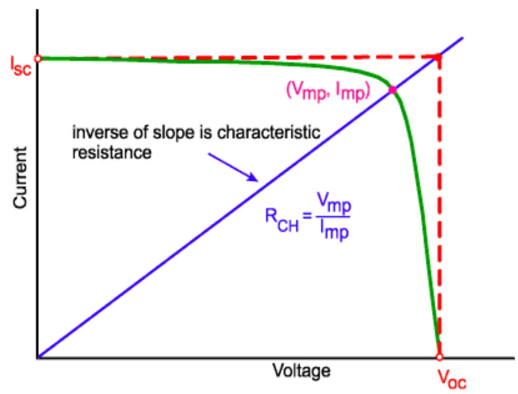


Fig-1: IV characteristics of PV array [2]

Typical I vs. V curve is shown in figure 1, for PV panel, with the X and Y-axes denoting voltage and current, respectively. For PV array connected with load, intersection of I-V curves of load and PV array is the system's operating point. Most of the time, this operational point isn't the maximum point of PV array (MPP). Making use of software codes, MPPT is build which comes to be the better solution to increase extraction of energy because of its less cost. MPPT always aims to maintain operating point at maximum power point (MPP). In literature various methods have been published [3-5], which can be separated into two categories: traditional computing and soft computing The perturb and observe (P&O) [6,7], hill climbing [8] and incremental conductance methods[12] are the most popularly used conventional MPPTs. Researchers frequently employ the strategies listed below.

• Perturb & Observe (P&O)

• Modified Perturb & Observe

These approaches are popular because they are simple and have a high degree of convergence. However, the algorithm has a severe flaw in the form of constant oscillation about the MPP. This issue leads to a loss of power and, as a result, a reduction in tracking efficiency. The researchers are always attempting to improve existing methodologies through the use of systems based on AI (artificial intelligence), such as ANFIS, Fuzzy, and Neural network. The AI based approaches like these tunes available algorithms finely while increasing the system's architecture complexity. In light of this, this paper recommends a more thorough revision to the P&O, with the goal of resolving the issue.

The purpose of this paper is to compare two basic MPPT approaches. The comparison of these MPPTs is presented in this work under both constant and variable environmental conditions. The benefits and downsides of these two MPPT approaches are examined in this way. And further we are proposing a new algorithm which will be helpful to generate stable power with less steady oscillations and will achieve more accurate MPP in minimum time. In the Matlab/Simulink environment, the system is modeled and tested.

2. SOLAR PHOTOVOTAIC MODULE MODELING

The solar cell generates current when surface of solar cell receives rays of light, Fig-2 shows the corresponding model of a PV device. It clearly shows a model of an ideal Photovoltaic cell as well as a practical Photovoltaic device. A single PV cell cannot generate enough power to be used in the majority of usages. Individual cells are connected to each other in parallel or series arrangements to obtain power that is suitable for most applications, such arrangements are referred as PV module. They have the ability to generate power of desired quantity. For PV module varieties of model are available in the literature; however, we choose the practical model based on single diode for our system since it provides an excellent balance of precision along with simplicity. An equation for unit solar photovoltaic cell is depicted.

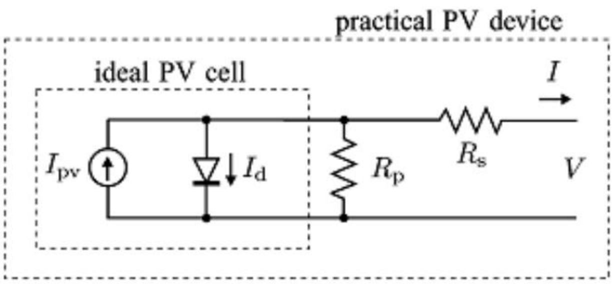


Fig-2: Equivalent model for a photovoltaic device [9]

below [9] :

$$I = Ipv - Io(exp(Vd/nVt) - 1) \quad (1)$$

Where,

- Schokley diode current – Id = ***Io(exp(Vd/nVt) – 1)***
- Photovoltaic current - Ipv
- leakage current - *Io*
- diode voltage - *Vd*
- The diode's thermal voltage (equal to kT q) - Vt
- Electron charge - q
- Boltzmann constant - *k*
- Temperature at PN junction (Kelvin) - *T*

In Fig-2, module's internal losses because of current flow is represented by resistance Rs and leakage current is represented by resistance Rp. eq.1 can Therefore be represented in terms of Rp & Rs as;

$$I = Ipv - Io(exp((V + IRs)/nVt) - 1) - (V + IRs)/ Rp \quad (2)$$

Where,
• PV device current - *Ipv*
• PV device voltage - *V*

PV module is modeled using equation 2.

The characteristics of Kyocera KC200GT module used for modeling are shown in table I.

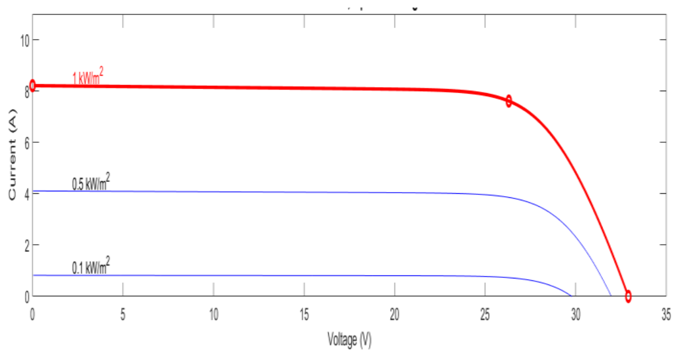


Fig-3: I-V curve

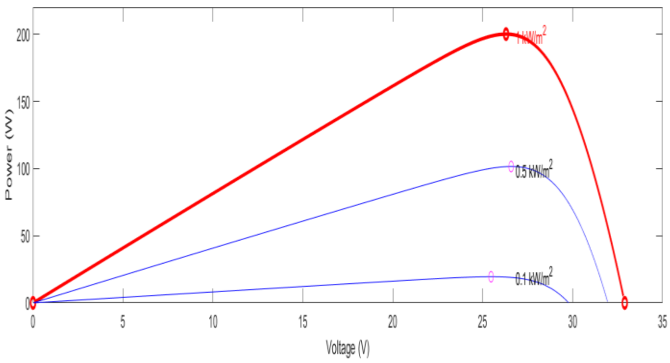


Fig-4: P-V curve

Curves of Kyocera KC200GT are represented in Fig-3 and Fig-4.

Table -1: DATASHEET

KYOCERA KC200GT MODULE	
Imp	7.61 A
Vmp	26.3 V
Pmax	200.14 W
Isc	8.21 A
Voc	32.9 V
Ns	54
α_{Voc}	-0.35502 %/°C
α_{Isc}	0.06 %/°C

3. CONVENTIONAL MPPT ALGORITHMS

3.1 Perturb and Observe (P&O) MPPT

The flow chart in Fig-5 illustrates its mechanism. The perturbation of voltage along one direction happens and the program perturbs along same direction if the power continues to rise. The direction of perturbation will get reversed, if the old power is higher than new power. However, once the system reach maximum power point, the oscillation about MPP is continued. Moreover, this algorithm tends to get confused if the weather conditions are rapidly changing [3]. The algorithm is simple because of which this algorithm is widely used.

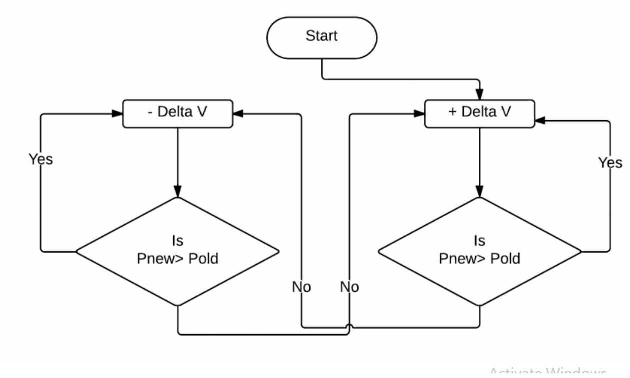


Fig-5: Algorithm of basic P&O MPPT.

3.2 Modified Perturb and Observe (P&O)

Inspite of being popular among MPPT techniques, P&O algorithm have drawbacks, inform of a poor tracking speed and oscillations around the MPP. The tracker computes the change (incrementing or decrementing) in current or voltage of the solar array using comparison of instentanious power with the previous. If PV generator's voltage is perturbed along a path and $dP/dV > 0$, algorithm may still perturb the PV voltage along same path. The MPP has been overruns when $dP/dV < 0$, hence the perturbation path is reversed. [10] Fig-6 depicts the flowchart for modified P&O algorithm.

3.3 Proposed MPPT Algorithm

Fast dynamic response with acceptable accuracy in the steady state cannot be achieved simultaneously in traditional P&O MPPT. Large step size leads to quick dynamic reaction but the steady state oscillations at maximum power point will grow, resulting a loss in power generation. Proposed method aims improving the performance of MPPT. The simulation outcomes shows, as compared to existing fixed step-size methods, proposed technique comes out to be significantly more precise and faster. Proposed method's algorithm is depicted in Fig-7 as a flowchart.

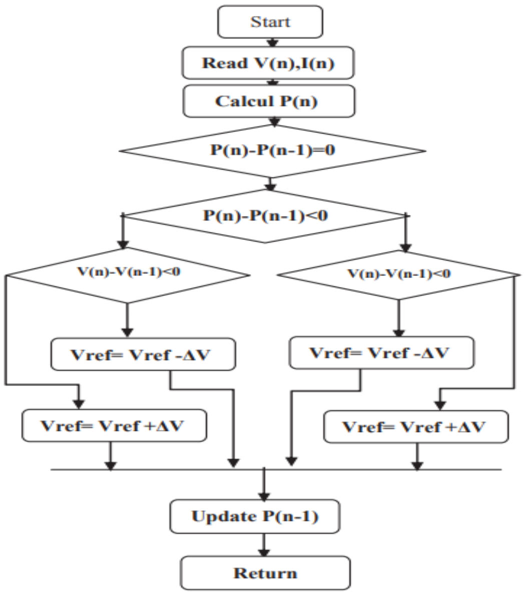


Fig-6: Algorithm of Modified P&O MPPT [10]

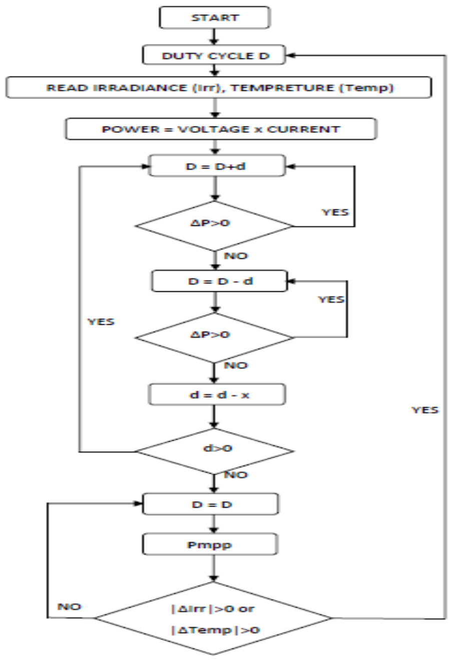


Fig-7: Algorithm for proposed MPPT algorithm

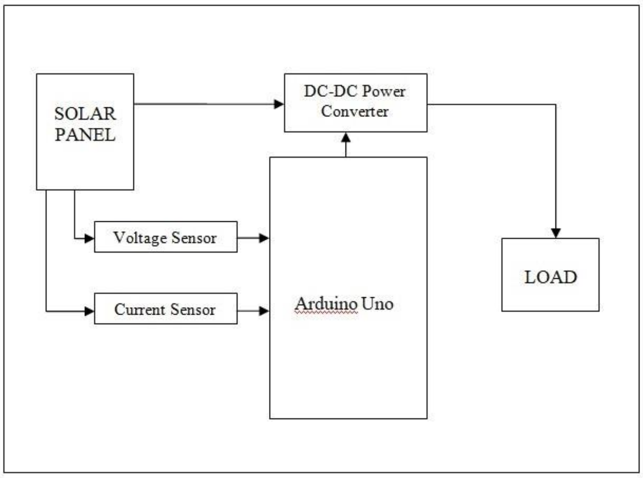


Fig-8: BLOCK DIAGRAM OF MPPT SETUP

4. SIMULATION SETUP

As shown in Fig-9, a photovoltaic system setup is built using Matlab/Simulink. In this simulation setting, all three strategies outlined above are implemented.

Simulation setup parameters are presented below:

A photovoltaic array consists of 1 x 1 i.e. single module. Table I shows the electrical characteristics parameters of the Kyocera KC200GT module under standard testing conditions (STC). 1000 W of power can be generated by each PV array under STC.

- DC-DC boost converter is designed using following component values:
  – Capacitor at input Cin = 400 uF
  – Inductor L = 15mH
  – Capacitor at output Cout = 10 uF
- 20 Ω resistive load is connected

5. SIMULATION & OUTCOMES

Simulation of PV system is performed in MATLAB/SIMULINK. A PWM generator, MPPT controller, and boost converter is used in setup and has been presented in Figure 9.

Proposed technique in Fig-10(c) can generate more smooth and stable MPP than P&O MPPT in Fig-10(a) and Modified P&O MPPT technique in Fig-10(b). P&O technique is constrained by step size; quick dynamic response but large steady state oscillations and low efficiency is achieved if the step size is large.

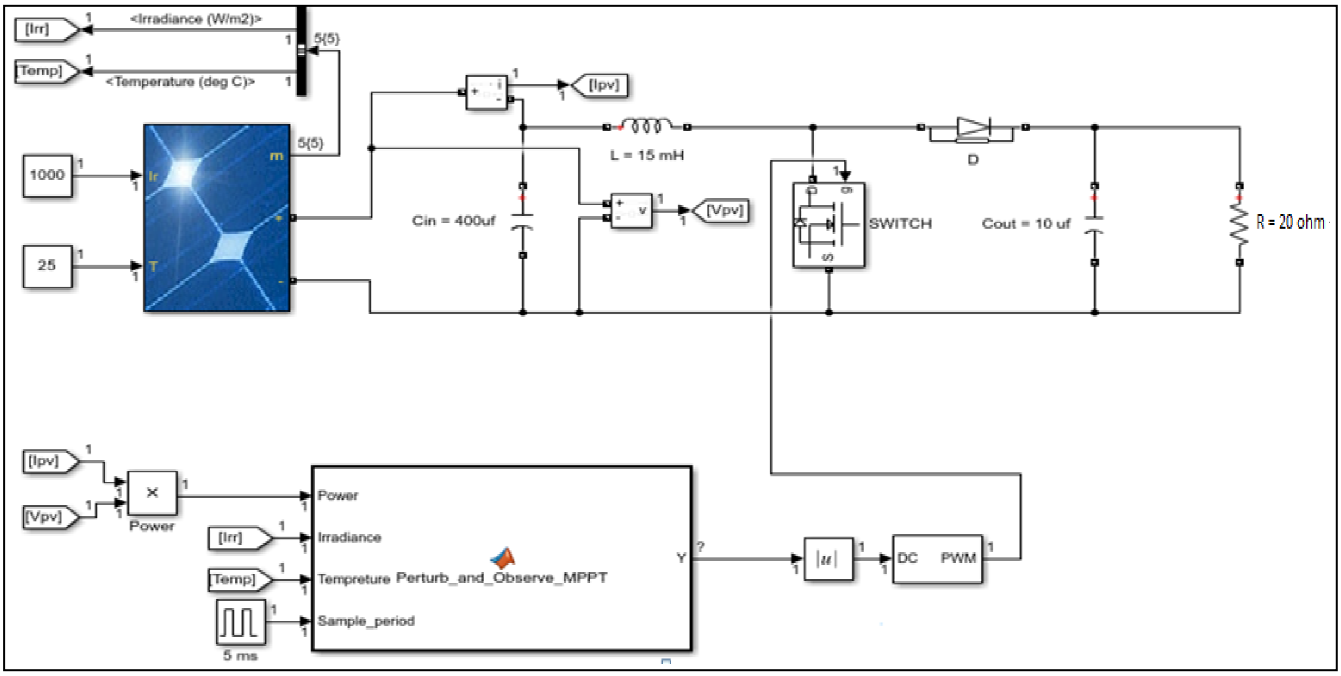
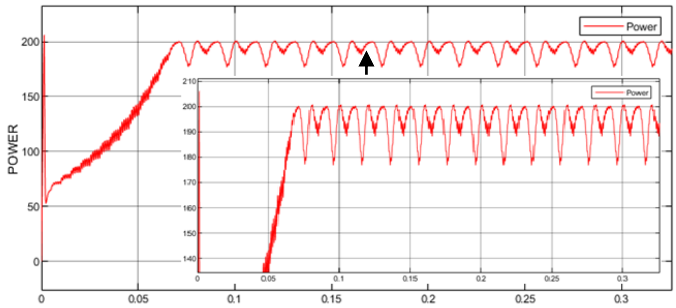


Fig-9: SIMULATION SETUP

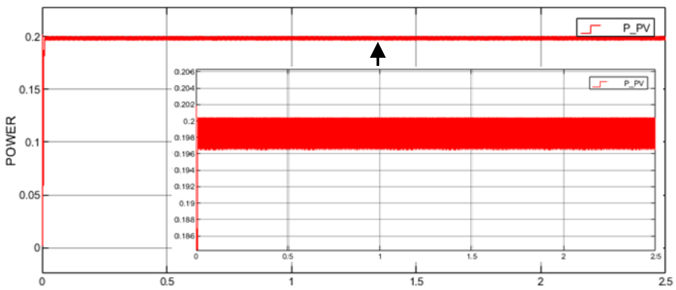
Furthermore, when the smaller step size is initiated, this condition is reversed. However, larger step size initiated when far from maximum power point to achieve MPP rapidly. Step size is set to smaller value when near the maximum power point to achieve small range of steady-state oscillations in proposed MPPT technique.

The proposed method could generate power oscillations ranging from 198.2W to 200W, whereas the P&O method could generate power oscillations ranging from 178W to 200W and the Modified P&O method could generate power oscillations ranging from 196.5W to 200W.

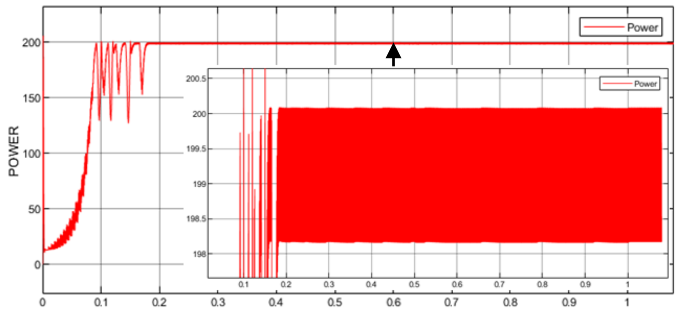
The proposed technique generates varying step size, resulting in an MPPT with small range of steady state oscillation and good dynamic performance.



(a) Perturb & Observe



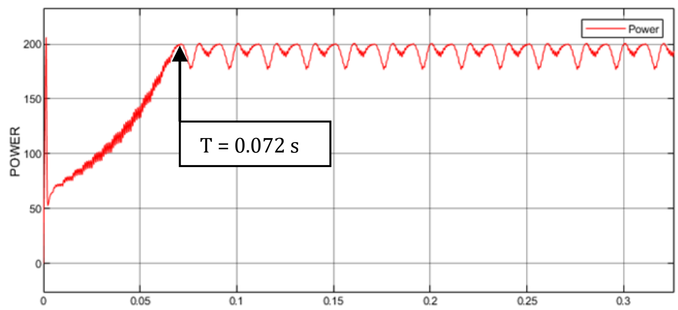
(b) Modified Perturb & Observe



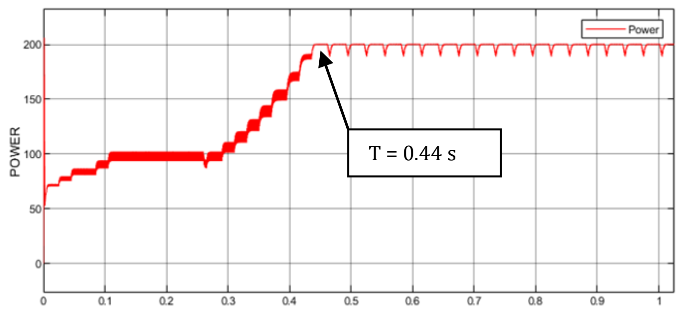
(c) Proposed MPPT

Fig-10: Output power of the PV at 1000 W/m2 and 25°C.

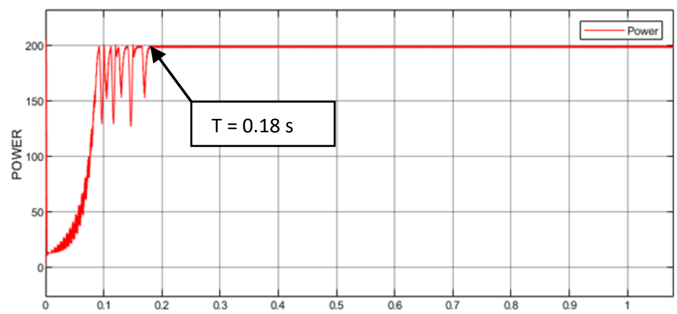
Fig. 11 depicts power performance of proposed algorithm, and performance of P&O algorithm with step size set at initial step size in proposed algorithm, and step size set at final value of step size in proposed algorithm respectively.



(a) P&O algorithm (Step-size = 0.05).



(b) P&O algorithm (step-size = 0.0125).



(c) Proposed MPPT algorithm

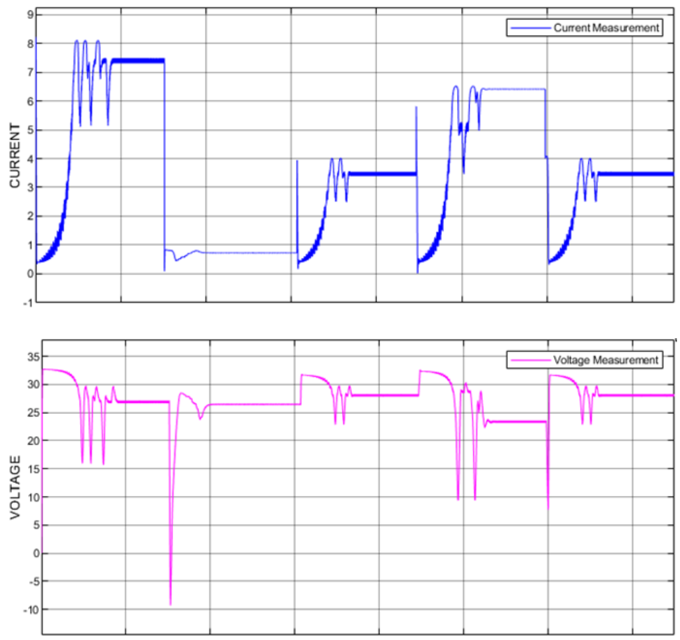
Fig-11: Power Performance

The above illustration in Fig-11(c) and Fig-11(a) depicts power output of algorithms when the initial step size in P&O algorithm and proposed algorithm was initiated as 0.05, and the power output for P&O algorithm when the step size was initiated as 0.0125, which is equal to gradually reduced step size in proposed algorithm. From above illustration the conclusion can be made that as compared to P&O algorithm, proposed algorithm takes more time for tracking of MPP. However, when the step size is kept constant, the power output is not stable, and the maximum power point is missed to some extent. Whereas, as per P&O algorithm concept, smaller the step size, more accurate is the MPP traced, as well as the stable output signal. The proposed algorithm uses the same concept, where the step size is gradually reduced and a more accurate and stable power output is generated.

The comparison in Fig-11 indicates that the proposed algorithm traces more accurate and stable power as compared to traditional P&O within minimal time period.

Fig-12 depicts the output performance with varying irradiation levels for proposed method.

The temperature is initiated to 25°C in each case, and the irradiation is abruptly varied from 1000 to 100W/m2 at 0.3 s, at 0.6 s 100 to 500W/m2, 500 to 800W/m2 at 0.9 s, and 800 to 500W/m2 at 1.2 s.



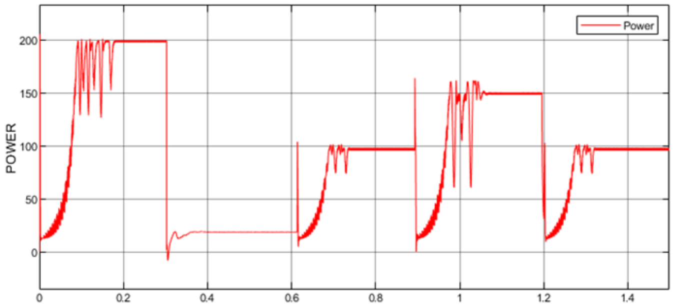


Fig-12: Performance under varying irradiation levels.

Proposed method's performance is shown in Fig-12, and it can efficiently converge to MPP with varying irradiation levels. Fig-13 depicts the trajectory of MPP in the same way that Fig. 12 depicts the condition irradiation.

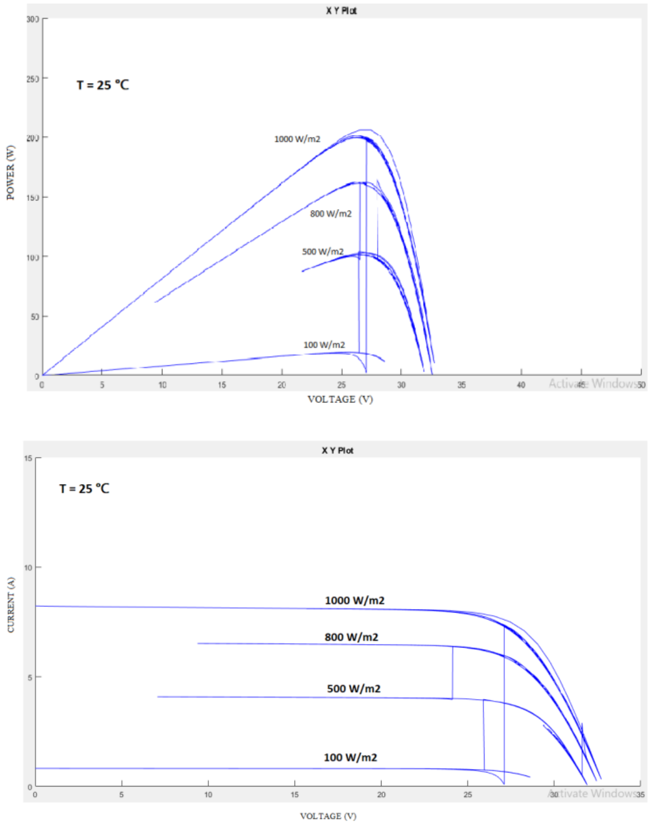


Fig-13: MPP's trajectory as irradiation changes

Fig-14 depicts the output performance with the varying temperature levels for proposed method. Irradiation is set to 1000W/m2, and the abrupt change in temperature from 25 to 50°C in 0.25 s, 50 to 35°C in 0.5 s, 35 to 45°C in 0.75 s, and 45 to 25°C in 1 s.

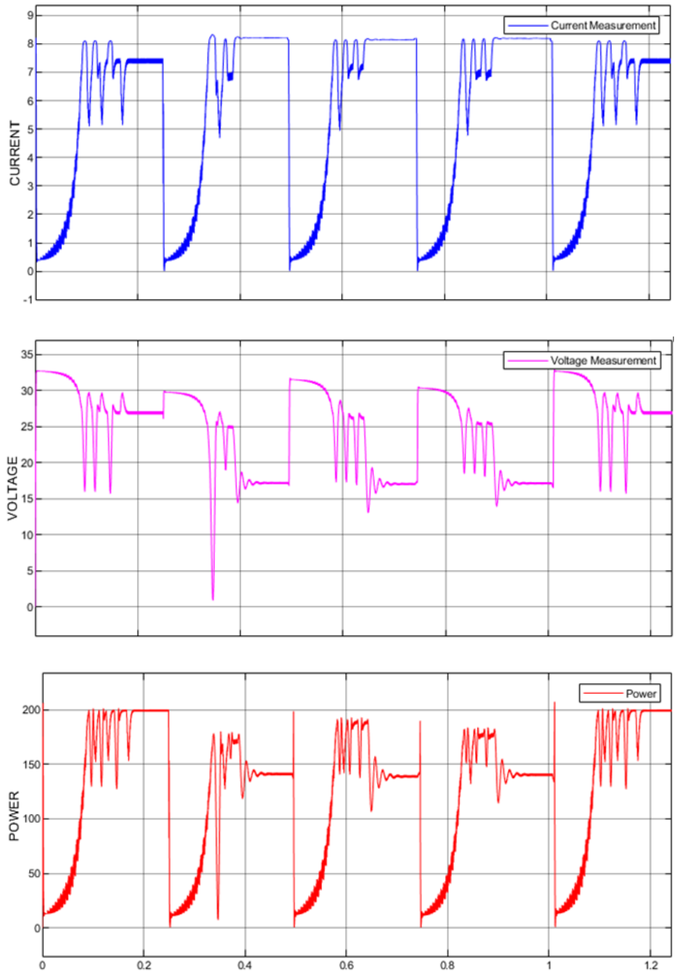


Fig-14: Performance under variable temperature conditions

Table II shows the response performance of the traditional P&O method, and the Modified P&O MPPT proposed technique.

TABLE-2: SIMULATION OUTCOMES OF MPPT TECHNIQUE

ALGORITHM	IRRADIANCE (W/M2)	TEMPRETURE (°C)	STEP SIZE	RESPONSE TIME	POWER OSCILLATION RANGE (W)	EFFICIENCY (%)
P&O	100	25	0.05	0.06	18.5-19.5	97.53
MODIFIED P&O	100	25	0.05	0.026	18-19.5	96.25
PROPOSED METHOD	100	25	0.05	0.11	19.3-19.4	99.33
P&O	500	25	0.05	0.07	96-101.5	97.22
MODIFIED P&O	500	25	0.05	0.02	98.7-101.5	98.55
PROPOSED METHOD	500	25	0.05	0.16	100.6-101.2	99.34
P&O	1000	25	0.05	0.07	178-200	94.44
MODIFIED P&O	1000	25	0.05	0.02	196.5-200	99.05
PROPOSED METHOD	1000	25	0.05	0.18	198.2-200	99.48

TABLE-3: MPPT TECHNIQUE COMPARISON

PARAMETERS	**P&O**	**Modified P&O**	**Proposed Method**
Dynamic Tracking	Reasonable	Reasonable	Reasonable
Advance tuning	No	No	No
Steady Tracking	Reasonable	Medium	High
Hardware complication	Less	Less	Less
Algorithm complication	Less	Less	Medium
Sensors	Voltage & Current	Voltage & Current	Voltage & Current

6. CONCLUSIONS

In this paper, P&O MPPT algorithm using variable step-size is presented, which results in improvement of variable and steady state performance simultaneously. The proposed method overcomes the shortcomings of traditional P&O MPPT. Increment of 2.99% in the average tracking efficiency was observed when compared with traditional P&O MPPT. Effectiveness along with feasibility is proven from the simulation outcomes of proposed method. As a result, it is expected that this algorithm will pique the interest of researchers and industries in developing a new MPPT algorithm for photovoltaic systems.

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