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Maximization Power of Photovoltaic Panels with Improved Perturb & Observe MPPT Algorithm

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Abstract

In this work, it is presented maximization power algorithm for photovoltaic panels to increase power and efficiency when the system is exposed to various weather conditions. For this study, the maximum power point tracking (MPPT) strategy used is the improved perturbation-observation strategy (IP&O) with variable step for the perturbation of the voltage which make possible to avoid oscillations when using the classical Peturb. & Observ. (P&O) algorithm. To determine the instantaneous electrical characteristics of photovoltaic modules under various weather conditions, simulation. To evaluate the performance of solar panels exposed to varying conditions, various comparisons have been presented. Firstly, by making a comparison between the two methods was presented. The findings demonstrate how successful the proposed method in enhancing power and efficiency under varying weather conditions.

Keywords

Photovoltaic, Maximization, DC/DC Converter, MPPT, Efficiency

1. Introduction

Photovoltaic panels have nonlinear voltage-current characteristics with a single MPP under normal conditions. Several factors such as temperature, irradiance, and clouds can all have an effect on the PV characteristics curve [1-5].

The maximization power seems the solution by using MPPT algorithm [6-9]. It maintains the power to its maximum value under variable conditions [8]. Several strategies can be used [8]. The most commonly an applied strategy is Perturb & Observ (P&O) due to is simplicity. Other methods, such as the fuzzy logic controller (FLC) [9] are also used. The drawback of these methods is that they need the design of rules, which makes the method more complicated than conventional methods. Advanced algorithms are also used [9] but the drawbacks of these methods are that they are complicated, with high convergence speed to track the global power points.

In our study, the perturbation-observation strategy with variable step (IP&O). It is applied for the perturbation of the voltage which make possible to avoid tracking loss for the maximum power point (MPP) when using P&O algorithm. This strategy's primary goal is to raise the duty cycle step size when the latest operational point deviates from the MPP. As the operating point approaches the MPP, the step size decreases. As a consequence, an MPPT strategy has been proposed to recover power losses. MATLAB/Simulink was used to achieve a simplified simulation implementation of the proposed controller.

The different results obtained by simulation (Matlab/Simulink) showed that the power generated by the proposed method was increased for different tests.

2. Studied system

2.1. Modeling of PV panel

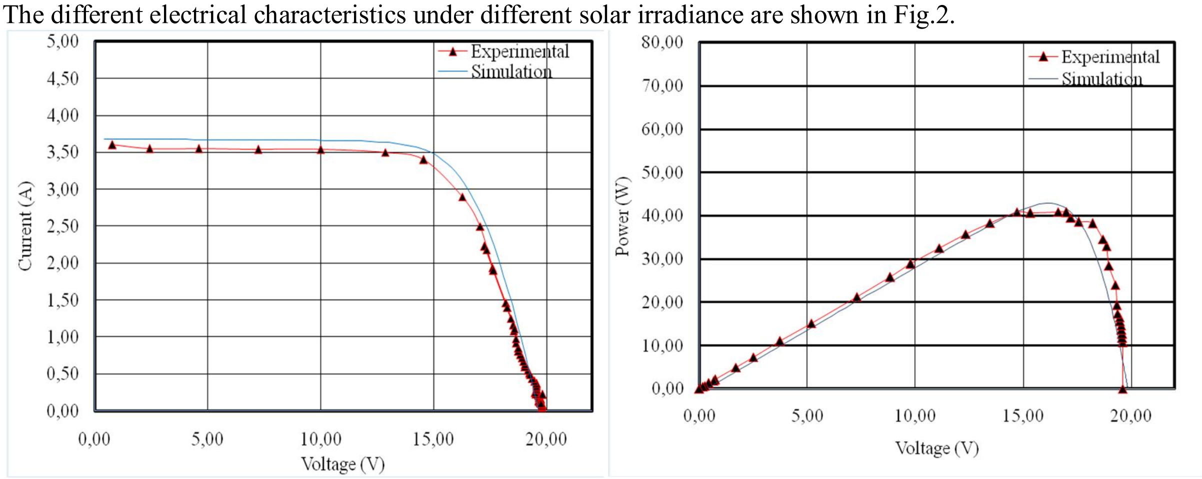
In this study, we adopted the single-diode model, a relatively simple yet effective approach for representing the electrical behavior of PV panels [1].

$$I_{pv} = I_{ph} - I_0 \times \left[\exp\left(\frac{q \times (V_{pv} + R_s \times I_{pv})}{A \times N_s \times K \times T_j} \right) - 1 \right] - \frac{V_{pv} + R_s \times I_{pv}}{R_{sh}} \quad (1)$$

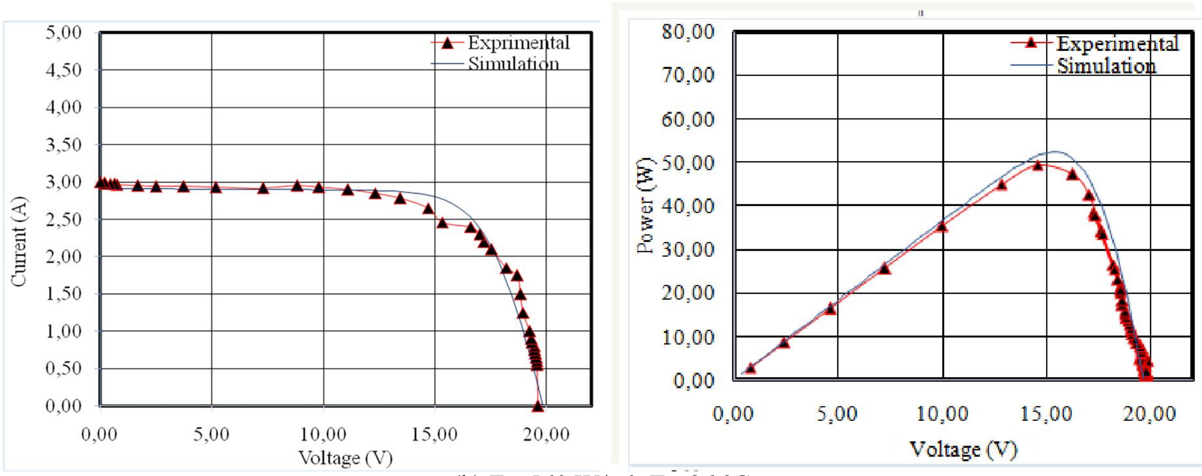
The PV electrical characteristics were determined (Fig. 1).

Fig.1. Test bench

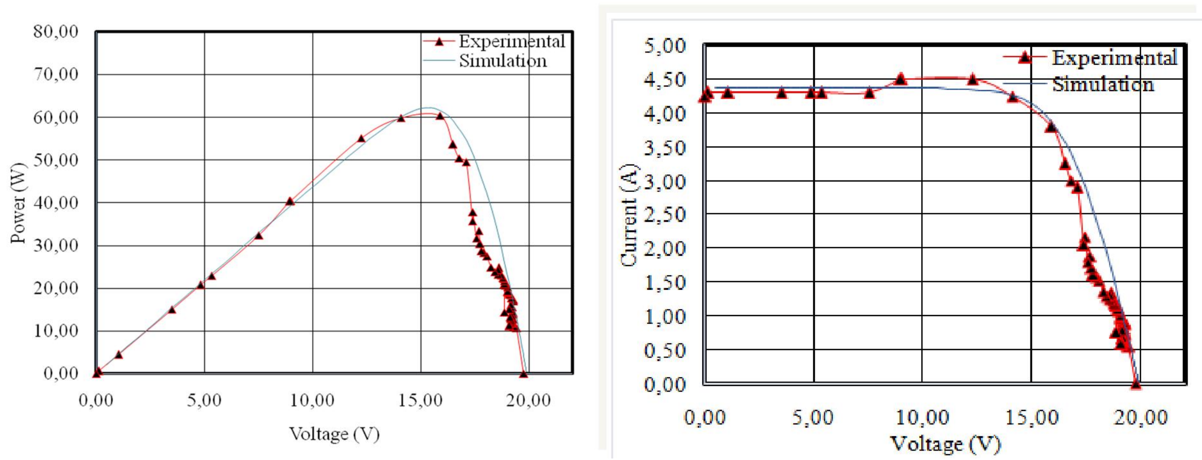
The different electrical characteristics under different solar irradiance are shown in Fig.2.



(a) E_s=320 W/m², T_a=19 °C



(b) E_s=560 W/m², T_a=26 °C



(c) E_s=780 W/m², T_a=32 °C

Fig 2. Electrical characteristics under different solar irradiance

2.2. Boost converter

A boost converter can be modeled as [6], [9]:

$$\frac{dV_{DC}}{dt} = \frac{1}{C}[(1 - S)I_L - I_{DC}]$$
$$\frac{dV_L}{dt} = \frac{1}{L}[V_{PV} - (1 - S)V_{DC}] \tag{2}$$

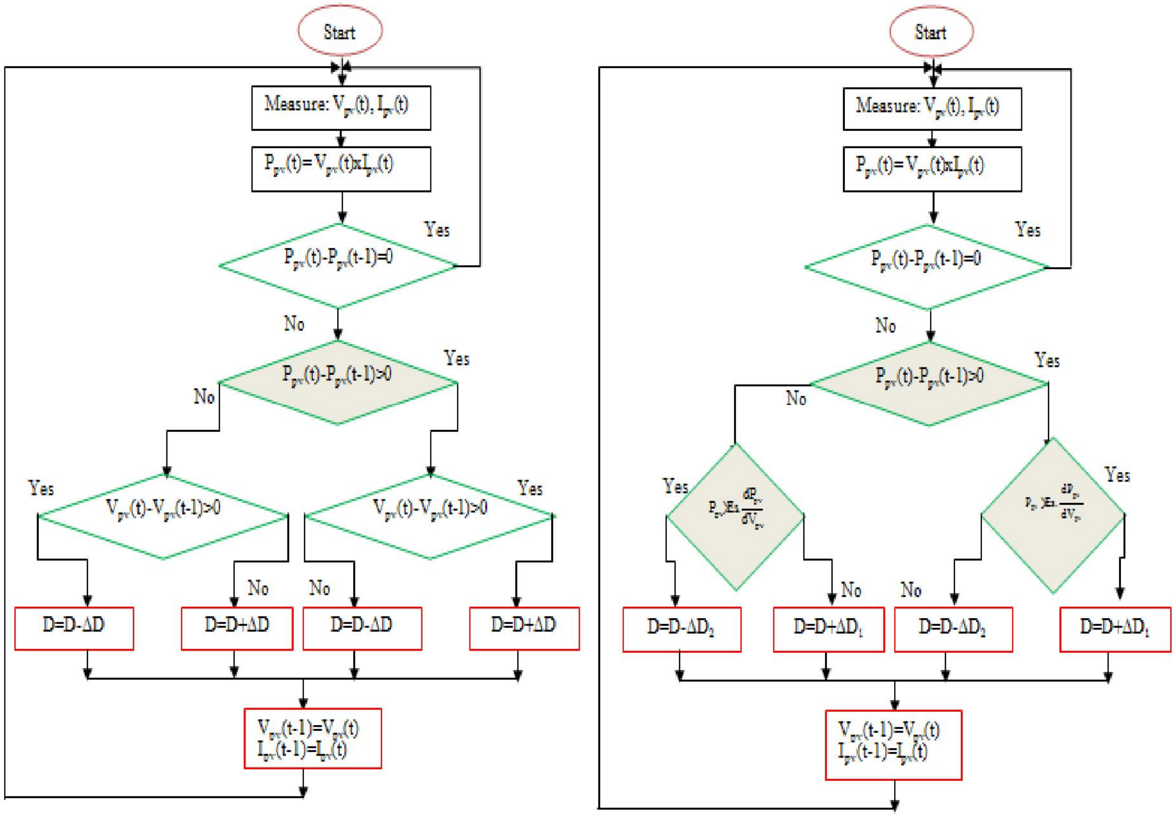
Where: S is the logic control state

The boost converter inductor and output capacitor are [9]:

$$L = \frac{V_{PV}.D}{\Delta I.f}$$
$$C = \frac{I_{DC}.D}{\Delta I_{DC}.f} \tag{3}$$

2.3. MPPT algorithms:

To avoid oscillations when using the P&O, the IP&O method with variable step was used (Fig 3).



(a) P&O MPPT flowchart (b) IP&O MPPT with variable step flowchart

Fig.3. MPPT flowcharts for the two strategies

The main idea behind this strategy is to increase the duty cycle step size when the recent operational point is away from the global point. As the operating point approaches the MPP, the step size decreases. It compares the power characteristic to a curve ($E_s.dP_{pv}/dV_{pv}$). With E_s is solar irradiation (W/m²), dP_{pv} is photovoltaic power variation (W) and dV_{pv} is photovoltaic voltage variations (V). The PV operating areas can be separated into four areas (A1, A2-a, A2-b, A3) (Fig. 4). Once the operating point in the region is identified, a variable voltage step will be applied. When the MPP is far away from the operational point, a significant voltage step (A1 and A3) is applied to reduce the time required to reach the MPP. To reduce oscillations in the steady state, a small step is used when the operating point is near the MPP (A2-a) and R2-b)) (Fig. 4).

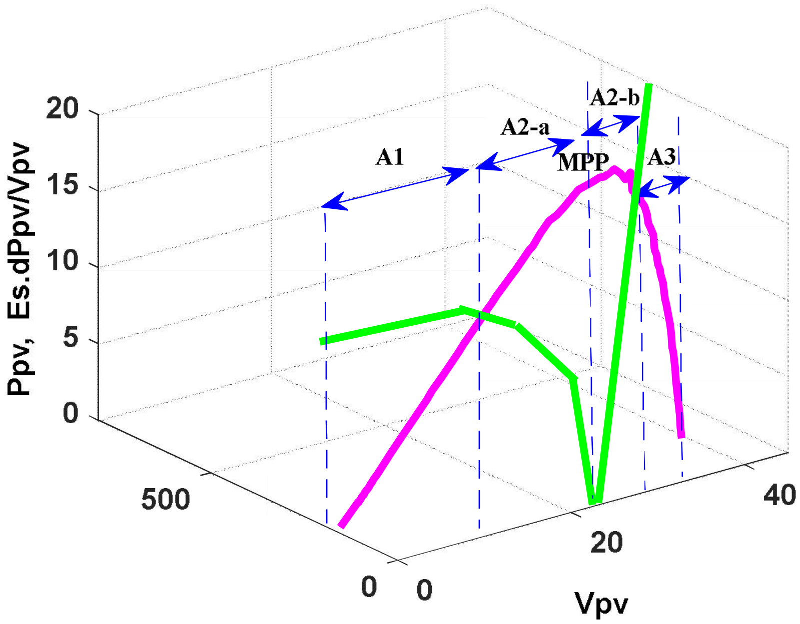
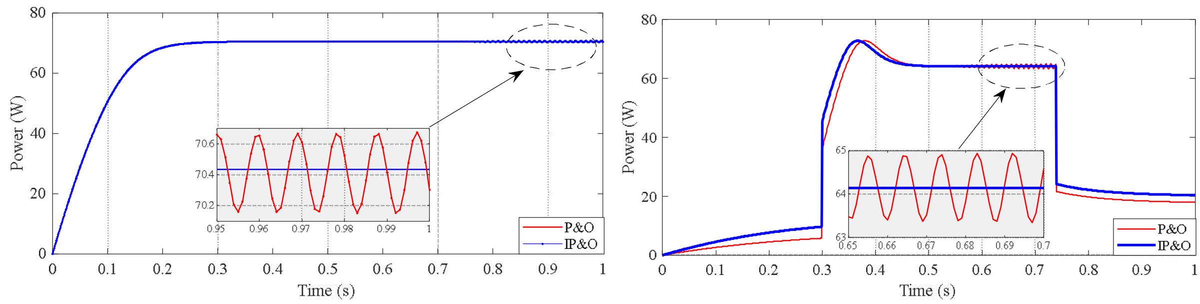


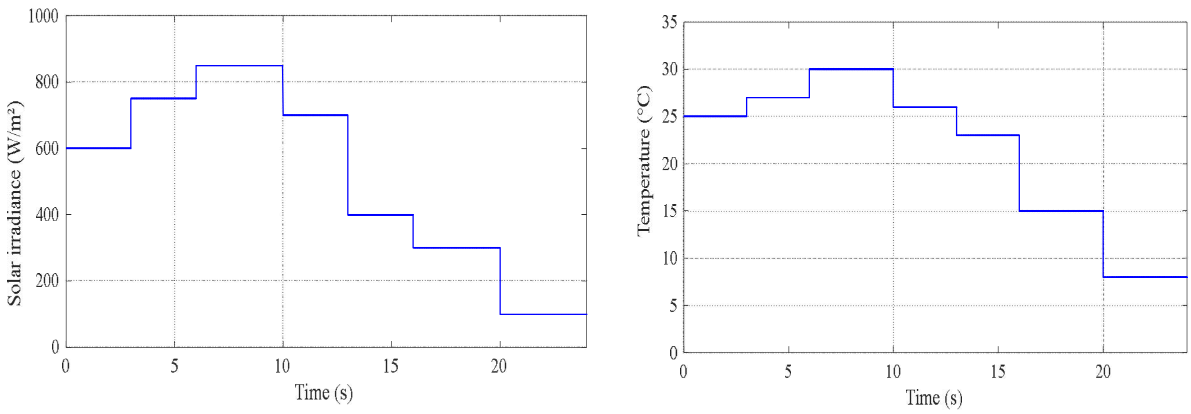
Fig.4. PV operating areas

Simulated photovoltaic power fluctuations using the two MPPT (P&O and IP&O) are listed under constant solar irradiance (Fig. 5(a)) and under solar irradiance step profile (Fig. 5(b)), respectively, to demonstrate improvements of the IP&O approach. It is noticed large oscillations with classical P&O which are reduced when IP&O method is used. To show other performances as efficiency and response time, a step profile of solar irradiance and ambient temperature was chosen (Fig.6).



(a) At constant solar irradiance (b) Under solar irradiance step profile

Fig. 5. Photovoltaic power variations under P&O and IP&O at constant and step solar irradiance profile



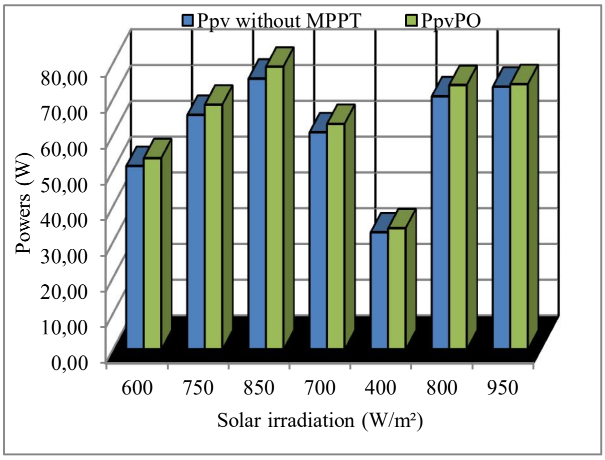
(a) Solar irradiance (b) Ambient temperature

Fig.6. Step profile of solar irradiation and ambient temperature

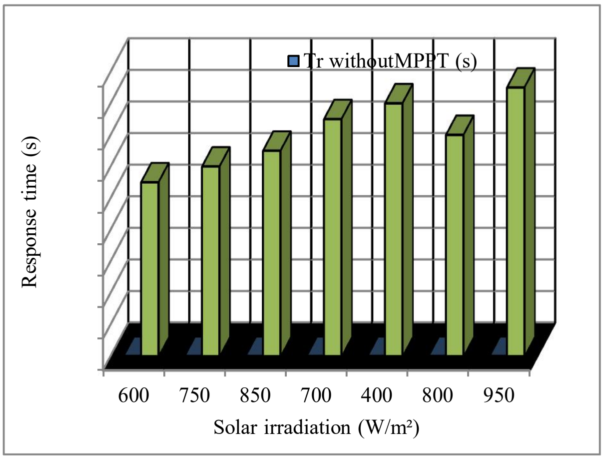
The efficiency can be calculated as:

$$\eta_{MPPT}(\%) = \frac{P_{opt}}{P_{pv}} x100 \quad (4)$$

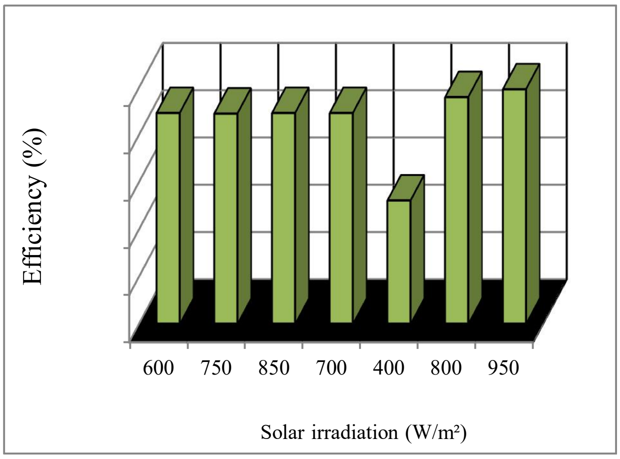
Regardless of the changing irradiance values, the IP&O approach shows a better power and efficiency compared to without MPPT (Fig.7).



(a) Photovoltaic power with and without MPPT



(b) Response time with MPPT



(b) MPPT efficiency

Fig.7. Performances of the IP&O algorithm

It is noticed in Fig. 7, when compared to the absence of MPPT method, the IP&O strategy increases power and efficiency.

4. Conclusion

The proposed MPPT strategy significantly enhances the performance of photovoltaic (PV) systems by ensuring optimal energy extraction, even under real-world conditions with varying irradiance levels. The proposed improved method reduces the tracking time, while improving the tracking efficiency. In addition, the proposed controller maintains stable output power with oscillations reduced, enhancing the overall energy yield under variable environmental conditions. The propose method presents a promising solution for future renewable energy applications due to its ability to dynamically adjust to environmental changes.

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Biography

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