

## Benefits of MPP tracking PV system using perturb and observe technique with boost converter

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### ABSTRACT

In recent decades, researchers have become interested in the photovoltaic (PV) system as one of the renewable energies. There are nonlinear I-V and P-V features in the PV generators. The greatest power generated varies with temperature and irradiation. To increase PV power, it is necessary to watch MPP carefully. In order to avoid some of shortcomings of conventional perturb & observe (P&O) MPP tracking approach and increase the transient responsiveness and decrease oscillations of steady-state terminal voltage, this study introduces a modified (P&O) MPPT algorithm employing fuzzy logic-based variable step size. An indoor simulated PV source built from a typical solar panel, DC power supplying, a DC-DC converter, in addition to P&O-based MPPT controlling unit was used to create and test the suggested MPPT algorithm. To demonstrate the P&O strategy's performance benefits under both constant and fluctuating irradiances and temperatures, their simulation under unsteady state circumstances is already performed with MATLAB/Simulink. Results of the simulations demonstrate that the photovoltaic simulation system can precisely monitor the highest power point. According to the simulation findings, efficiency is attained at 95% under typical test settings and at 96% when the weather is unpredictable and there are changes in temperature and irradiance.

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## 1. INTRODUCTION

Since PV solar energy considers among the most recent and most affordable solutions to satisfy the enormous energy demands of humanity in this century, there has been an increased focus on research into it in recent years [1]. PV solar energy seems to be expanding with an extraordinary rate. The extensive usage of fossil fuels has created environmental damage, which is why renewable energy is growing in popularity. The widespread use of fossil fuels contributes to possible economic instability, severe environmental problems, and greenhouse gases that cause climate change. The need for green energy supplied by utilizing renewable energy, along with hydroelectric energy, biomass, biofuel, geo-thermal energy, and energy of tidal, has surged as a result of all these environmental degradations [2], [3].

The need for renewable energy sources has grown as a result of current energy situation. Solar, wind, biomass, with further similar energy sources are widely regarded. It has been determined that the solar energy that the planet receives in a single day is enough for each of its energy requirements for an entire year [4]. Electricity from solar photovoltaic systems can be used for home or industrial uses. The biggest difficulty with this method is how little energy it can store and how intermittent it is.

Due to recent advancements in manufacturing technology and increased PV efficiency, the usage of PV panels has been steadily increasing. Many countries have recently installed a large number of PV modules into their electric grids. The use of PV systems has gained popularity because of their environmental credentials, well-established technology, free energy source, minimal maintenance needs, higher efficiency, a costs reduction, electric power generation Unlike other renewable sources, it has a finite lifetime and really no moving parts that considered popular method of generating electricity [5]. PV solar panels may instantly transform solar energy systems' stored energy into electricity thanks to the photovoltaic effect. But the cost of electricity generated is relatively expensive and the conversion efficiency is poor. Numerous benefits come with PV generating, including cheap fuel costs, little pollution, minimal maintenance requirements, and a variety of additional qualities [6].

To extract the most power possible to the PVG terminals, an MPPT controller is required since PV system output characteristics are not linear and vary with temperature and irradiance. As a result, the PV works are maintained at their MPPT using MPPT approaches. The indoor simulating PV source made of a typical solar panel, a DC power supply, a DC-DC converter, and then a P&O-based MPPT control system was used to design and test the proposed MPPT algorithm as shown in Figure 1. To make the most of the PV module's power, several MPPT techniques had been planned within literatures. Both traditional approaches, such as open-loop control, perturb and observe (P&O), and incremental conductance (InC) [7], and intelligent control methods, such as fuzzy and neural, may be used to categorize these techniques. The efficiency, tracking speed, need for a sensor, complexity, and cost of these approaches vary [8]. By continually adjusting by using the DC-DC converter's duty cycle as control factors, the control of intelligent fuzzy MPPT has examined then associated with a traditional (P&O) and (InC) MPPT techniques in this study in relation to the system's transient in addition to steady responding.

PV applications may be split into two categories: grid-connected and standalone energy systems. For low power applications, stand-alone energy schemes can use batteries system for the PV energy's storing. Additionally, battery banks are not necessary for grid-connected PV energy systems since they were often re-established in high-power presentations [9]. A photovoltaic (PV) device considers as power system created to provide usable electricity using solar cells. The principal purpose of this research focuses on constructing and simulating PV system utilizing MPPT technique depending on the P&O approach with DC-DC converter intended for separating PV system enable to charge a battery, therefore offer great reliability with varying atmospheric conditions. Additional goals include developing limited-cost, high performance MPPT controlling and evaluating the effectiveness of conventional (P&O) technology.

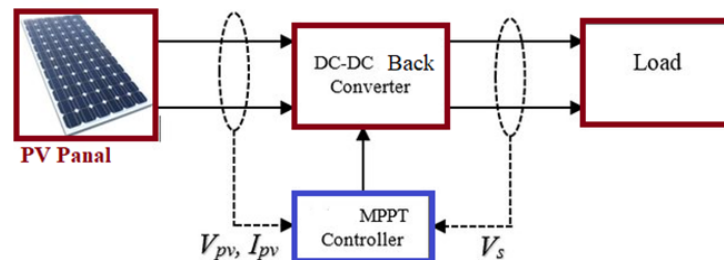


Figure 1. PV system graphic diagram

## 2. MATERIAL AND METHOD

### 2.1. PV modeling system

There are various types of models, including as the single-diode model, double-diode model, three-diode model, and many other, that have been described in various literatures during the last few years to illustrate the nonlinear properties of the PV system. Due to their simplicity of implementation, the single-diode model as well as double-diode model consider the greatest often used classic. Additionally, they provide the parameters of solar PV cells according to the manufacturer's datasheet with the least amount of mistake [10]. The dominant equations for a solar cell have been determined from the circuit in Figure 2.

$$I = I_L - I_d - I_{SH} \quad (1)$$

Here, the photocurrent ( $I_L$ ) is the current produced from sunlight and applied on the photovoltaic cell.  $I_d$  is the current through the diode, while  $I_{SH}$  is the current flowing across the shunt resistance.

Therefore, the PV Cell structural characteristics as well as the temperature will determine the current created by solar energy forced on the PV Cell. If a short circuit current is  $I_{SC}$  related to PV cell on test method conditions ( $S = 1000 \text{ W/m}^2$ ,  $T = 25^\circ \text{C}$ ).

$$I_L = \left( \frac{I_{SC} * S}{1000} \right) + \{ (T - T_r) K_i \} \quad (2)$$

Where, a temperature coefficient is  $K_i$  for  $I_{SH}$  and reference temperature is  $T_r$ , an ambient temperature is  $T$ . So, the PV currents could have written by way of, In Table 1 represent the PV characteristics.

$$I = I_{ph} - I_o \left[ \exp \left[ \frac{q(V + IR_s)}{nKT} \right] - 1 \right] - \frac{(V + IR_s)}{R_p} \quad (3)$$

The reverse saturation current  $I_{rs}$  can be determined related to reference temp. with setting the conditions of ( $T = T_{ref}$  and  $I = 0$ ,  $V = V_{oc}$ ) to get

$$I_{or} = I_{scr} / \left[ \exp(qV_{ocr}/(nKT_r)) - 1 \right] \quad (4)$$

Therefore,  $I_{rs}$  at a given temp. is

$$I_o = I_{or} (T/T_r)^3 \exp(qE_g/(K_n)(1/T_r - 1/T)) \quad (5)$$

$I_{sc}$ , a current with short circuit is expressed with an irradiation ( $G$ ) and panel temp. ( $T$ ) as,

$$I_{sc} = G/G_0 (I_{scr} + \alpha(T - T_r)) \quad (6)$$

Here,  $\alpha$  is the coefficient of current temp. at short circuit.

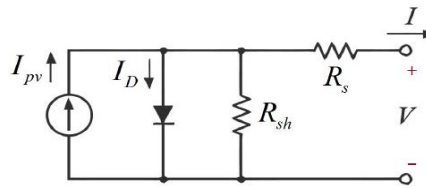


Figure 2. Photovoltaic cell equivalent circuit [9]

Table 1. PV module parameters

Parameters	Value
Max. Power	160 W
Voltage at Max. P	350 V
Current at Max. P	4.5 A
Short- cct I	4.75 A
Open -cct V	45 V
Cur- tem. Co. of $I_{sc}$	$(0.065 \pm 0.01)\% / \text{K}$
Cur- tem. Co. of $V_{oc}$	$-(160 \pm 10) \text{ mV/K}$

## 2.2. MPPT technique

The A key component of a PV converter is MPPT, which makes sure the converter gets the most power possible from the PV module. The output voltage and current of a solar PV display its electrical properties as a function of changing solar irradiation. The maximum power point is reached when the PV source terminal voltage is effectively controlled to maintain a rate that causes PV output of  $V$  &  $I$  to reach its maximum value (MPP). Both open & short circuit currents restrictions are at this point, which concerning the PV diode's "knee" of the regular I-V curve [11].

In general, PV solar systems employ the (MPPT) approach to extract the most electricity possible regardless of the ambient factors. Depending on the application and weather circumstances, to fulfil the MPP, various MPPT algorithms were created for usage in PV systems [12]. These algorithms range from basic to more sophisticated. The MPPT's primary duty is to maximize output power under a variety of radiation and temperature conditions from the PV module. To date, a variety of MPPT algorithms were created in the

literature to fulfil the ideal MPPT and boost PV system efficiency. The hardware needed for development and application, tracking speed, and other factors vary across these algorithms. In general, (P&O), fraction open-circuit voltage (FOCV), fraction short-circuit current (FSCC), INC, ANN, fuzzy logic (FL), in addition to (PSO) are the most well-known MPPT techniques [13], [14].

PV maximum output power fluctuates as a result of environmental factors including irradiance. Thus, MPPT is necessary for PV converters to control the voltage or current of the connected PV module in order to extract the greatest amount of power from it. Perturb and observe (P&O)-based MPPT methods are among the most widely used MPPT strategies. Various MPPT algorithms have been explored in [15]. Despite the fact that P&O is frequently used to measure MPP, this approach is mostly used to track single maximum power points since they are unable to detect global maximum power points (GMPP) once PV panels remain partially shaded, which causes many local maximum power points (LMPP). Furthermore, a generic algorithm (GA) through P&O built within GA's structure was developed in [16] to overcome this constraint by scanning the PV panel properties into nonlinear fashion. This single algorithm can then track numerous LMPP. To overcome the drawbacks of many local maximum power points, a GMPPT tracking controller strategy which combines the typical (P&O) algorithm along with Firework Algorithm (FWA) had correspondingly suggested in [17].

P&O changes the duty cycle by increasing or decreasing it with a tiny  $\Delta D$  step-size, and then they monitor how the PV power ( $\Delta P$ ) changes as a consequence. When  $\Delta P > 0$ , an operating point could move nearer to MPP, causing the duty cycle to be further disturbed in that way. If  $\Delta P < 0$ , the operating point has moved in the opposite direction. When the MPP is found, this procedure is stopped. The method significantly lowers PV efficiency while oscillating the operational point near MPP.  $\Delta D$  must be carefully tuned since reducing  $\Delta D$  step size reduces oscillation but delays the dynamic response. P&O quickly reaches MPP with large step sizes, however the amplitude of oscillations around MPP is unbearable. Corresponding to this, when the step size is low, the amplitude of oscillations is reduced but MPP is not achieved in an efficient manner. Generally, using a step size of 10% of the PV system's open circuit voltage is preferable. Figure 3 explains how altering the step-size affects the tracking response [18].

Numerous ways have also been described for in what way for enhancing dynamic characteristics of traditional P&O MPPT strategies, including the strategy that focuses on optimizing the sample interval amount in accordance with the dynamics of the converters [19]. Additionally, to address the drawbacks of the traditional P&O MPPT approaches, a variable step size-based method was presented in [20] that automatically switched stages of the PV array's operational points that changed as the sun's radiation did.

### 2.3. DC-DC boost converter

With a view for tracking the MPP, the PV generator output must include a DC-DC converter to maintain the output voltage of the solar panels at the necessary level. The devices utilized in many industrial applications are power converters. The buck power converter, boost, besides buck-boost are the three topologies that are most widely used. Depending on how the devices are connected to one another, these topologies have different characteristics.

The DC-DC converter switching mode is an MPPT's core. It is often utilized to optimize power transmission towards the load by the PV panels via regulating the PV unit functioning voltage corresponding to MPP voltage ( $V_{mp}$ ) and matching between load impedances and an PV optimum impedance ( $R_{opt}$ ). In this work, the MPPT is equipped with a boost converter. By presuming an idealized (loss-less) converter, the PV module supplies power on average. supplying ( $P_{in}$ ) must match the average power utilized with the load ( $P_{out}$ ) [21], [22].

The boost converter architecture is utilized because it amplifies the output voltage of the PV array effectively, has a free-wheeling diode that may be utilized to stop reverse current, so it can be controlling via a pulse width modulation (PWM) switching. Without using a transformer, the boost power converter architecture increases the input voltage to the needed output voltage [23], [24]. According to Figure 4, the fundamental parts of a boost converter including inductors, diodes, capacitors, besides high-frequency switching.

The input-output voltage equation is explicable by:

$$P_{in} = P_{out} \text{ therefore, } V I = V_L I_L \quad (7)$$

$$V_L / V = D / 1 - D \text{ \& } I / I_L = D / 1 - D \quad (8)$$

Where, the load voltage and current are  $V_L$  and  $I_L$ .  $D$  is a converter duty cycle [25]. An expression of the duty cycle and voltage relationship is, (If  $D$  more than 0.5 and less than one then converter output voltage is greater than the input voltage) for Boost converter.

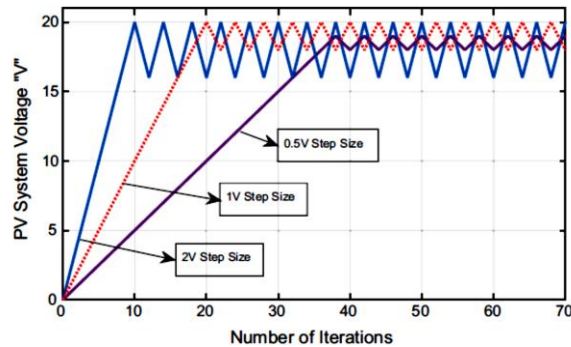


Figure 3. MPPT Responses with P&O at several step sizes [18]

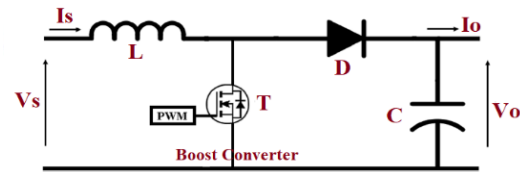


Figure 4. Simple boost converter layout circuit

### 3. P&O MPPT ALGORITHMS

MPPT techniques are essential since they can boost a PV model's effectiveness. One of the most significant MPPT approaches are (P&O) besides other like INC and FL control. The level of detail, complexity, acceptability, quick congregating, technical qualifications, and effectiveness of each of the aforementioned has a varied range [25].

The hill climbing method, normally identified as a Perturbation and Observation algorithm, considers among the most widely used strategies because it is so simple and clear and a most used algorithm for monitoring the maximum power point [26]. The P&O MPPT approach worked by repeatedly changing a control parameter by a little amount until it reached the maximum power point, perturbing the PV array terminal voltage. A little perturbation is introduced after the power has been measured, and after that, the new power is measured. If the result is positive, the control system will continue to perturb in the same direction. The control system will change the operating point in the other direction once the new power reading is negative [27]– [28].

The graph's MPP point has a slope of zero, a positive result represents the increased power region on the left form, and a negative slope to the right MPP point's part denotes the decreased power region. Accordingly, the procedure will have oscillated and repeated till the MPP is reached or attained. In order to decrease oscillation, the size of the turbulence step is decreased; nevertheless, this could be slowing down the manner of reaching MPP [29]. Figure 5 shows the P&O algorithms.

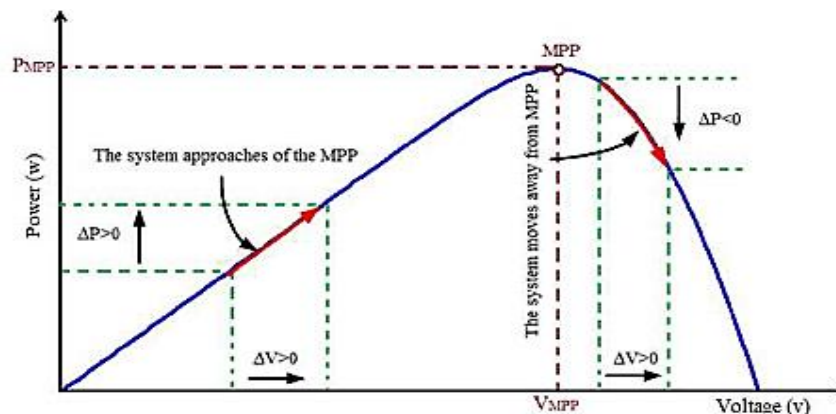


Figure 5. A P-V advantage curve with (P&O)

The fundamental disadvantages of this approach are that during steady state operation, the obtaining power oscillated about a maximum power point, which means it may track incorrectly under rapidly varying environmental conditions [30]. Additionally, the step size controls both the assembly speed to the MPP in addition to oscillated range about the MPP during steady state operation [31].

### 4. SIMULATION RESULTS

In this article, a starting by simulating the photovoltaic system and evaluating it using the simulation tool from MATLAB/Simulink. The study of MPPT (P&O) approaches. It is emulated using a variety of

different weather conditions and regular environmental settings. The PV model system constructed is shown in Figure 6. Sets of solar panels make up the 810-watt photovoltaic array connecting in series and parallel. A boost converter is used to reduce the high DC voltage produced by the solar cells for lesser DC voltage (48 V), which is then sent to the battery. The MPPT algorithm will run in two cases:

- i) Performances under standard testing scenarios: Irradiance and temperature are remained constant during this test. It uses the values of the standard circumstances, which are  $T = 25^{\circ}\text{C}$  and  $I = 1000\text{ W/m}^2$ . These simulations are meant to show how the operation point differs from the MPP point.
- ii) Performances when temperature and irradiance are not constant: The MPPT will execute with the following tests to evaluate their response times. First, a constant temperature and fluctuating irradiance. Then a variable temperature and a constant irradiance of  $1000\text{ W/m}^2$ . Irradiance and temperature are expressed numerically as  $1000\text{ W/m}^2$  and  $25^{\circ}\text{C}$  under standard test conditions (STC). The capacity of a PV panel to deliver precise parameters is offered by the panel designers at STC. The MPPT controller must ensure MPP voltage within a reasonable amount of time because a PV system is first.
  - Case1: Standard test condition. In this instance, at  $\text{Temp} = 25^{\circ}\text{C}$  and solar radiation near  $1000\text{ W/m}^2$  are used to evaluate the P&O approach. Figure 7 shows the depicts the voltage, current, and power results obtained from the solar cells in addition to the results delivered towards a duty cycle battery that can be considered as an output of the DC-DC converter in Figure 8 with a simulation time of one second.

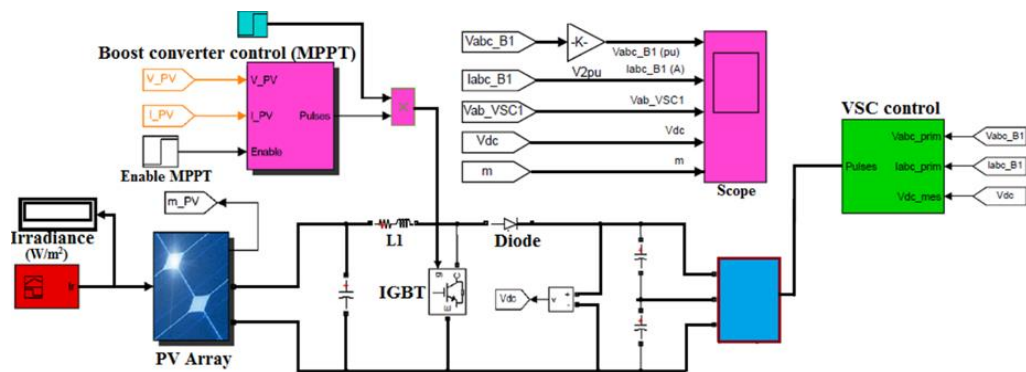


Figure 6. Simulation of P&O for MPPT

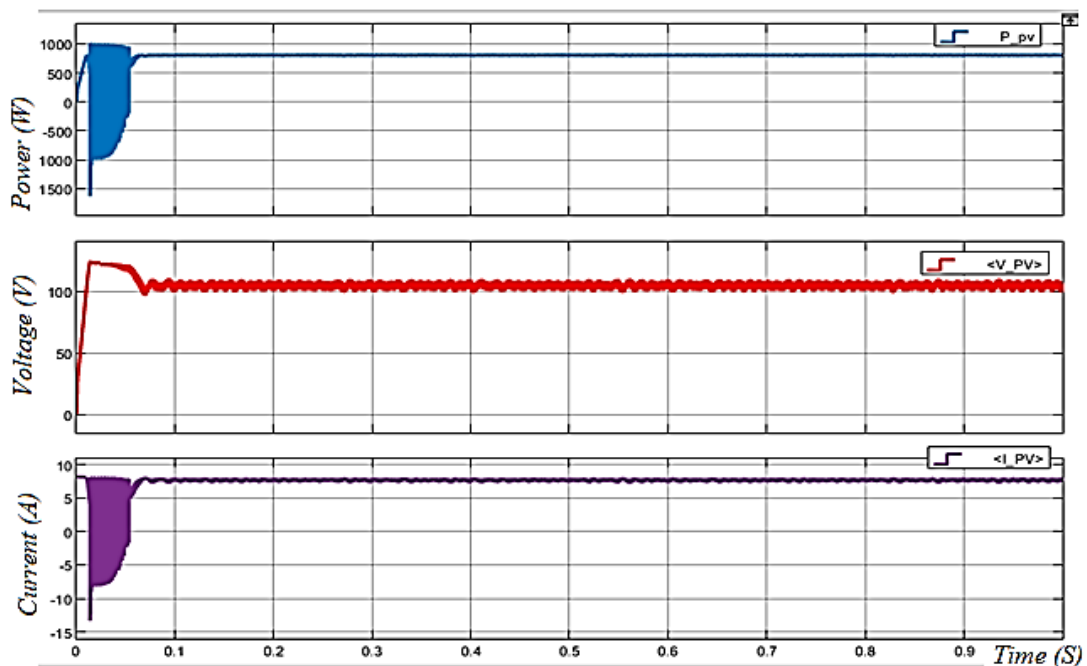


Figure 7. O/P PV module (P&O algorithm) with test condition



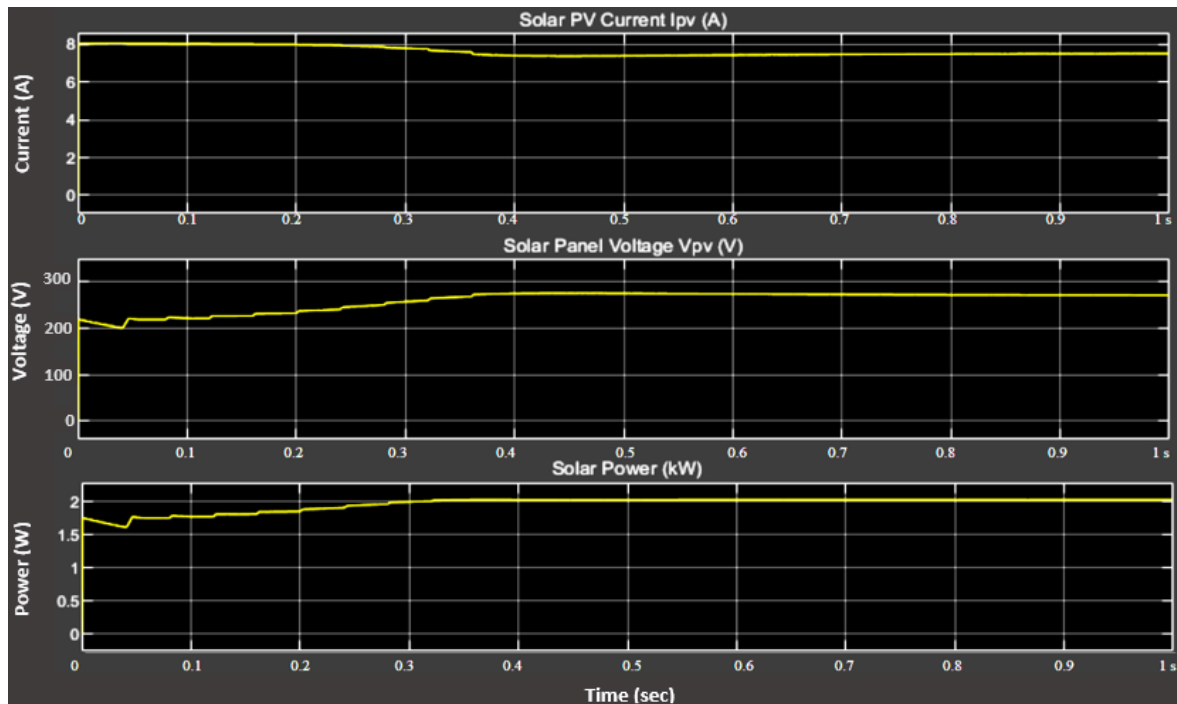


Figure 8. Solar PV system with MPPT using boost converter

- Scenario 2: A solar radiation of 1000, 800, and 600 W/m<sup>2</sup> is simulated, with constant temperature of 25 °C. Here, solar irradiance was variable and a constant temperature. Figure 9 demonstrate the variable Irradiance (1000, 800, and 600 W/m<sup>2</sup>) applied, while Figure 10 explain the PV output system (voltage, current, power) with a simulation time of 1 second. Now, PV array is under rapid deviation of temperature (from 35 to 45 and then 55) in time of 1 second, Figure 11 show the temperature variation and the PV output (Voltage, current, and power) at Figure 12

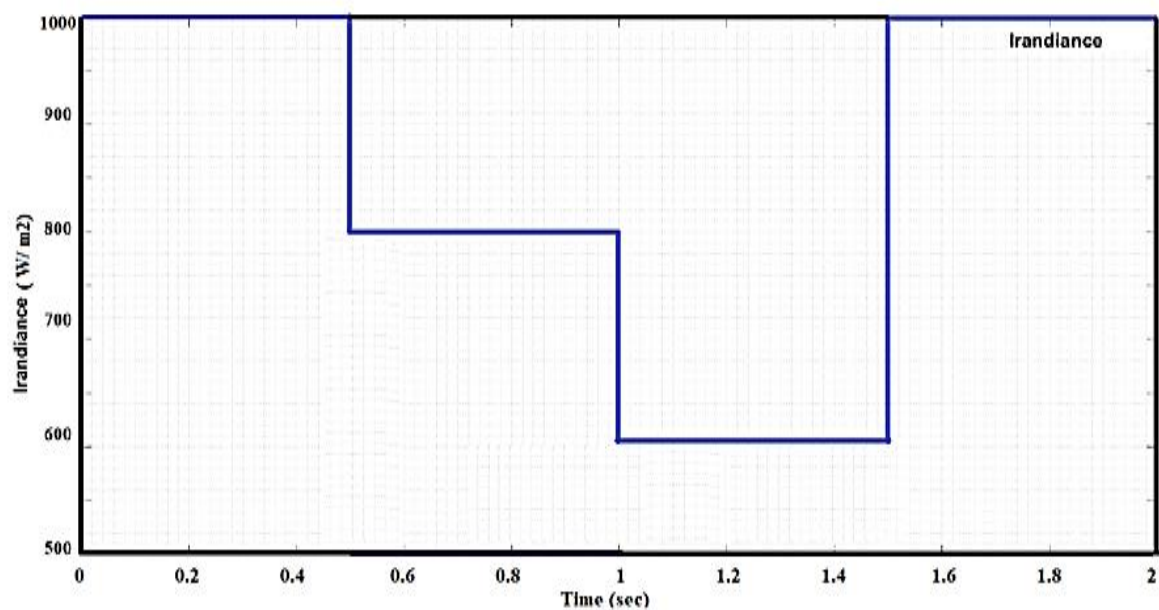


Figure 9. Variable irradiance (1000, 800, and 600 W/m<sup>2</sup>)

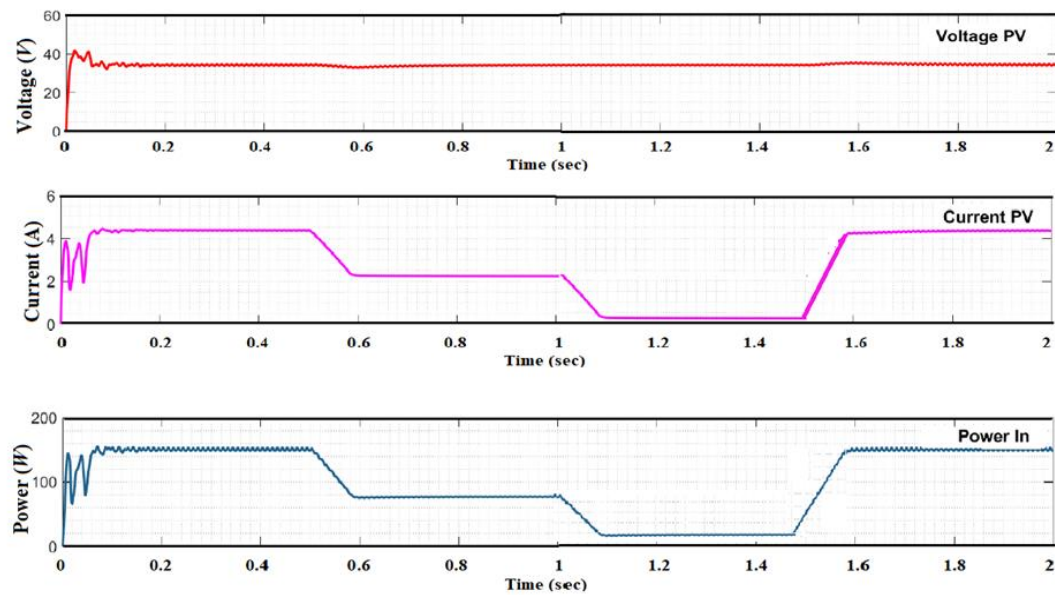


Figure 10. PV output module (P&amp;O algorithm) with irradiation variable

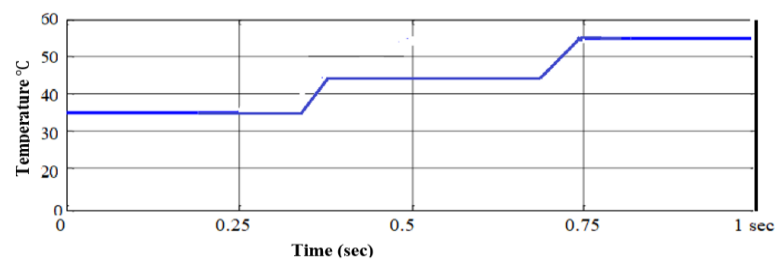


Figure 11. Temperature is varied from 35 to 55

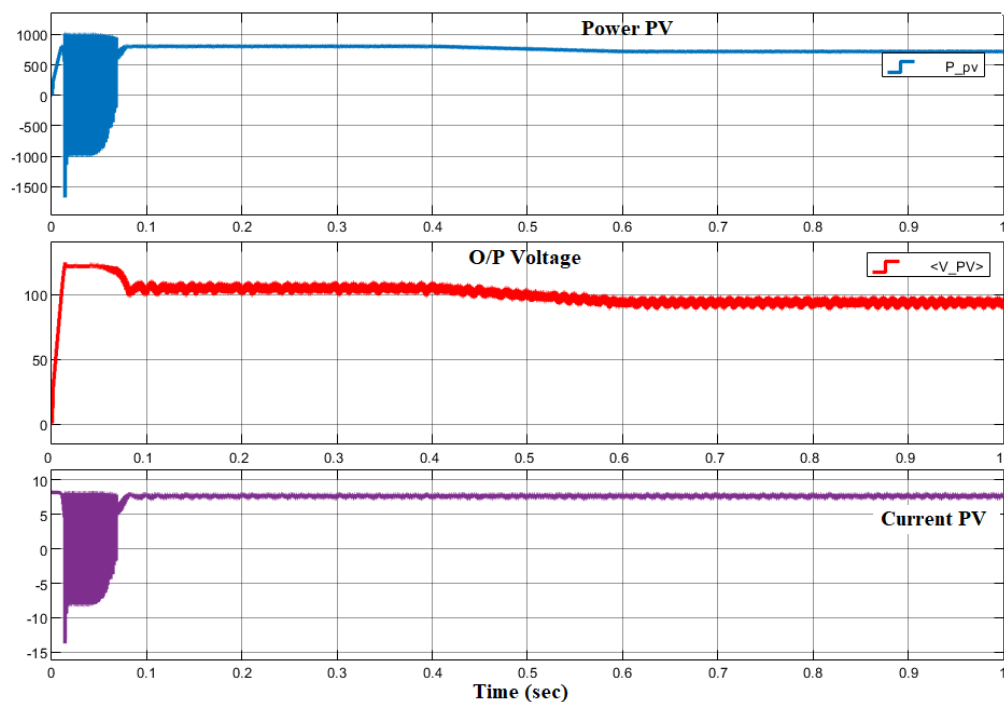


Figure 12. Output photovoltaic module (P&amp;O algorithm) with Temp. variable



## 5. CONCLUSION

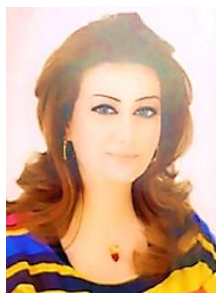
The MPPT controllers are frequently employed to guarantee the best possible performance of a photovoltaic system. The MPP and minimizing any error happened with the operating power and maximum power are two goals that are pursued by many controllers. The most power is available when using an MPPT system with a single system. A DC-DC power converter was used in the development of the suggested MPPT-based system. When compared to the conventional P&O scheme, the suggested MPPT technique significantly monitors the power locus in all weather. In tests with dynamic irradiance and actual environmental conditions, the suggested plan perfectly collects maximum power. The main benefits of the suggested schemes are that they accurately adapt to changes in temperature and irradiance on the panel surface and transmit the greatest amount of power from source to load. Quickly achieves MPP in every situation and is easy to deploy. With boost converter topology, perturb and observe (P&O) is used to perform MPPT algorithms. The performance of the PV side with time and irradiance fluctuation is demonstrated by the simulation results with MATLAB/Simulink. The voltage never reaches a precise value but oscillates round the MPP, and the P&O system follows rapidly varying irradiation circumstances more effectively.




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