P&O Algorithm-Based Maximum Powerpoint Tracking Under Uniform Irradiance and Partially Shaded Conditions

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Abstract- In recent years, solar energy has become increasingly popular and receiving a lot of attention from several research. The effectiveness of Photovoltaic (PV) arrays is affected by the output power of these systems, which is dependent on temperature and solar radiation. Though, in order to excerpt the greatest power feasible from a Photovoltaic arrays, Maximum Power Point Tracking (MPPT) control method is applied. The MPPT controller attempts to gather the most energy even in conditions of partial shading. MPPT algorithms are not effective on Partial Shading Conditions (PSC), where complex algorithms are effective but need high computational resources and practice. To enhance the efficacy and economy of Photovoltaic systems, perturb and observe (P&O) algorithm based MPPT approach is proposed in this paper, which tracks the MPP even in PSC. With the P&O MPPT approach, solar Photovoltaic is utilized properly in a variety of operating conditions and a constant power supply is provided to the consumer uninterruptedly. As a result, the control system structure of the suggested method is simpler and more constant, which is simulated by the MATLAB software.

Keywords: Photovoltaic array, MPPT, Partially Shading Conditions, P&O algorithm.

I. INTRODUCTION

Over the last few decades, the world has increasingly moved away from fossil fuels for a variety of reasons. The use of fossil fuels for energy generation is causing carbon emissions to rise further, which is changing the atmosphere. Therefore, solar energy, as well as other renewable energy sources, will be a significant component of future energy supplies [1-2]. Solar energy, which is obtained by transforming sunlight into electrical power through a photovoltaic device, is one of the most well-known renewable energy sources [3]. In recent decades, solar power generation has gained recognition as a promising method for generating electricity. As a result, several countries now use PV-based energy as their major or backup source of electricity [4]. Commercial PV modules still have a low conversion efficiency, thus it is especially essential to get as much energy as possible for a usable PV power system [5]. The use of this kind of power source raises various problems that need to be resolved in order to produce a workable system for the generation of electricity. Since the electricity generated by solar panels is highly dependent on environmental factors like radiation and temperature, one of the problems is connected to its intermittent nature [6]. The common goal is to sustain the Photovoltaic module at its maximum power operation to maximise the effectiveness of the photovoltaic system. As a result, MPPT approach is crucial to controlling these issues and verifying that the Photovoltaic system is operating at the MPP [7]. Several traditional and soft computing MPP tracking methods exist, however due to the presence of multiple peaks in the P-V features, it is impossible to assess the efficacy of each MPPT method for tracking the GMPP in shaded situations [8]. Several MPPT computations are suggested to compensate for the low transformation productivity by providing robotized control over power points of interaction and achieving optimal power efficacy [10]. The MPP can also be successfully tracked using the artificial neural network (ANN) technique, although with small overshoots. But, if something problem occurs, it will take a while to get back to detecting the PV reference voltage effectively [11]. A distributed MPPT (DMPPT) algorithm be used to compensate for the energy loss brought on by PSCs. This method is appropriate for using more converters, this will raise the cost of the entire system [12]. Overall, standard fixed perturbation-size MPP tracking algorithms oscillate about the MPP as a result of their limited step size, which has an impact on the PV power production under steady-state and dynamic operating situations [13]. Conventional incremental conductance (INC) approaches can track a single peak Nevertheless, under non-uniform irradiation conditions and significant irradiance variations, these approaches perform badly [14]. A Photovoltaic system therefore requires to be able to function at its MPP in regardless of local atmospheric factors. Which is necessary to overcome the drawback [15].

In this proposed work, P&O based MPPT technique is suggested to track the MPP for a Photovoltaic module under a rapidly varying solar irradiation level and it provided a constant power supply to the consumer successively. As a result, this paper demonstrates that the proposed algorithm enhances the stability of the system and avoids error when the irradiance changes and it is simulated by the MATLAB software.

II. PROPOSED METHODOLOGY

The continual optimization of Photovoltaic system mathematics as well as the control model is currently the main development direction for the MPPT technique. There is no requirement to modify other settings because converter duty cycle can be controlled directly. This provides strong control performance during the external environment is constant and minimizes the MPPT control structure. In addition to the currently used module building method, the MPPT control system, when combined with an improved control algorithm, produce tracking effects which are more precise, quicker, and more stable.

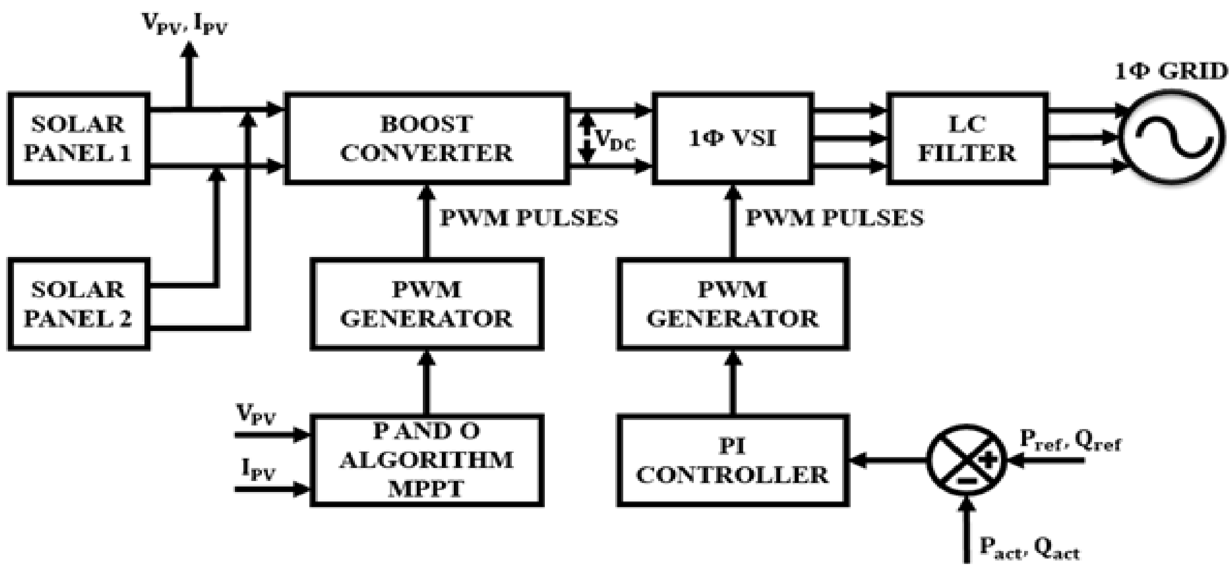

Figure: 1 Block diagram of the proposed method

A) PV SYSTEM

The Photovoltaic system is employed for power conversion which involves multiple series and parallel combinations of Photovoltaic modules, the power converters, such as inverters and DC-DC converters, and the tracking controller. As a result, a DC-DC utilized to boost the DC voltage output and an inverter is employed to transfer the DC voltage to AC. The load rating impacts the selection of photovoltaic panel.

Figure 2 depicts the electrical equivalent diode model of a photovoltaic cell.

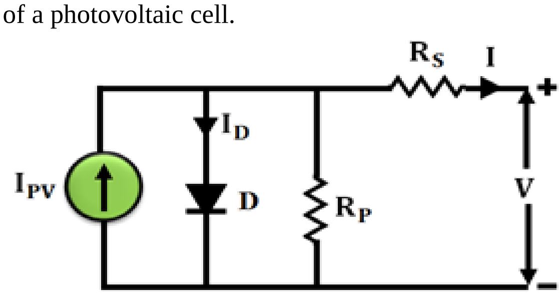

Figure: 2 Equivalent circuit of PV cell

The components of the Photovoltaic module are the current sources, diode Shunt resistance $R_{sh}$and series resistance R_s. Shunt Resistance R_{sh} is a representation of the edges' cell surface leakage.

The entire current I is the difference between the current produced by light I_{ph}, diode current Id and current through R_{sh}.

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Equations (2) and (3) give the values of the Diode current I_d and Shunt Resistance current I_{sh}

$$I_d = I_0 \left\{\exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1\right\} \quad (2)$$

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \quad (3)$$

$$I = I_G - I_0 \left\{exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1\right\} - \frac{V + IR_s}{R_{sh}} \quad (4)$$

B) BOOST CONVERTER

This method focus on the step-up chopper or boost converter Choppers is termed as another name for DC-DC converter, which enhances the input DC voltage to a determined DC output value. . The solid state switch operating method is connected across the source. Diodes are used as the second switch as illustrated in Figure 3, the diode is linked to a capacitor as well as the loads are connected in parallel.

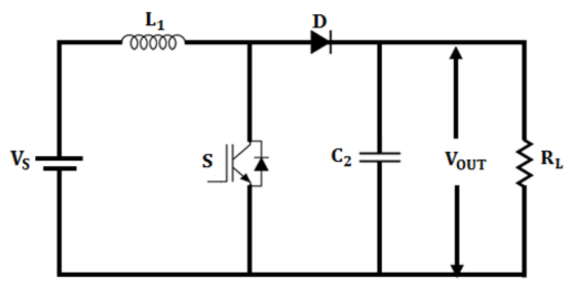

Figure 3 BOOST converter

There are 2 methods which the Boost converter operate. The switch is conducting in the first mode when it's turned on.

$$f=1/T \quad (5)$$

Let us express a different term, the duty cycle,

$$D = \frac{T_{ON}}{T} \quad (6)$$

Using KVL, let's evaluate the Boost converter in steady state operation for this mode.

$V_{in} = V_L$

The BOOST converter's duty cycle is determined by,

$$D = \frac{V_{in}}{V_{out}} \quad (7)$$

Where V_i- input voltage, V_o- output voltage, V_D- diode voltage

$$D = \frac{V_o}{V_o - V_{in}} \quad (8)$$

The values of inductance are given by,

$$L = \frac{Vs*D}{fsw*\Delta Io} \quad (9)$$

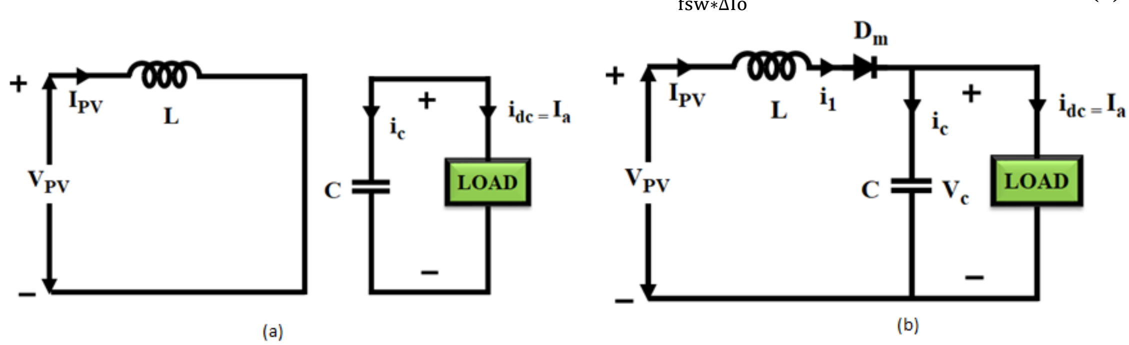

Figure: 4 (a) ON condition (b) OFF condition

C) P&O ALGORITHM

The duty ratio of the converter and the reference voltage are two commonly employed techniques when using the P&O approach. The latter technique uses a PI controller to change the PV module's output voltage, which allows MPP to function under standard test settings. To obtain the greatest output power from a Photovoltaic module, the DC-DC converter duty ratio is increased in the previous technique. Also, it is difficult to operate the component at its highest output energy due to fluctuating atmospheric conditions. Figure 5 represents the flowchart of this approach.

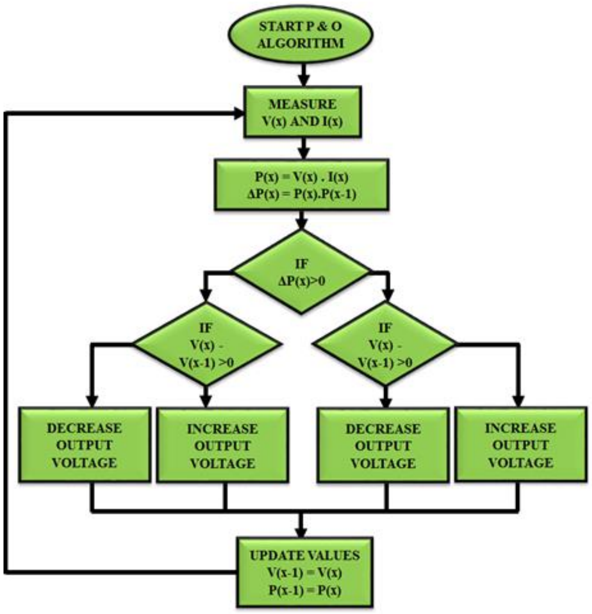

Figure 5 Flow Chart of P & O Algorithm

The majority of methods which use perturbation approaches to deliver data related to the derivatives involve speed restrictions due to the average current, voltage and power. Many analyses have demonstrated that MPP is pursued using a conventional P&O system with few tens of milliseconds or more. While the MPP being observed, PV module's functioning point continues to fluctuate as a result of the MPPT's continuous usage of perturbations.

P&O algorithms suggest that uncertainty is based on by changes in output power. Any fluctuation from the MPP is occur if the perturbation direction responsible for increasing the output power is maintained, because they are not dependent on measured values to detect predicted fluctuations in climatic conditions. Since, quick tracking cycles assist in reducing the loss of power and duration.

D) PI CONTROLLER

Polarization Index Controllers have been used to regulate basically every process presently in use, from motion control to aerospace and from slow to fast systems. Since, there is still significant research being done on the issue of tuning PI-controllers. Moreover, PI-Controllers require to be retrieved on a regular basis because of swings in operating points as well as changes in system dynamics. Loosely defined, adaptive PI controllers provide the optimum Polarization Index controller settings routinely as the system dynamics or functioning points varies.

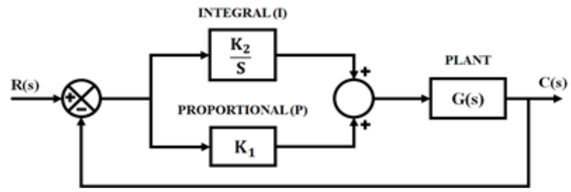

Figure: 6 Basic block of PI Controller

The PI controller decreases maximum error and enhances damping. Moreover, it reduces bandwidth while enhancing rising time. In the case of noisy data, the inclusion of derivative action may increase the system's stability in the steady state. This is because the inputs' high frequency terms have a greater impact on the derivative behavior. In the exclusion of derivative action, the PI controlled system becomes less responsive to actual.

E) PWM GENERATOR

The switch within the BOOST converter is used to produce and transmit the pulse width modulated signal. Basically, a PWM generator separates the average power reduction into discrete components. The average voltage and current values which are delivered to the load side when the switch ON for longer time than OFF time. Longer ON times will therefore result in the supply of more power. The PWM generator's main objective is to generate pulse width modulated gate pulse signals, which are subsequently transmitted to the switch within the Boost converter.

F) LC FILTER

First, the maximum ac current ripple needs to be defined before designing the LC filter, a phase current of 5% at rated power is used to select the inductance on the inverter side. The basic constituent of grid current is considered to be zero depending on this rule. The voltage of the filter's inductor have zero as its basic component. The voltage across the inductor is therefore described as:

$$V_L = V_{inl} - V_g \quad (10)$$

The switching frequency,f_s which is greater than the grid frequency,F_N defines the phase voltage. As a result, it is possible to define the time average value of the inverter output voltage V_{av} as stable during the switching period T_s. The filter inductor current's peak to peak value in this instance. When utilising PWM switching

$$\Delta I_{pp} = 2I_{rpm} = \frac{\frac{V_{dc}}{2} - V_{av}}{L_f} \cdot \frac{d_1}{f_s} \quad (11)$$

Where I_{pp} and I_{rpm} represent for the highest and peak values of the current ripple in the filter inductor, correspondingly. The filter inductance value is L, and the duty cycle is d_1. During the interval of 0< ωt< π,

$$V_{av}(\omega t) = d_1(\omega t)\frac{V_{dc}}{2} \quad (12)$$

$$d_1(\omega t) = m_a \sin(\omega t) \quad (13)$$

Where, m_a stands for modulation index. Thus, the following formula can be used to define the maximum inductor current ripple:

$$I_{rpm} = \frac{V_{dc}}{4L_f f_s}[1 - d_1(\omega t)]\, d_1(\omega t) \quad (14)$$

$$= \frac{V_{dc}}{4L_f f_s}[1 - m_a \sin(\omega t)]\, m_a \sin(\omega t) \quad (15)$$

Assuming $m_a = 1$, the maximum value of I_{rpm} is ¼ at π/ 6, 5π /6.

$$L_f = \frac{V_{dc}}{16.f_s.\Delta I_{ph(max)}} \quad (16)$$

Hence, the value of an inverter side inductor is selected on the basis on switching frequency. It is proposed that the grid's high power factor change be set at 5% when selecting the filter capacitance. The base value for the entire system impedance,Z_B is derived from the capacitance fluctuation as follows:

$$Z_B = \frac{v_G^2}{P_{Av./3}} \quad (17)$$

$$C_B = \frac{1}{\omega_{N}.Z_B} = \frac{1}{2\pi f_{N}.Z_B} \quad (18)$$

$$C_{max} = 0.05.\, C_B \quad (19)$$

Where P_{AV} is the rated active power, v_G is a line to line r_{ms} voltage, ω is a grid frequency. When utilizing values higher than 5%, the system's power factor will be lesser than initially anticipated. So, if extremely large capacitors are chosen, the inductor current ripple will be boosted.

$$f_N \leq f_{res} \leq \frac{f_s}{2} \quad (20)$$

Where, f_{res} is defined as the resonance frequency:

$$f_{res} = \frac{1}{2\pi\sqrt{L_f C_f}} \quad (21)$$

It is obvious that the switching frequency chosen to be much higher than the LC filter's resonant frequency.

III. RESULTS AND DISCUSSION

The P&O MPPT approach is utilized to maintain a steady power supply while tracking the MPP for a Photovoltaic module under rapidly varying solar irradiation levels. As a result, the suggested algorithm's control system structure is simpler and more reliable and it can detect and respond to MP with accuracy. The proposed method is simulated by the MATLAB/Simulink and the resulting output is illustrated in below tables.

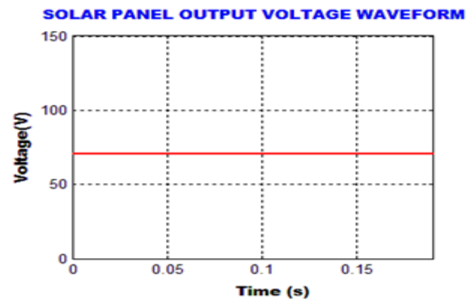

Figure: 7 Solar Panel Output Voltage Waveform

Figure 7 indicates the waveform for PV panel voltage and it represents a constant DC voltage. Generally it remains constant during the presence of sufficient irradiance from sunlight. A stabilized voltage of 70V is sustained throughout the system.

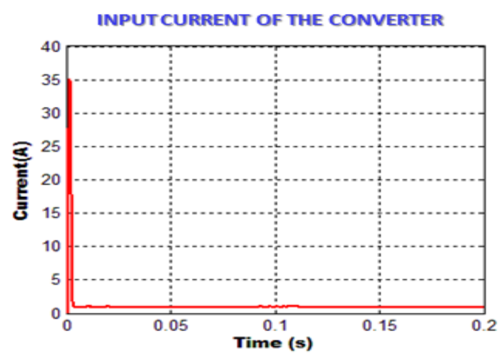

Figure: 8 Input Current of the Converter

The waveform illustration of converter input current is illustrated in Figure 8. It is observed that, with initial current of 35A, a stabilized current of 2A is achieved after 0.15s and further maintained stable.

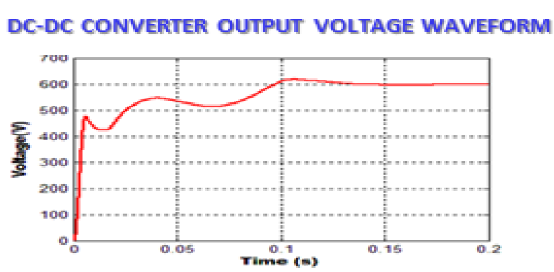

Figure: 9 DC-DC Converter Output Voltage Waveform

Figure 9 represents the output voltage attained by using the proposed converter. It is observed that, with fluctuation at initial stage a stable voltage of 600V is attained after 0.15s.

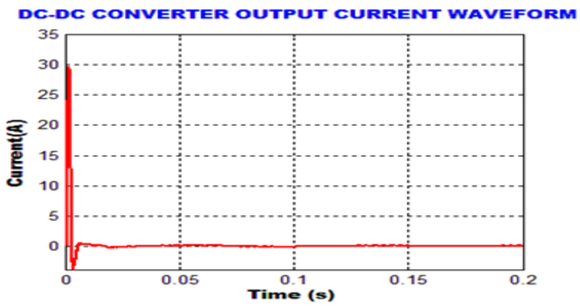

Figure 10: DC-DC Converter output current waveform

The waveform representation of converter output current is illustrated in Figure 10. It is observed that a peak current of 29A is attained at its initial stage. After 0.05s, a stabilized Current of 0.1A is sustained throughout the system.

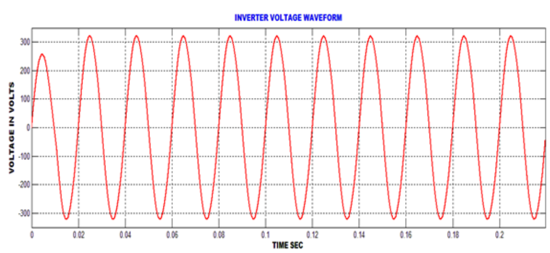

Figure 11: Single phase voltage source inverter output waveform

The Figure 11 shows the single phase bidirectional grid connected inverter output voltage waveform. The Polarization Index controller based grid synchronization achieves reactive power compensation.

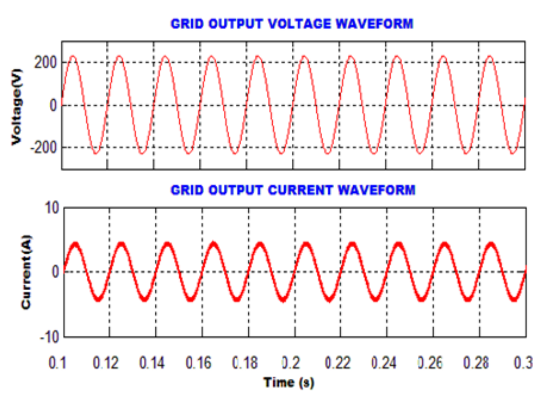

Figure 12: Single phase grid output waveform

The Figure 12 shows the single phase grid voltage and current waveform. For the synchronization of Photovoltaic inverter with the grid a single phase PLL controller is obtained. The performance of suggested PLL controller is validated under changing frequency conditions.

IV. CONCLUSION

The MPP for a Photovoltaic panel is tracked using a P&O-based MPPT algorithm under rapidly changing solar irradiation levels. Modifications are suggested to minimize the erroneous response caused by the traditional algorithm's confusion. The control system structure of the suggested method is simpler and more constant than the existing research status, and it can properly respond to and track MPP. This enhances the system's stability and prevents errors when the irradiance varies. The structure of the suggested algorithm is identical to that of the existing technique, and no new hardware is required for its implementation. As a result, this study demonstrates the suggested method enhances the system's stability and prevents inaccuracy when the irradiance varies. The method is utilised in actual PV power generation systems because it is simple to implement using MATLAB Simulation.

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