ABSTRACT
This paper proposes a simple, cost effective and efficient brushless DC (BLDC) motor drive for solar photovoltaic (SPV) array fed water pumping system. The importance of using a maximum power point tracking (MPPT) algorithm is demonstrated to ensure that a PV system provides the most energy possible. Two different maximum power point tracking (MPPT) algorithms are introduced. A boost converter is used in order to extract the maximum available power from the SPV. An appropriate control of boost converter through the Perturb & Observe maximum power point tracking (PO-MPPT) algorithm offers soft starting of the BLDC motor. Increment conductance is used and compared with the PO-MPPT. The speed control of BLDC motor is performed by PWM (Pulse Width Modulation) control of the voltage source inverter (VSI) using DC link voltage regulator. A Matlab/Simulink models of the solar panel, dc to dc boost converter, and control algorithms are validated.

Keywords
Solar PV, maximum power point tracking (MPPT) algorithms, BLDC motor, DC –DC boost converter.

1. INTRODUCTION
The water pumping has become the most attractive application of solar photovoltaic (SPV) energy particularly in the remote rural areas where power transmission is either almost impossible or uneconomical if possible. In general, a DC-DC converter is employed for maximum power point tracking (MPPT) of a SPV. A DC-DC Boost converter is used in for a permanent magnet brushless DC (BLDC) motor driven centrifugal pump. A DC-DC boost converter is utilized in MPPT of the SPV. The reasons behind opting this converter are its inherent properties of minimum possible switching stress, high conversion efficiency because of less number of components. The merits of both BLDC motor and Boost converter can contribute to develop a SPV array fed water pumping system possessing a potential of operating satisfactorily under dynamically changing atmospheric conditions. The BLDC motor has high reliability, high efficiency, improved cooling, low noise and requires practically no maintenance, since the BLDC motor speed is commanded by pulse width modulation (PWM) of VSI using a DC link voltage regulator. The centrifugal pump connected to the shaft of the motor operates the pump at constant speed to deliver the desired throughput for different irradiance levels of the SPV. The experimental analysis of impact of MPPT methods on energy efficiency for photovoltaic power systems is presented [1]. The modified incremental conductance MPPT algorithm to mitigate inaccurate responses under fast-changing solar irradiation level is introduced [2-3]. References [4-5] discuss and demonstrate a comparison of maximum power point tracking techniques for photovoltaic power systems.

A relationship between the dc power produced by PV array and the solar radiation has been investigated in [6]. It is showed that the power delivered by the PV array under the MPPT algorithm is linear with the radiation and it depends on temperature, etc. The steady state and transient conditions have been solved by using current based MPPT [7]. In this paper, the importance of using a maximum power point tracking (MPPT) algorithm is demonstrated to ensure that a PV system provides the most energy possible. Two different MPPT algorithms are introduced. A Matlab/Simulink models of the solar panel, dc to dc boost converter, and control algorithms are validated.

2. MAXIMUM POWER POINT TRACKING ALGORITHM
In order to investigate the mismatching between the operating characteristics of the load and the PV array, that’s point represents the intersection of the IV curves of the PV array and the load. Therefore, this substantial problem can be solved avoiding the direct connection of PV array to the load. A maximum power point tracking is considered. MPPT keeps the PV array point at the maximum. Several MPP techniques have been utilized by many researchers such as (Perturb and Observe (P&O), Incremental Conductance (IC) and Fuzzy Logic [8]). However, the two most commonly used are P&O and IC among the other techniques because of its simple structure and ease of implementation. The PV array characteristics and the detail of its modeling are discussed in Ref [9]. Consequently, the important values of the PV array are the open voltage, the short circuit current and the MPP to represent the intersection of the IV curves of the PV array.

It is based on the concept that on the power-voltage curve, the change in the PV array output power is equal to zero (∆Ppv

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Maximum power (Pmax)</td>
<td>300</td>
<td>W</td>
</tr>
<tr>
<td>Maximum power voltage (Vmax)</td>
<td>36.48</td>
<td>V</td>
</tr>
<tr>
<td>Maximum power current (Imax)</td>
<td>7.95</td>
<td>A</td>
</tr>
<tr>
<td>Short circuit current (Isc)</td>
<td>8.9</td>
<td>A</td>
</tr>
<tr>
<td>Open circuit voltage (Voc)</td>
<td>45.29</td>
<td>V</td>
</tr>
<tr>
<td>Series resistance (Rs)</td>
<td>0.4</td>
<td>Ω</td>
</tr>
<tr>
<td>Shunt resistance (Rsh)</td>
<td>68.4</td>
<td>Ω</td>
</tr>
</tbody>
</table>
= 0) on the top of the curve as illustrated in Fig. 1. The P&O technique compares the power of the previous step and the new step so that it increases or decreases the voltage or current [10-11]. Operating on the left of the MPP, it is noticeable that incrementing (decrementing) the voltage allows to increase (decrease) the power and decrease (increase) the power when on the right of the MPP. The perturbation is kept the same to reach the MPP when there is an increase in power and vice-versa. P&O has a good behavior when the irradiance does not change quickly with time. However, the power oscillates around the MPP in steady state operation and it fails with variations of temperature and irradiance. Considering a small perturbation size to maintain a small power variation. The basic flow chart of P&O algorithm is shown in Fig. 2.

This algorithm is developed to set up the duty ratio of the PWM generator that it controls the boost DC – DC converter (section 3).

2.2 Incremental conductance (INC) algorithm

The INC algorithm is based on the fact that, the derivative of PV array output power with respect to its output voltage is zero (dP / dV = 0) at the MPP and at any irradiation and temperature level. It is negative on the right of MPP and positive on the left of the MPP as shown in Fig 3. The Flowchart of the incremental conductance algorithm is shown in Fig 4.

\[\Delta V/\Delta P = 0 \quad (\Delta I/\Delta P = 0) \text{ at the MPP} \]
\[\Delta V/\Delta P > 0 \quad (\Delta I/\Delta P < 0) \text{ on the left} \]
\[\Delta V/\Delta P < 0 \quad (\Delta I/\Delta P > 0) \text{ on the right} \]
3.1 Boost Converter Model

The model of a boost converter is given in Ref [12-14]. Figure 5 shows the Matlab/Simulink model for the whole system including PV solar, boost dc converter, MPPT, and BLDC motor with its drive. A 300W PV module has been used in the simulation (Table 1). Two MPPT algorithms are simulated as:

A. Perturb and Observe Simulation Results:

The PO – MPPT simulation results are discussed. Output voltage for the boost converter with PO - MPPT algorithm is shown in Figure 6, when the irradiance is 1000 W/m².

B. Increment Conductance Simulation Results:

Figure 7 shows the output voltage for the boost converter with increment conductance IC - MPPT algorithm. Notice how this looks essentially the same as the voltage plots in Figure 2. The main difference is that the IC algorithm locks onto a specific setting at the maximum power point. Thus, the input and output currents stop fluctuating so much. The duty cycle rises to acquire the MPP for PO-MPPT and IC-MPPT as shown in Figures 9 and 10. Figure 11 shows the comparative results of PO and IC-MPPT.

From Figs 6 and 7, it can be observed that the output voltage reaches its rated within 0.2 sec for P&O algorithm and reaches its rated within 0.15sec for IC algorithm that it is quit
faster therefore IC under different irradiance conditions has higher accuracy. In other hand, IC is quit complex compared with P&O algorithm. The performance of SPV boost converter is shown in Fig 8. The results show the current output, voltage output, PV power when the irradiance is 1000W/m².

The simulation results of P&O MPPT algorithm for the duty cycle shown in Fig. 9. The result illustrates that the duty cycle changes for a time period of 0.01sec and the duty cycle takes 0.005sec for IC MPPT as shown in Fig. 10.

The PV curves are shown in Figs 11, 12 and 13 that display the performance for PV without MPPT and compared when using the MPPT algorithms. It is cleared that tracking for maximum power point for IC MPPT is better than that for PO MPPT due to fast response. Consequently, the comparative between the two algorithms PO and IC maximum power point tracking is given in Table 2.
In addition, the tracking efficiency for PO and IC MPPT is illustrated in Fig. 14. This figure shows that the variations of irradiance on the tracking efficiency for IC is higher than that for PO. Therefore, the PV array will operate at voltages lower than without MPP voltage, results in increasing the energy utilization efficiency of the system. At lower values of irradiance 200W/m2 the efficiencies are 92% for PO MPPT and 96% for IC MPPT.

In Table 2, we can observe that the IC MPPT algorithm has a more robust performance under varying operational conditions compared to the P&O algorithm. The table shows the simulated results of the P&O and IC MPPT algorithms under different irradiance conditions. The P&O algorithm shows lower efficiency and stability compared to the IC MPPT, especially at lower irradiance levels.

5. REFERENCES


[6] Chighali Ould Ehsein, Abdellahi Ba1, Ne Ould, Dah, Mamadou Ibrahima Lam and Diakité Amadou1, Aroudam El Hassan, 2018 “Monitoring a maximum power point tracking photovoltaic pumping system”, The 9th International Renewable Energy Congress (IREC).


