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# Efficient Generation of Electricity by Photovoltaic Systems for Water Pumping in Rural Areas

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***Abstract:*** For many decades people have been using mechanical type of system which can be run by diesel, petrol but now the need is more to use renewable source so that people will not face the challenge of exhaustion of energy. It is known that photovoltaic system which takes solar light as its energy source and convert into electrical energy and same can be used instead of other source. In this paper the solar energy is used for water pumping so that water can be provided to remote locations for drinking and irrigation purpose. Till date people of rural areas they are not finding the pure water for drinking and most of the village people have to walk few kilometers for collecting water for drinking. As India is a developing country largely depends on cultivation and that can be possible if sufficient water available in the particular land. In this proposed system the solar energy will be more efficient for providing water to rural areas. In a PV Pumping System (PVPS), a pump driven by a motor performs optimally at a specific PV array configuration and pumping head profile. The necessity of efficient and reliable energy conversion is a pressing need of today's problems. PV alone amidst thermal insolation does not conform to efficient way of energy conversion and certainly needs good heat sinks to operate efficiently throughout the duration of solar insolation. In this paper solar tracking with maximum power point tracking is taken up for improving the efficiency of water pumping system by using MATLAB simulation.

***Keywords:*** Insolation, MPPT, Solar Tracking, Microcontroller, MATLAB, Simulation

## 1. INTRODUCTION

A water pumping system needs a source of power to operate. In general, AC powered system is economic and takes minimum maintenance when AC power is available from the nearby power grid. However, in many rural areas, water sources are spread over many miles of land and power lines are scarce. Installation of a new transmission line and a transformer to the location is often prohibitively expensive. Windmills have been installed traditionally in such areas; many of them are, however, inoperative now due to lack of proper maintenance and age. Today, many stand-alone type water pumping systems use internal combustion engines. These systems are portable and easy to install. However, they have some major disadvantages, such as: they require frequent site visits for refuelling and maintenance, and furthermore diesel fuel is often expensive and not readily available in rural areas of many developing countries.

The consumption of fossil fuels also has an environmental impact, in particular the release of carbon dioxide (CO2) into the atmosphere. CO2 emissions can be greatly reduced through the applications of renewable energy technologies, which are already cost competitive with fossil fuels in many situations. Good examples include large-scale grid-connected wind turbines, solar water heating, and off-grid stand-alone PV systems. The use of renewable energy for water pumping systems is, therefore, a very attractive proposition. Windmills are a long-established method of using renewable energy; however they are quickly phasing out from the scene despite success of large-scale grid-tied wind turbines. PV systems are highly reliable and are often chosen because they offer the lowest life-cycle cost, especially for applications requiring less than 10 KW, where grid electricity is not available and where internal-combustion engines are expensive to operate. If the water source is 1/3 mile (app. 0.53KM) or more from the power line, PV is a favourable economic choice.

The proposed work is based on maximum power point tracking and simulation has been done using MATLAB. For increasing the solar efficiency solar tracking has been done using microcontroller and stepper motor so that we can receive the maximum intensity as per change in sun position.

## 2. WORKING OF PV CELL

To understand the operation of a PV cell, we need to consider both the nature of the material and the nature of sunlight. Solar cells consist of two types of material, often p-type silicon and n-type silicon. Light of certain wavelengths is able to ionize the atoms in the silicon and the internal field produced by the junction separates some of the positive charges ("holes") from the negative charges (electrons) within the photovoltaic device. The holes are swept into the positive or p-layer and the electrons are swept into the negative or n-layer. Although these opposite charges are attracted to each other, most of them can only recombine by passing through an external circuit outside the material because of the internal potential energy barrier. Therefore if a circuit is made (see Figure 1) power can be produced from the cells under illumination, since the free electrons have to pass through the load to recombine with the positive holes.

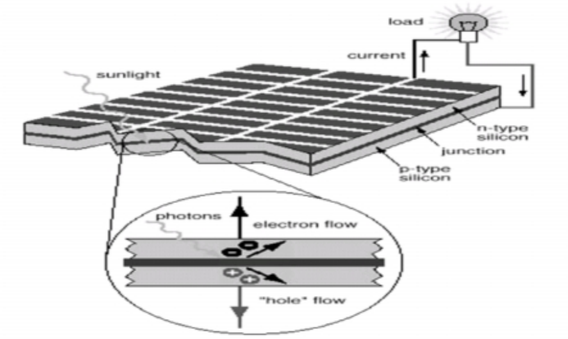


**Figure 1: The Photovoltaic Effect in a Solar Cell**

## 3. PROPOSED WORK

The experimental water pumping system proposed in this work is a stand-alone type without backup batteries [1,2,3]. The system is very simple and consists of a single PV module, a maximum power point tracker (MPPT), and a DC water pump. The size of the system is intended to be small. The proposed work includes the solar tracking system which will need few more additional components like microcontroller and stepper motor. The system including the subsystems will be simulated to verify the functionalities.

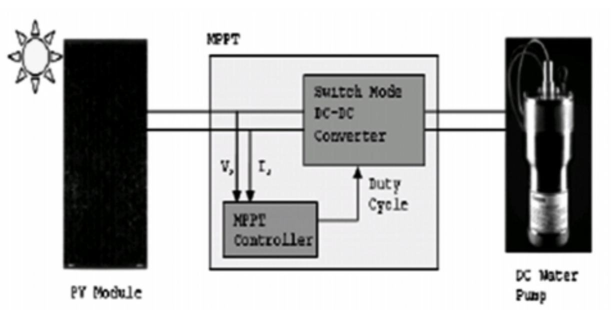


**Figure 2: Block Diagram of Proposed System**

PHOTOVOLTAIC (PV) systems find increased use in electric power technologies. The main drawbacks of PV systems are high fabrication cost and low energy-conversion efficiency, which are partly caused by their nonlinear and temperature- dependent *V–I* and *P–I* characteristics. To overcome these drawbacks, three essential approaches can be followed:

- Improving manufacturing processes of solar arrays: many research efforts have been performed with respect to materials and manufacturing of PV arrays.
- Controlling the insolation input to PV arrays: the input solar energy is maximized using sun-tracking solar collectors or rearranging the solar-cell configurations of PV arrays with respect to changes in environmental conditions.
- Utilization of output electric power of solar arrays: the main reasons for the low electrical efficiency are the nonlinear variations of output voltage and current with solar radiation levels, operating temperature, and load current. To overcome these problems, the maximum power operating point of the PV system (at a given condition) is tracked using online or offline algorithms and the system operating point is forced toward this optimal condition.

The thesis work is to use maximum power point tracker (MPPT) in photovoltaic(PV) water pumping system by using different types of algorithm for MATLAB simulation. The comparative study of perturb and observe (P&O) and incremental Conductance (incCond) algorithm is going to be discussed and solar tracking system is also going to be implemented. The solar tracking system is nothing but the adjustment of solar panel angle in accordance with the position of the sun.

The PV System is also going to be equipped with a solar tracking system which will be more beneficial to us for trapping more amount of solar energy compared to non solar tracking system. The solar tracking system includes microcontroller and stepper motor. Microcontroller will provide the necessary controlling action needed for rotating the stepper motor as per our requirement, so that we will be able to adjust the angle of solar panel according to the position/direction of the sun. This thesis work will help for efficient utilization of solar energy even if the position of the sun changes as per the day progresses.

## 4. DESIGN AND IMPLEMENTATION

The comparisons between the PV water pumping system equipped with a Maximum power point tracker (MPPT) and the direct coupled system without MPPT has been done with the addition of a solar tracking using microcontroller. Microcontroller has been used to rotate the panel so that we can utilize maximum renewable energy in more efficient way.

Also, the design and simulations of MPPT has been done using MATLAB to perform comparative tests of the perturb and observe (P&O) [6] and incremental Conductance (incCond) algorithm. Simulations also verify the functionality of MPPT with a resistive load and then with the DC pump motor load [4]. The comparisons between the PV water pumping system equipped with MPPT and the direct coupled system without MPPT has been done also solar tracking using microcontroller has been used so that we can utilize maximum renewable energy in more efficient way.

The two MPPT algorithms, P&O and incCond, discussed and are implemented in MATLAB simulations and tested for their performance. Since the purpose is to make comparisons of two algorithms, each simulation contains only the PV model and the algorithm in order to isolate any influence from a converter or load. First, they are verified to locate the MPP correctly under the constant irradiance, as shown in Figure 3.

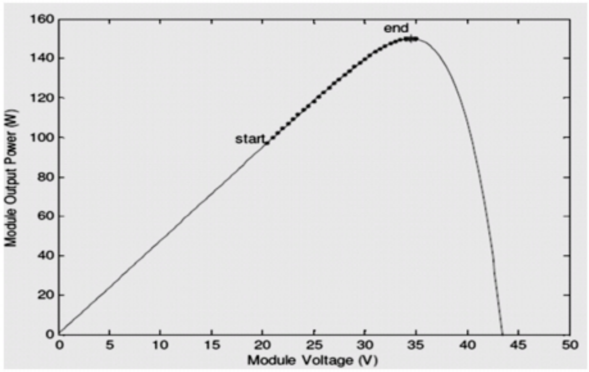


**Figure 3: Searching the MPP (1KW/m2, 25°C)**

The traces of PV operating point are shown in green, and the MPP is the red asterisk. A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline silicon (Si) cells, thus a number of PV cells are connected in series to archive a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Si cells have either 36 or 72 series-connected cells. A 36-cell module provides a voltage suitable for charging a 12V battery, and similarly a 72-cell module is appropriate for a 24V battery.

PV module, pictured in Figure 4, is chosen for a MATLAB simulation model. The module is made of 72 multi-crystalline silicon solar cells in series and provides 150W of nominal maximum power.

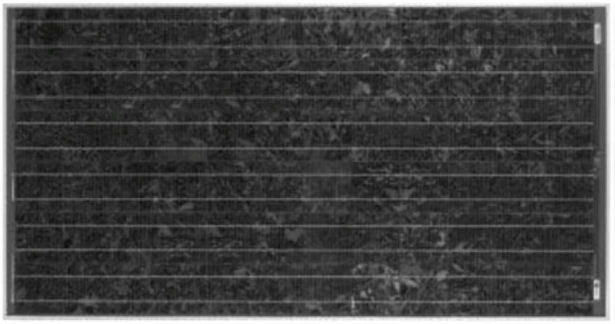

**Figure 4: Picture of BP SX 150S PV Module**

**Table 1**
**Electrical Characteristics of Solar Cell**

| *Electrical Characteristics* | |
|---|---|
| Maximum Power (*Pmax*) | 150W |
| Voltage at *Pmax* (*Vmp*) | 34.5V |
| Current at *Pmax* (*Imp*) | 4.35A |
| Open-circuit voltage (*Voc*) | 43.5V |
| Short-circuit current (*Isc*) | 4.75A |
| Temperature coefficient of *Isc* | 0.065 ± 0.015 %/ Oc |
| Temperature coefficient of *Voc* | -160 ± 20 mV/ oC |
| Temperature coefficient of power | -0.5 ± 0.05 %/ oC |
| NOCT | 47 ± 2Oc |

Figure 5 shows the plots of *I-V* characteristics at various module temperatures simulated with the MATLAB model for BP SX 150S PV module.

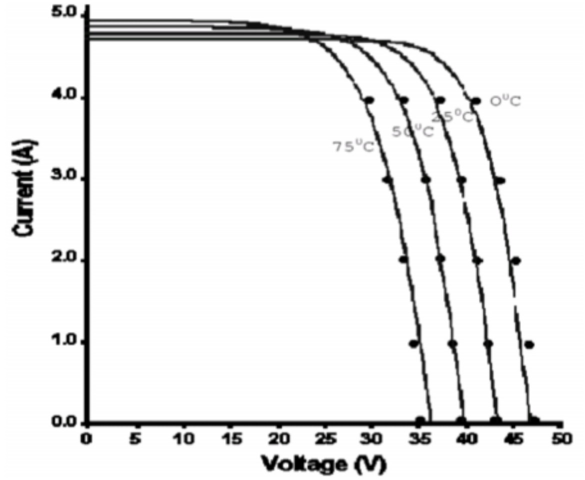


**Figure 5: I-V Curves of BP SX 150S PV Module at Various Temperatures**

When a PV module is directly coupled to a load, the PV module's operating point will be at the intersection of its *I–V* curve and the load line which is the *I-V* relationship of load. For example in Figure 6, a resistive load has a straight line with a slope of *1/Rload* as shown in Figure 7. In other words, the impedance of load dictates the operating condition of the PV module. In general, this operating point is seldom at the PV module's MPP, thus it is not producing the maximum power. A study shows that a direct-coupled system utilizes a mere 31% of the PV capacity. A PV array is usually oversized to compensate for a low power yield during winter months. This mismatching between a PV module and a load requires further over-sizing of the PV array and thus increases the overall system cost. To mitigate this problem, a maximum power point tracker (MPPT) can be used to maintain the PV module's operating point at the MPP. MPPTs can extract more than 97% of the PV power when properly optimized. This chapter discusses the *I-V* characteristics of PV modules and loads, matching between the two, and the use of DC-DC converters as a means of MPPT. It also discusses the details of some MPPT algorithms and control methods, and limitations of MPPT.

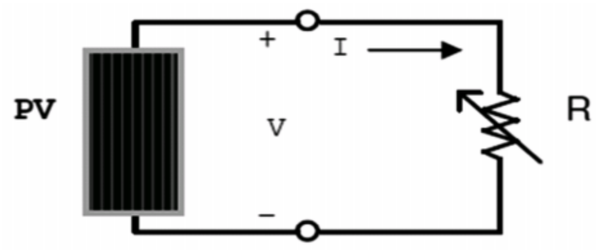


**Figure 6: PV Module is Directly Connected to a (Variable) Resistive Load**

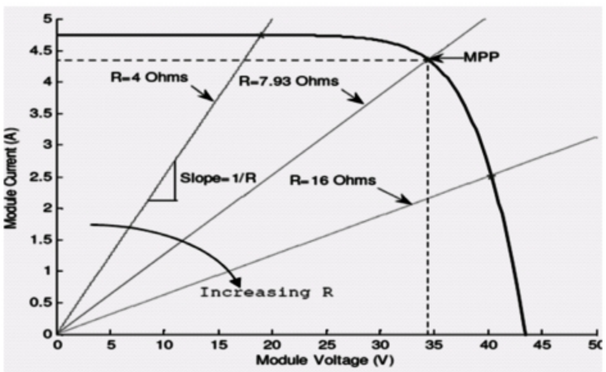


**Figure 7: I-V Curves of BP SX 150S PV Module and Various Resistive Loads Simulated with the MATLAB Model ($1KW/m^2$, $25^oC$**

### The I-V Curve and Maximum Power Point

Figure 8 shows the *I-V* curve of the BP SX 150S PV module simulated with the MATLAB model [5]. A PV module can produce the power at a point, called an operating point, anywhere on the *I-V* curve. The coordinates of the operating point are the operating voltage and current. There is a unique point near the knee of the *I-V* curve, called a maximum

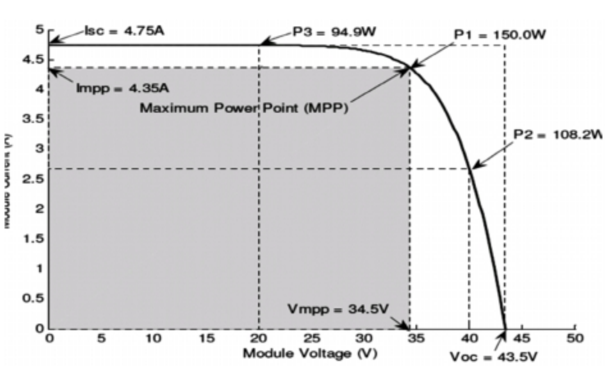


**Figure 8: Simulated I-V Curve of BP SX 150S PV Module ($1KW/m^2$, $25^oC$)**

power point (MPP), at which the module operates with the maximum efficiency and produces the maximum output power. It is possible to visualize the location of the by fitting the largest possible rectangle inside of the *I-V* curve, and its area equal to the output power which is a product of voltage and current. Similarly Figure 9, 10 & 11 shows the different curve by using MATLAB simulation [8, 9, 10].

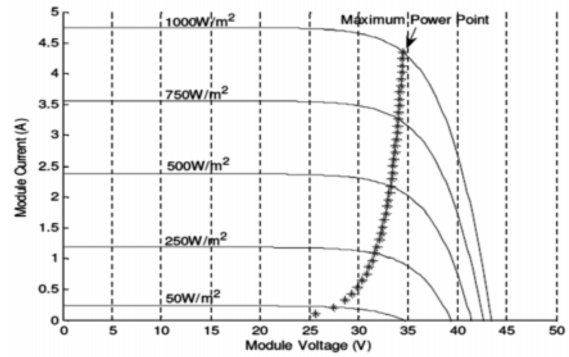


**Figure 9: I-V Curves for Varying Irradiance and a Trace of MPPs (25oC)**

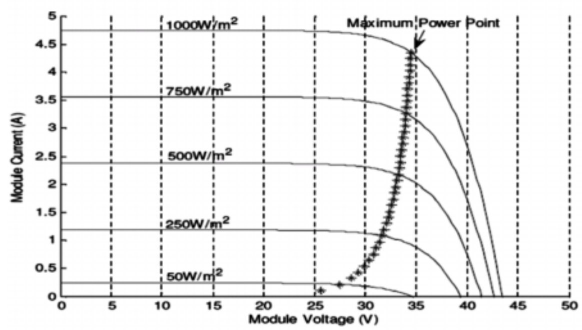


**Figure 10: I-V Curves for Varying Irradiance and a Trace of MPPs ($50^oC$)**

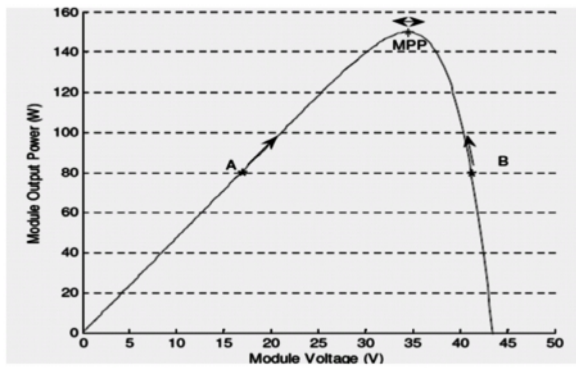


**Figure 11: Plot of Power vs. Voltage for BP SX 150S PV Module (1KW/m2, $25^oC$)**

## 5. CONCLUSION

Simulations perform comparative tests for the two MPPT algorithms using actual irradiance data in the two different weather conditions. The incCond algorithm shows narrowly but better performance in terms of efficiency compared to the P&O algorithm under the cloudy weather condition. Even a small improvement of efficiency could bring large savings if the system is large. However, it could be difficult to justify the use of incCond algorithm for small low-cost systems since it requires four sensors. In order to develop a simple low-cost system, this work adopts the direct control method which employs the P&O algorithm but requires only two sensors for output. This control method offers another benefit of allowing steady-state analysis of the DC-DC converter, as opposed to the more complex state-space averaging method, because it performs sampling of voltage and current at the periodic steady state. Simulations use SimPower Systems in SIMULINK to model a DC pump motor, and then the model is transferred into MATLAB. It performs simulations of the whole system and verifies functionality and benefits of MPPT. Simulations also make comparisons with the system without MPPT in terms of total energy produced and total volume of water pumped a day. The results validate that MPPT can significantly increase the efficiency of energy production from PV and the performance of the PV water pumping system compared to the system without MPPT.

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