



Simulation of Maximum Power Point Tracking Techniques for Photovoltaic Application

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Abstract: In this project, Maximum Power Point tracking (MPPT) Techniques is used to compare the amount of energy extracted from the photovoltaic (PV) panel tracking factor (TF) in relation to the available power, PV voltage ripple, dynamic response, and use of sensors. Digitally controlled boost dc–dc converter can be implemented and connected to a simulator in order to verify the analytical procedures. The main experimental results are presented for conventional MPPT algorithms and improved MPPT algorithms using proportional–integral (PI) and perturb and observe technique. Moreover, the dynamic response and the TF are also evaluated using a user-friendly interface, which is capable of online programming and TF is computed. Finally, a typical daily insolation is used in order to verify the experimental results for the main PV MPPT methods. In this paper photovoltaic simulation can track the maximum power point accurately. Analysis and verifications can be made by MATLAB simulation.

Keywords: Photovoltaic Cell, Maximum power point tracking factor, Converter

I. INTRODUCTION

Increasing efforts are being made now-a-days to use renewable energy sources. Processing the energy obtained from sun, wind or water is coming to the fore. The energy supplied by these sources does not have constant values, but fluctuates according to the surrounding conditions (intensity of sun rays, water flow, etc.). These supplies are therefore supplemented by additional converters. The most used types are inverters or DC/DC converters. The area of high power converters for solar application is already covered by industrial manufacturers. However, the area of low power devices is not fully covered. These converters are mostly built from commercially produced parts that can perform demanded functions, but they are not developed for this type of application and therefore the efficiency of the whole system is low. Low power devices are important in applications where there is no voltage grid present and electric power is required (mountains, desert expeditions, etc.)

The power produced by solar arrays depends on surrounding conditions, e.g. temperature and intensity of sun exposure E . The solar array output power is not therefore constant. The output power also depends on the withdrawn current and voltage. Maximum Power Point Tracking

(MPPT) is one of the most important and well-known problem for all PV systems. An efficient MPPT algorithm is very important to increase the efficiency of PV system. Recently, many MPPT algorithms and control schemes of PV generation system have been proposed. As for the Non-Artificial Intelligence method of the MPPT algorithms, Constant Voltage Tracking (CVT) method, Fraction Open-Circuit Voltage (OCV) method, Hill climbing and Perturb and Observe (P&O) method, Incremental Conductance (INC-CON) method, Variable Step Size (VSS) method based on INC-CON method, and hybrid method which combined above algorithms are introduced

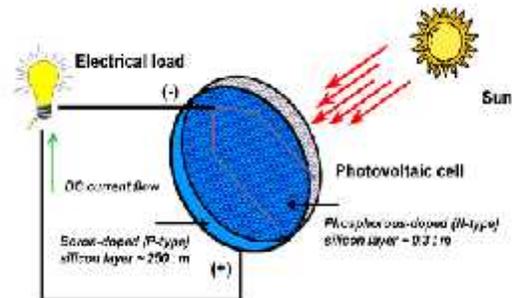


Fig 1 Photovoltaic Cell



The MPPT control algorithm ensures that the solar array operates at its optimal point and that it delivers maximal power. The algorithm periodically changes the duty cycle of the converter in the defined hysteresis range, it increases the duty cycle, it decreases the duty cycle, and it compares the powers delivered by the solar cell. Then it chooses the duty cycle that corresponds with the maximal delivered power.

If the converter operates on the left side of the MPP, the algorithm will decrease the duty cycle. When it is operating on the right of the MPP, the controller will increase the duty cycle. If the converter is operating at MPP, the power obtained on both sides will be lower and the duty cycle remains the same. The converter works with a fixed duty cycle and boosts the input voltage to the voltage level required by the inverter.

The duty cycle is the ratio of output voltage to input voltage. When the solar panel is partially shaded the power versus voltage characteristics shows a global peak and local peaks for the shaded section, this is a major disadvantage as it results in severe power losses. The purpose of this project is to identify the most suitable approach to MPPT and to modify it to take account of partial shading.

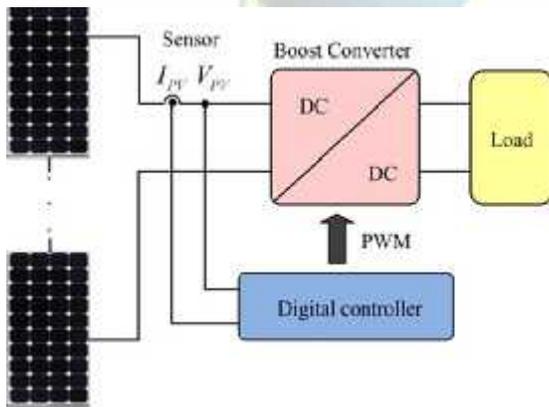


Fig 2 Block Diagram of PV Generation System

The basic objective would be to study MPPT and successfully implement the MPPT algorithms either in code form or using the Simulink models. Modeling the converter and the solar cell in Simulink and interfacing both with the MPPT algorithm to obtain the maximum power point operation would be of prime importance.

Design a DC-DC converter solution to connect the solar panel to the load. This will have the ability to output a constant voltage when partial shading affects a solar powered system. Develop a model of a partially shaded PV

system, being able to demonstrate how partial shading of the solar panel result in solar panel output losses. Demonstrate the modified MPPT for partial shading. Partial shading will the effect the outputs from the solar panel but the load output will be effected minimally when the system is implemented. Implementation of a new algorithm for a micro controller to deal with the issues sup pounding MPPT. Such an algorithm will have the ability to read the current and voltage which the solar panel is producing, perturb these values and have the ability to vary the duty cycle in the DC-DC converter which will result in a overall constant output power being produced.

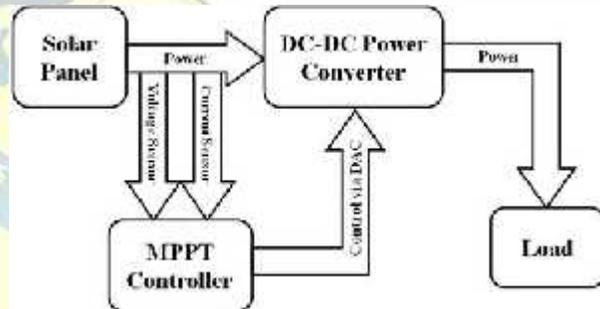


Fig 3 Block Diagram of MPPT

II. MPPT TECHNIQUES

2.1 Fixed Duty Cycle

The fixed duty cycle represents the simplest of the methods, and it does not require any feedback, where the load impedance is adjusted only once for the MPP.CV Method. The constant voltage (CV) method uses empirical results, indicating that the voltage at MPP (V_{MPP}) is around 70%–80% of the PV open-circuit voltage (VOC), for the standard atmo- spheric condition. Among the points of MPP (varying atmo- spheric conditions), the voltage at the terminals of the module varies very little even when the intensity of solar radiation changes, but it varies when the temperature changes. So, this method must be used in regions where the temperature varies very little. A positive point is that only the PV voltage is necessary to be measured, and a simple control loop can reach the MPP [4], [5], [10], [12].

2.1 Perturb and Observe method

This method is the most common. In this method very less number of sensors are utilized and. The operating voltage is sampled and the algorithm a change the operating



voltage in the required direction and samples is positive, then the algorithm increases the voltage value towards the MPP until it is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point. The system by increasing or decreasing the array operating voltage and observing its impact on the array output power operating voltage is perturbed with every MPPT cycle. As soon as the MPP is reached, V will oscillate around the ideal operating voltage V_{mp} . summarized the control action of the P&O method. The value of the reference voltage, V_{ref} , will be changed according to the current operating point. For example, for when the controller senses that the power from solar array increases ($dP > 0$) and voltage decreases ($dV < 0$), it will decrease (-) V_{ref} by a step size $C1$, so V_{ref} is closer to the MPP. The MPP represents the point where V_{ref} and scaled down V_{sa} become equal.

The oscillation around a maximum power point causes a power loss that depends on the step width of a single perturbation. The value for the ideal step width is system dependent and needs to be determined experimentally to pursue the trade-off of increased losses under stable or slowly changing conditions. In fact, since the AC component of the output power signal is much smaller than the DC component and will contain a high noise level due to the switching DC-DC converter, an increase in the amplitude of the modulating signal had to be implemented to improve the signal to noise ratio (SNR), however, this will lead to higher oscillations at the MPP and therefore increase power losses even under stable environmental conditions.

Several improvements of the P&O algorithm have been proposed. One of the simplest entails the addition of a 'waiting' function that causes a momentary cessation of perturbations if the algebraic sign of the perturbation is reversed several times in a row, indicating that the MPP has been reached. This reduces the oscillation about the MPP in the steady state and improves the algorithm's efficiency under constant irradiance conditions.

However, it also makes the MPPT slower to respond to changing atmospheric conditions, worsening the erratic behaviour on partly cloudy days. Another modification involves measuring the array's power $P1$ at array voltage $V1$, perturbing the voltage and again measuring the array's power, $P2$, at the new array voltage $V2$, and then changing the voltage back to its previous value and re measuring the array's power, $P1$, at $V1$. From the two measurements at $V1$, the algorithm can determine whether the irradiance is changing. Again, as with the previous

modifications, increasing the number of samples of the array's power slows the algorithm down. Also, it is possible to use the two measurements at $V1$ to make an estimate of how much the irradiance has changed between sampling periods, and to use this estimate in deciding how to perturb the operating point. This, however, increases the complexity of the algorithm, and also slows the operation of the MPPT.

2.2 Constant Voltage and Current Methods.

The constant voltage algorithm is based on the observation from I-V curves that the ratio of the array's maximum power voltage, V_{mp} , to its open-circuit voltage, V_{oc} , is approximately constant: $V_{mp} / V_{oc} = K < 1$. The constant voltage algorithm can be implemented using the flowchart. The solar array is temporarily isolated from the MPPT, and a V_{oc} measurement is taken. Next, the MPPT calculates the correct operating point and the preset value of K , and adjusts the array's voltage until the calculated V_{mp} is reached. This operation is repeated periodically to track the position of the MPP. Although this method is extremely simple, it is difficult to choose the optimal value of the constant K . The literature reports success with K values ranging from 73 to 80%. Constant voltage control can be easily implemented with analog hardware. However, its MPPT tracking efficiency is low relative to those of other algorithms. Reasons for this include the aforementioned error in the value of K , and the fact that measuring the open-circuit voltage requires a momentary interruption of PV power.

It is also possible to use a constant current MPPT algorithm that approximates the MPP current as a constant percentage of the short-circuit current. To implement this algorithm,[7] a switch is placed across the input terminals of the converter and switched on momentarily. The short-circuit current is measured and the MPP current is calculated, and the PV array output current is then adjusted by the MPPT until the calculated MPP current is reached. This operation is repeated periodically.[8][9] However, constant voltage control is normally favoured because of the relative ease of measuring voltages, and because open-circuiting the array is simple to accomplish, but it is not practically possible to short-circuit the array (i.e., to establish zero resistance across the array terminals) and still make a current measurement.

2.3 Incremental Conductance

The incremental conductance (Inc Cond) method is based on comparing the instantaneous panel Conductance with the incremental panel conductance. The input impedance of the DC-DC converter is matched with



optimum impedance of PV panel. As noted in literatures, this method has a good performance under rapidly changing conditions. The algorithm uses the fact that the derivative of the output power P with respect to the panel voltage V is equal to zero at the maximum power point.

III. SIMULINK MODEL

The Simulink model used for the implementation of the required solar cell system.

3.1 PV Array

Photovoltaic cell also known as a solar cell is used to convert energy from the sun directly into electrical energy without any form of rotational parts. Photovoltaic cells represent the basic fundamental power conversion unit of photovoltaic system.

A solar panel cell basically is a p-n semiconductor junction. When exposed to the light, a DC current is generated. The generated current varies linearly with the solar irradiance.

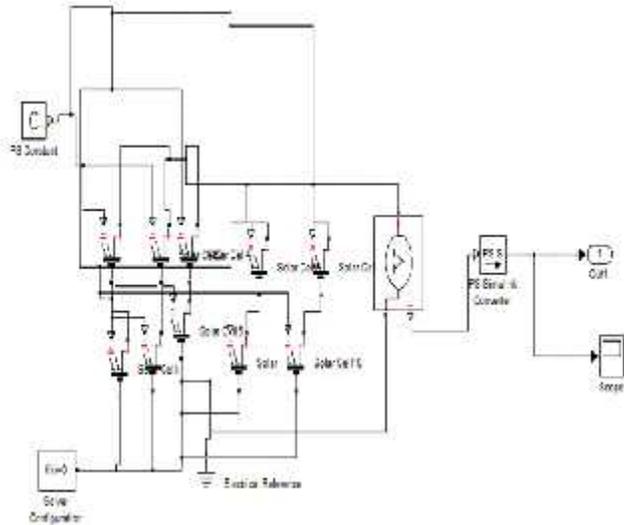


Fig 4 Model of PV Array

The Simulink model used for the implementation of the required solar cell and boost converter system. Other elements of the model constitute the boost converter, which consists of a 0.2 mH inductor and a 1 mF capacitor. This boost converter is used to step up the voltage to the required value.

3.2 BOOST CONVERTER

The boost converter is also known as the step-up converter. The name implies its typical application of converting a low input-voltage to a high output voltage, essentially functioning like a reversed buck converter. The gating signal to the boost converter is generated by comparing the signal generated by the MPPT algorithm to a repeating sequence operating at a high frequency. The load is a 10 ohm resistance.

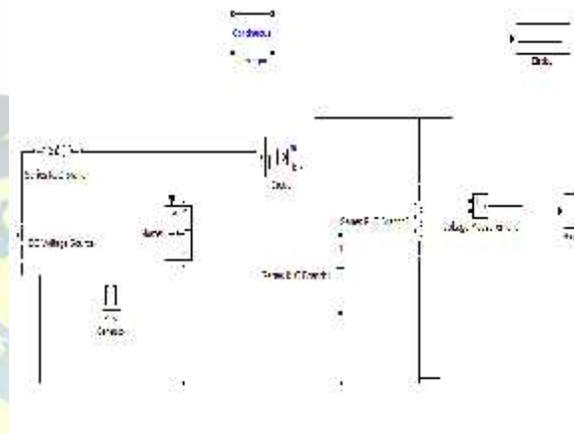


Fig 5 Model of Boost Converter

3.3 Single Diode Model

Renewable energy sources such as solar energy are acquiring more significance, due to shortage and environmental impacts of conventional fuels. The photovoltaic (PV) system for converting solar energy into electricity is in general costly and is a vital way of electricity generation only if it can produce the maximum possible output for all weather conditions.

A controlled current source is utilized to drive the solar cell. The control signal is provided by the generator unit. The generator takes into account the number of series connected, number of parallel connected solar cells and the temperature to determine the input signal from the solar cells.

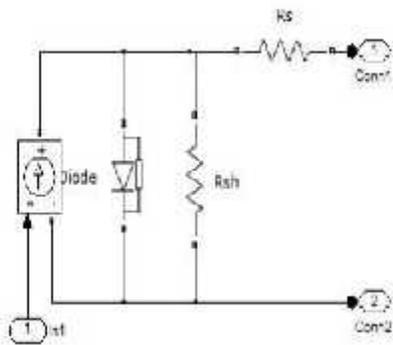


Fig 6 Solar cell modelled in single diode format

IV. SIMULATION RESULT

Photovoltaic cells represent the basic fundamental power conversion unit of Photovoltaic system. Photovoltaic cells are usually arranged into modules and arrays when applied practically. There are several factors that affect the electrical performance of a photovoltaic module from operating at optimal operating point. These factors are

- (1) Sunlight intensity/irradiation
- (2) Cell temperature
- (3) Load resistance
- (4) Shading

And the use of photovoltaic array and maximum power point tracker (MPPT) to curb the challenges are developing rapidly. The designed DC - DC boost converter is connected between the photovoltaic module and the load so as to enable the module operates at maximum power at all time. Boost converter is made of up four elements as shown below in figure 8. They include the inductance, diode, capacitor and MOSFET. As the name of the converter implies, it steps up the input voltage which makes the output voltage greater than the input voltage.

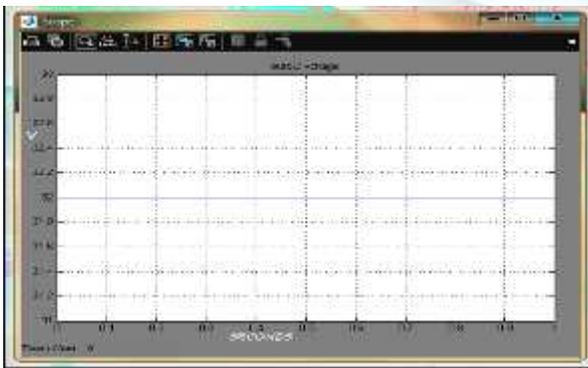


Fig 7 PV Array Output Voltage

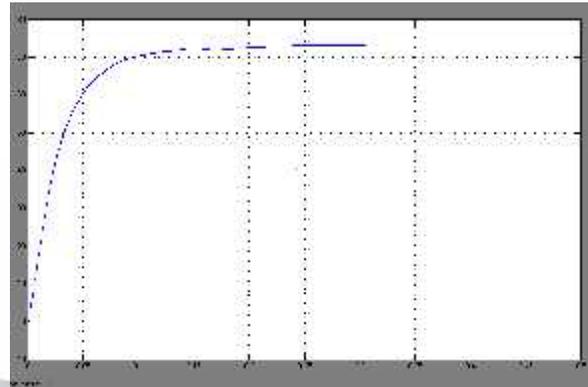


Fig 8 Converter Output Voltage

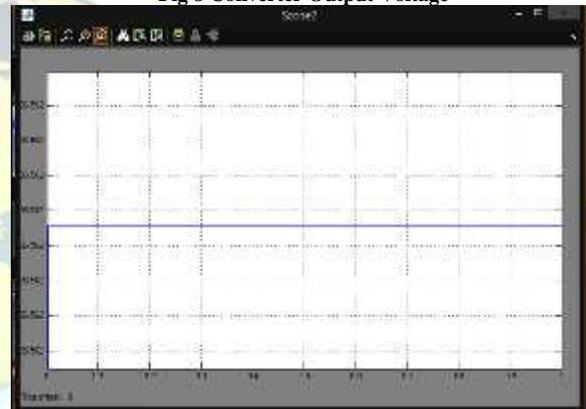


Fig 9 Single Diode Model Output Voltage

The converter is controlled through the MOSFET which acts as a switch. The ON and OFF of the switch (MOSFET) controls the output voltage by changing the voltage of the inductance so as to enable the load. The operation of the converter is analyzed in continuous conduction mode.

The operation of the converter analyzed in photovoltaic module power at maximum. The simulations were carried out in Simulink and the various voltages, currents and power plots were obtained. The solar cell was modelled in the single diode format. This consists of a 0.1 ohm series resistance and an 8 ohm parallel resistance. This was modelled using the Sim Power System blocks in the MATLAB library.

A controlled current source is utilized to drive the solar cell. The control signal is provided by the Ilg generator unit. The Ilg generator takes into account the number of series connected, number of parallel connected solar cells and the temperature to determine the input signal from the solar cell.



V. CONCLUSION

A resistive load of 10 ohms was used with the boost converter thereby making the output current and voltage similar. When MPPT is used there is no need to input the duty cycle, the algorithm iterates and decides the duty cycle by itself. But if MPPT had not been used, then the user would have had to input the duty cycle to the system. When there is change in the solar irradiation the maximum power point changes and thus the required duty cycle for the operation of the model also changes. But if constant duty cycle is used then maximum power point cannot be tracked and thus the system is less efficient. The various P-V and I-V characteristics of PV array waveforms were obtained by using the plot mechanism in MATLAB.

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