

Maximum Power Point Tracking (MPPT) Technique in Solar Photovoltaic Array

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Abstract: This paper introduced a new technique for increasing the output of solar system which is called maximum power point tracking method. The need for renewable energy sources is on the rise because of the acute energy crisis in the world today. Solar energy is a vital untapped resource in a tropical country like ours. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. In this paper, we examine a schematic to extract maximum obtainable solar power from a PV module and use the energy for a DC application. This project investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system.

Keywords: MPPT, Solar Module, Switches

1. Introduction

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe.

Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons. Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a trade off between complexity and efficiency.

1.1 Boost Converter

The maximum power point tracking is basically a load matching problem. In order to change the input resistance of

the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid or for a water pumping system which requires 230 V at the output end, so we use a boost converter.

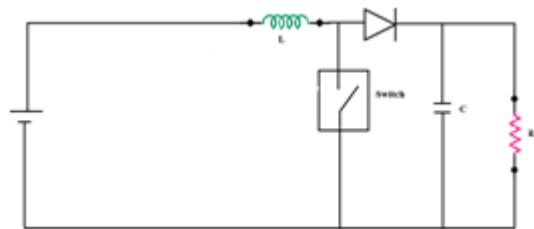


Figure 1.1: Circuit diagram of a Boost Converter

Mode 1: operation of the Boost Converter

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.

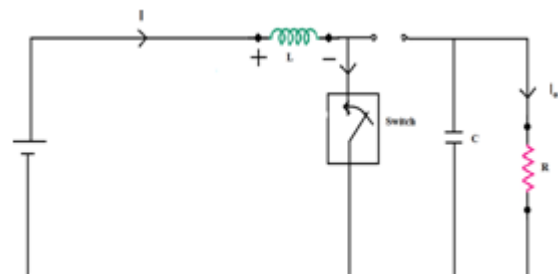


Figure 1.2: Mode 2 operation of the Boost Converter

Mode 2: operation of the Boost Converter

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The

load current remains constant throughout the operation. The waveforms for a boost converter are shown in Figure 3.7.

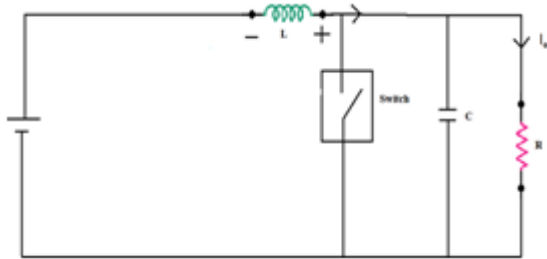


Figure 1.3: Mode 2 operation of Boost Converter

Maximum Power Point Tracking Algorithms

2.1 An overview of Maximum Power Point Tracking

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solarpanel.

According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matchingproblem.

In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

2.2 Different MPPT techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

- 1) Perturb and Observe (hill climbing method)
- 2) Incremental Conductance method
- 3) Fractional short circuit current
- 4) Fractional open circuit voltage
- 5) Neural networks
- 6) Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

2.2.1 Perturb & Observe

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

However the method does not take account of the rapid

change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

2.2.2 Incremental Conductance

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. At MPP the slope of the PV curve is 0.

$$(dP/dV)_{MPP} = d(VI)/dV$$

$$0 = I + V dI/dV_{MPP} \tag{4.2}$$

$$dI/dV_{MPP} = -I/V \tag{4.3}$$

The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached.

Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However the complexity and the cost of implementation increases.

As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms. Owing to its simplicity of implementation we have chosen the Perturb & Observe algorithm for our study among the two.

2.2.3 Fractional open circuit voltage

The near linear relationship between V_{MPP} and V_{OC} of the PV array, under varying irradiance and temperature levels, has given rise to the fractional V_{OC} method.

$$V_{MPP} = k_1 V_{oc} \tag{4.4}$$

Where k_1 is a constant of proportionality. Since k_1 is dependent on the characteristics of the PV array being used, it usually has to be computed beforehand by empirically determining V_{MPP} and V_{OC} for the specific PV array at different irradiance and temperature levels. The factor k_1 has been reported to be between 0.71 and 0.78. Once k_1 is known, V_{MPP} can be computed with V_{OC} measured periodically by momentarily shutting down the power converter. However, this incurs some disadvantages, including temporary loss of power.

2.2.4 Fractional short circuit current

Fractional I_{SC} results from the fact that, under varying atmospheric conditions, I_{MPP} is approximately linearly related to the I_{SC} of the PV array.

$$I_{MPP} = k_2 I_{sc} \tag{4.5}$$

Where k_2 is a proportionality constant. Just like in the fractional V_{OC} technique, k_2 has to be determined according to the PV array in use. The constant k_2 is generally found to be between 0.78 and 0.92. Measuring I_{SC} during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that I_{SC} can be measured using a current sensor.

2.2.5 Fuzzy Logic Control

Microcontrollers have made using fuzzy logic control popular for MPPT over last decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity.

2.2.6 NeuralNetwork

Another technique of implementing MPPT which are also well adapted for microcontrollers is neural networks. Neural networks commonly have three layers: input, hidden, and output layers. The number nodes in each layer vary and are user-dependent. The input variables can be PV array parameters like V_{OC} and I_{SC} , atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP.

Table 2.1: Characteristics of different MPPT techniques

MPPT technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, current
Fractional V_{oc}	Medium	Low	Yes	Voltage
Fractional I_{sc}	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

2.3 Limitations of Perturb & Observealgorithm

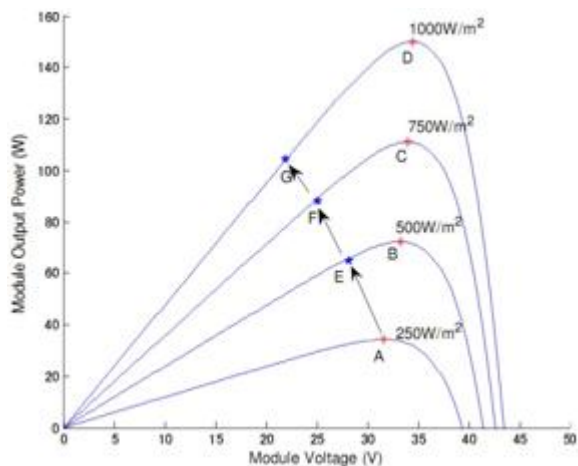


Figure 2.3.1 : Curve showing wrongtracking of MPP by P&O algorithm under rapidly varying irradiance

In a situation where the irradiance changes rapidly, the MPP also moves on the right hand side of the curve. The algorithm takes it as a change due to perturbation and in the next iteration it changes the direction of perturbation and hence goes away from the MPP as shown in the figure.

However, in this algorithm we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on

reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing in both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

2.4 Implementation of MPPT using a boost converter

The system uses a boost converter to obtain more practical uses out of the solar panel. The initially low voltage output is stepped up to a higher level using the boost converter, though the use of the converter does tend to introduce switching losses. The block diagram shown in Figure

2.4.1gives an overview of the required implementation

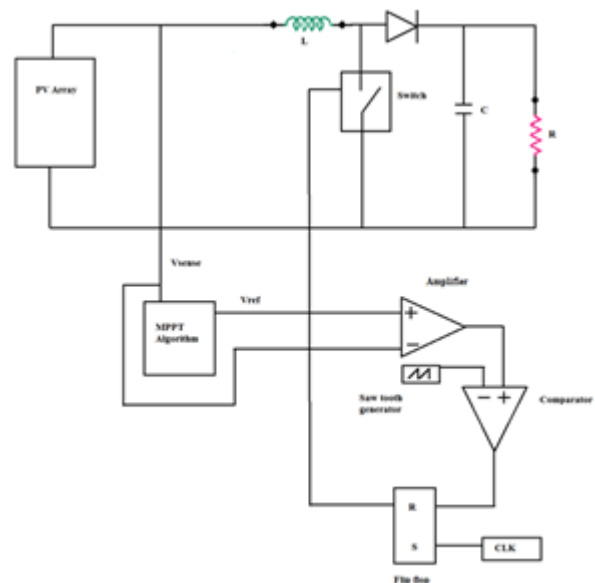


Figure 2.4.1: Requisite implementation for MPPT system

3. MPPT Interfacing

The controlled voltage source and the current source inverter have been used to interface the modeled panel with the rest of the system and the boost converter which are built using the PowerSystems module of MATLAB. The block diagram for the model shown in Figure3.1 is a simulation for the case where we obtain a varying voltage output. This model is used to highlight the difference between the power obtained on using an MPPT algorithm and the power obtained without using an MPPTalgorithm.

To compare the power output in both the cases stated above, the model is equipped with a manual switch as shown. When the switch is thrown to the left the circuit bypasses the MPPT algorithm and we obtain the desired power, voltage and current outputs through the respective scopes. Contrarily when the switch is thrown to the right, the embedded MPPT function block is included in the circuit and we obtain the desired outputs through the respectivescopes.

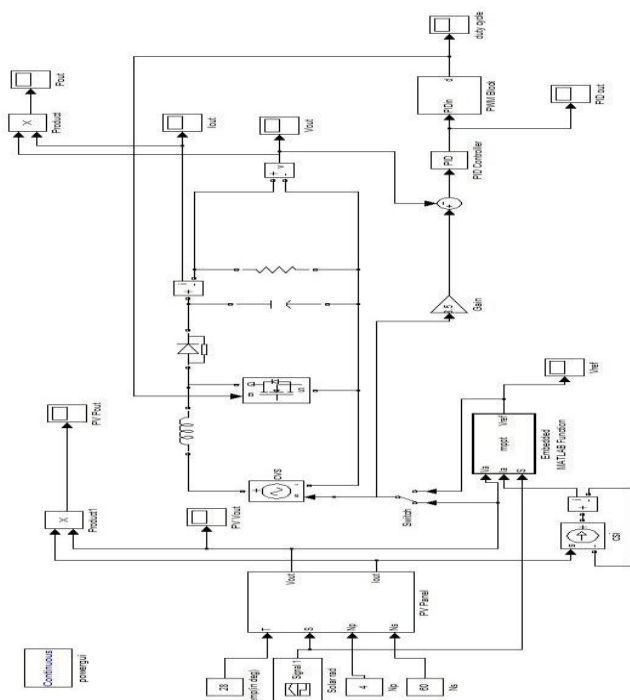


Figure 3.1: SIMULINK Model of MPPT system using P&O algorithm

4. Conclusion

The model shown in Figure 3.1 was simulated using SIMULINK and MATLAB. The simulation was first run with the switch on no MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load side was around 95 Watts (for a solar irradiation value of 85 Watts per sq. cm). It must be noted that the PV panel generated around 250 Watts power for this level of solar irradiation. Therefore, the conversion efficiency came out to be very low.

The simulation was then run with the switch on MPPT mode. This included the MPPT block in the circuit and the PI controller was fed the V_{ref} as calculated by the P&O algorithm. Under the same irradiation conditions, the PV panel continued to generate around 250 Watts power (Figure 6.8). In this case, however, the power obtained at the load side was found to be around 215 Watts, thus increasing the conversion efficiency.

The loss of power from the available 250 Watts generated by the PV panel can be explained by switching losses in the high frequency PWM switching circuit and the inductive and capacitive losses in the Boost Converter circuit.

Therefore, it was seen that using the Perturb & Observe MPPT technique increased the efficiency of the photovoltaic system by approximately 126% from an earlier output power of around 95 Watts to an obtained output power of around 215 Watts.

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