Maximum Power Point Tracking

Publish Date: Jul 07, 2009

Table of Contents

1. Overview

With the limitations of fossil fuels becoming more apparent, solar energy is emerging as the renewable energy source that could change the future. It is abundantly available and its usage does not harm the environment with greenhouse gas emissions. Although the technology to tap solar energy has existed since the 1970s, it presents several challenges. With the help of solar tracking and maximum power point tracking, engineers are working to meet the main challenge of improving the efficiency of solar energy systems.

The amount of electrical power generated by a photovoltaic system depends on solar irradiance (solar energy per unit area of the solar panel's surface) and other conditions such as temperature and cloud cover. The current and voltage at which a solar module generates the maximum power is known as the maximum power point. The location of the maximum power point is not known in advance.

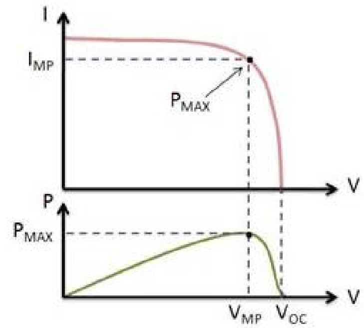

Figure 1. The current and voltage at which a solar module generates the maximum power is known as the maximum power point.

Maximum power point tracking (MPPT) modifies the electrical operating point of a solar energy system to ensure it generates the maximum amount of power. This involves finding the current or voltage of the solar panel at which maximum power can be generated. MPPT improves the electrical efficiency of a solar energy system, thus reducing the number of solar panels or arrays required to generate a desired output.

2. Theory Behind a Few Algorithms

You can use many algorithms to perform MPPT. Some of the important factors to consider when choosing a technique to perform MPPT are sensors used, ability of an algorithm to detect multiple maxima, costs, and convergence speed.

Sensors Used

For a large-scale application, the number of sensors you use can affect its complexity and accuracy. Often, for more precise MPPT, you may need to use more sensors. The number and type of sensors required depend largely on your MPPT technique.

Ability of an Algorithm to Detect Multiple Local Maxima

It is common for the irradiance levels at different points on a solar panel's surface to vary. This leads to multiple local maxima in one system. The efficiency and complexity of an algorithm determine if the true maximum power point or a local maximum power point is calculated. In the latter case, the maximum electrical power is not extracted from the solar panel.

Costs

The number of sensors as well as the type of hardware you use to monitor and control the electrical tracking system affect the cost of implementing it. The type of algorithm you use largely determines the resources required to set up this application.

Convergence Speed

For a high-performance MPPT system, the time taken to converge to the required operating voltage or current should be low. Depending on how fast you need to do this and your tracking system requirements, the system has to accordingly maintain the load at the maximum power point.

A few popular and effective MPPT algorithms are described below.

Perturb and Observe

The concept behind the "perturb and observe" method is to modify the operating voltage or current of the photovoltaic panel until you obtain maximum power from it. For example, if increasing the voltage to a cell increases the power output of a cell, the system increases the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreased to get back to the maximum power output value. This process continues until the maximum power point is reached. Thus, the power output value oscillates around a maximum power value until it stabilizes. Perturb and observe is the most commonly used MPPT method due to its ease of implementation.

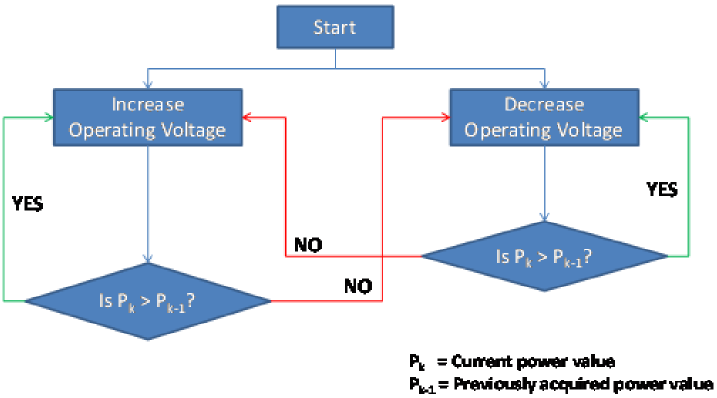

Figure 2. Flowchart for a Perturb and Observe Tracking System

One of the major drawbacks of the perturb and observe method is that the power obtained oscillates around the maximum power point in steady state operation. Also, this algorithm can track in the wrong direction under rapidly varying irradiance levels.

Incremental Conductance

Incremental conductance is a technique that takes advantage of the fact that the slope of the power-voltage curve is zero at the maximum power point. The slope of the power-voltage curve is positive at the left of the MPP and negative at the right of the MPP.

$$\frac{dP}{dV} = 0 \quad \text{at MPP}$$

$$\frac{dP}{dV} > 0 \quad \text{left of MPP} \qquad (1)$$

$$\frac{dP}{dV} < 0 \quad \text{right of MPP}$$

where dP = change in Power
dV = change in Voltage

As Power (P) = IV,

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V}$$

Therefore, the equations in (1) can be rewritten as

Figure 3. The slope of the power-voltage curve is positive at the left of the MPP and negative at the right of the MPP.

You can find the MPP by comparing the instantaneous conductance (I/V) to the incremental conductance ($\Delta I / \Delta V$). Once you have the MPP, the solar module maintains this power point unless a change in ΔI occurs. This usually happens when there is a change in the MPP and in the ambient conditions. If this happens, the algorithm modifies the operating voltage until you reach the new MPP.

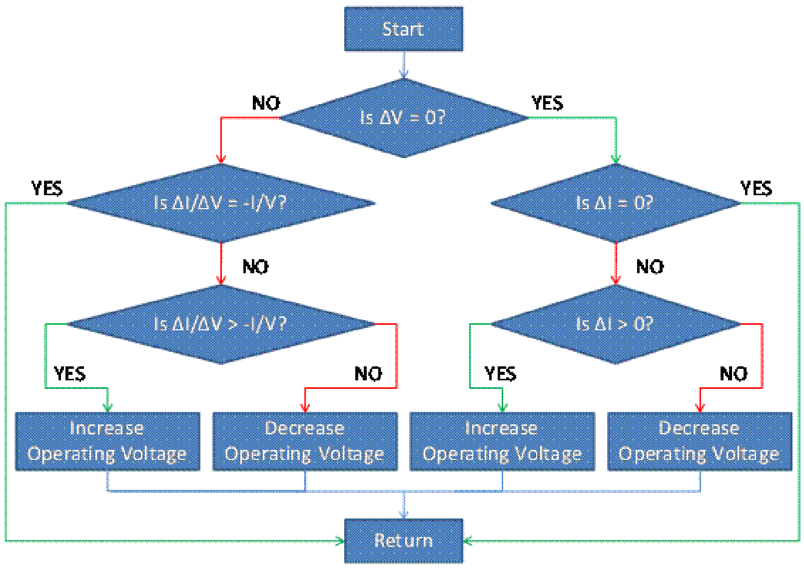

Figure 4. Flowchart for an Incremental Conductance Tracking System

This technique has an advantage over the perturb and observe method because it can determine when you reach the MPP without having to oscillate around this value. It can also perform MPPT under rapidly increasing and decreasing irradiance conditions with higher accuracy than the perturb and observe method. The disadvantage of this method is that it takes longer to compute the MPP and it slows down the sampling frequency of the operating voltage and current.

Load I or V Maximization

When a photovoltaic module is connected to a power converter, maximizing the power of the solar module maximizes the output power at the load of the converter. This also implies that increasing the output power of the DC-to-DC converter or load should increase the power generated by the solar module.

Most loads are similar to a voltage source, a current source, a resistor, or a combination of these. For a voltage source load, you should maximize the load current to generate the maximum output power. Similarly, for a current source load, you can increase the load voltage to generate more power. The operating point of the system occurs at the intersection of the electrical characteristics of the solar panel and that of the load. Figure 5 shows the maximum power point for a resistive load.

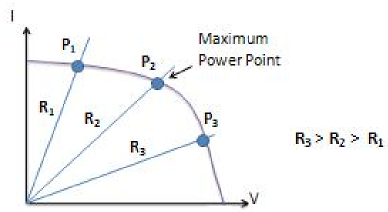

Figure 5. I-V Curve Showing Maximum Power Point at Specific Resistive Load

3. Using NI CompactRIO for MPPT

To implement MPPT in the field, consider the following factors. The maximum power point tracker must be able to withstand diverse weather conditions. It should also be able to monitor current and/or voltage readings from multiple sensors. In implementing many MPPT algorithms, it is extremely useful to be able to sense current and voltage values and accordingly control the operating voltage or current as quickly as possible. This improves the speed at which MPP is reached, thus increasing the efficiency of the solar energy system.

NI CompactRIO is an ideal platform to satisfy these requirements and provide additional functionality. You can use it to simultaneously monitor and control the electrical characteristics of a solar panel. The real-time controller incorporated in an NI cRIO-9074 CompactRIO system provides the ability to implement an MPPT algorithm deterministically. The ruggedness and compactness of this device make it a reliable technology for applications in the field.

Figure 6. The NI cRIO-9074 integrated system combines a real-time processor and a reconfigurable field-programmable gate array (FPGA) within the same chassis for embedded machine control and monitoring applications.

With the NI LabVIEW Real-Time Module, you can develop custom applications on the CompactRIO system to achieve greater flexibility when implementing tracking systems and to simplify algorithm engineering. Because you can deploy stand-alone applications on CompactRIO, you can also implement long-term data logging and system control and monitoring. This functionality is valuable in cases where you need to use historical data to estimate overall system efficiency. With the high-performance field-programmable gate array (FPGA) chassis on this device, you can configure timing for an application and achieve faster response times at the hardware level.

For analog voltage input readings, you can use the NI 9221 analog input module. This module helps you monitor the voltage across the solar panel to calculate the power generated. Use the NI 9263 analog output module to send analog output signals to control the operating voltage. You can use these modules not only to implement MPPT but also to monitor the electrical health of a tracking system.

Figure 7. NI 9221 Analog Input Module

Figure 8. NI 9263 Analog Output Module

Ambient Conditions

Ambient conditions play a major role in the performance of a solar energy system. From uneven distribution of light on a solar panel to the surrounding temperature of a solar cell, they can significantly affect the power generated by a system. To monitor conditions such as temperature, humidity, and pressure, NI offers several C Series modules, such as the NI 9211 thermocouple input module, that you can use in CompactRIO systems.

Figure 9. NI 9211 Thermocouple Input Module