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Study of Maximum Power Point Tracking Using Perturb and Observe Method

Sonali Surawdhaniwar and Ritesh Diwan
Raipur Institute of Technology, Raipur, Chhattisgarh, India.

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ABSTRACT

The need for renewable energy sources is on the rise because of the acute energy crisis in the world today. India plans to produce 20 Gigawatts of Solar power by the year 2020, whereas we have only realized less than half a Gigawatt of our potential as of March 2010. 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. To maximize a photovoltaic (PV) system's output power, continuously tracking the maximum power point (MPP) of the system is necessary. Maximum power point tracking (MPPT) is a technique that grid tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more solar panels. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Maximum power point tracking (MPPT) algorithms provide the theoretical means to achieve the MPP of solar panels; these algorithms can be realized in many different forms of hardware and software.

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Introduction

The need for Renewable Energy

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 [1]. 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.

Different sources of Renewable Energy

Wind power

Wind turbines can be used to harness the energy available in airflows. Current day turbines range from around 600 kW to 5 MW [2] of rated power. Since the power output is a function of the cube of the wind speed, it increases rapidly with an increase in available wind velocity. Recent advancements have led to aerofoil wind turbines, which are more efficient due to a better aerodynamic structure.

Solar power

The tapping of solar energy owes its origins to the British astronomer John Herschel [3] who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells [3] or with concentrating solar power plants.

Photovoltaic

Photovoltaic (PV) converts sunlight directly into electricity, shown in figure 1.1

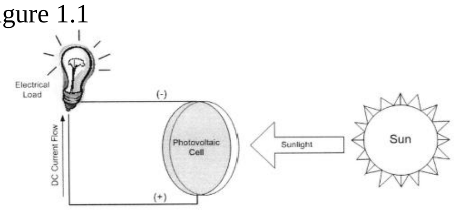

Figure1.1 Working of Photovoltaic

PV cells are made of semi-conducting materials similar to those used in computer chips. When these materials absorb sunlight, the solar energy knocks electron loose from their atoms, allowing the electrons to flow through the material to produce electricity [4].

Renewable Energy trends across the globe

The current trend across developed economies tips the scale in favor of Renewable Energy. For the last three years, the continents of North America and Europe have embraced more renewable power capacity as compared to conventional power capacity. Renewables accounted for 60% of the newly installed power capacity in Europe in 2009 and nearly 20% of the annual power production [5].

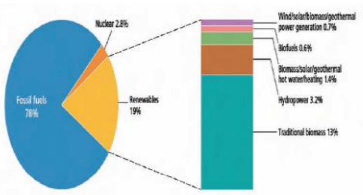

Figure1.2 Global energy consumption in the year 2008

Tele:
E-mail addresses: sonali.rit@gmail.com

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As can be seen from the figure 1.2, wind and biomass occupy a major share of the current renewable energy consumption. Recent advancements in solar photovoltaic technology and constant incubation of projects in countries like Germany and Spain have brought around tremendous growth in the solar PV market as well, which is projected to surpass other renewable energy sources in the coming years.

By 2009, more than 85 countries had some policy target to achieve a predetermined share of their power capacity through renewables. This was an increase from around 45 countries in 2005. Most of the targets are also very ambitious, landing in the range of 30-90% share of national production through renewable [6].

In this paper we present a detailed study of Maximum Power Point Tracking (MPPT). Maximum Power Point is tracked using PV modules which work on photovoltaic effect. Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power. The analysis of PV Model of the cell is described below [7]. A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array.

Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.

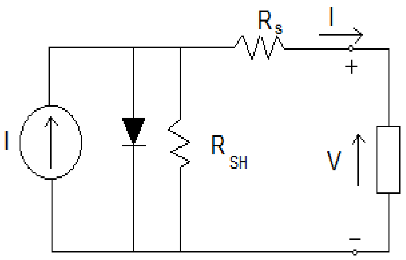


Figure 1.3: Single diode model of a PV cell

Where

current source (I) along with a diode and series resistance (Rs). The shunt resistance (RSH) in parallel is very high has a negligible effect and can be neglected. The output current from the photovoltaic array is

I=Isc – Id 1.1

Id= Io (eqVd/kT - 1) 1.2

where Io is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K)

From eq. 2.1 and 2.2

I = Isc – Io (eqVd/kT - 1) 1.3

Using suitable approximations,

I = Isc – Io (eq((V+IRs)/nkT) - 1) 1.4

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor. In order to model the solar panel accurately we can use two diode model but in our project our scope of study is limited to the single diode model. Also, the shunt resistance is very high and can be neglected during the course of our study.

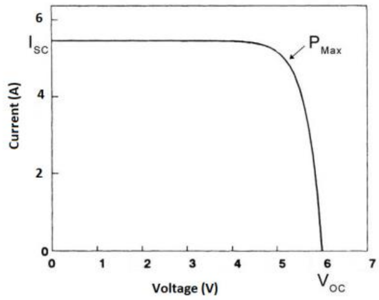


Figure 1.4: I-V characteristics of a solar panel

The I-V characteristics of a typical solar cell are as shown in the Figure1.4. When the voltage and the current characteristics are multiplied we get the P-V characteristics as shown in Figure 1.5. The point indicated as MPP is the point at which the panel power output is maximum.

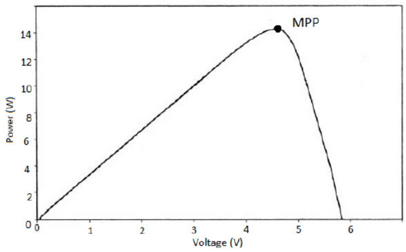


Figure 1.5: PV Characteristic curve of Photovoltaic cell

In figure 1.6 the I-V characteristics of solar cell only for a certain insolation G_a and a certain cell temperature T_c are illustrated. The influence of cell insolation G_a and a certain cell temperature T_c on the cell characteristics is presented in Figure 1.6 and Figure 1.7

Figure 1.7 shows the open circuit voltage increases slightly with the ambient irradiation, while the short circuit current is a linear function of ambient irradiation[117_1014_1 pb]

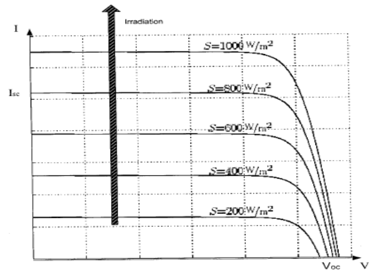


Figure 1.6 Influence of Ambient Irradiation on PV Cells

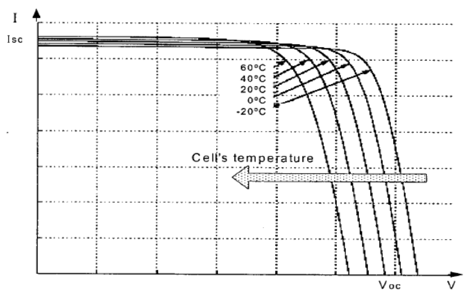


Figure 1.7 Effect of Cell Temperature on Cell's Characteristics

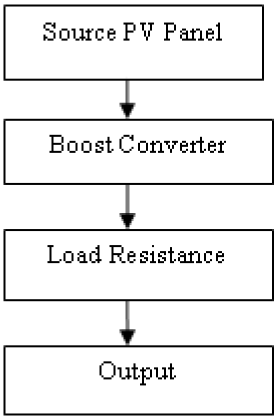
The parameters effecting MPP are shown above. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. 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.

There are different techniques used to track the maximum power point 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

Methodology

Step1:



. Figure 1.8 Basics of MPPT Technique

As shown in Figure 1.8 the first block is source i.e Solar Panel. There are some materials, which are photo sensitive and they find a place in photo voltaic conversion. A junction of materials, which have different electrical properties semiconductors are used in solar cells, provides the electrical field in most solar cells. Semiconductors are a class of materials with conductivity somewhere between metals and insulators. Solar cells are manufactured from monocrystalline materials. Low cost cells are round because they are made from sheets, which are cut from monocrystalline rods as they are pulled from the melt. Joining p and n type material in to a single crystal makes the cross section of a silicon solar cell.

Step 2:

The Output from this is fed to the boost converter [8]. A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. 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. 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 output voltage equation of boost converter is stated below:

$$\frac{V_o}{V_i} = \frac{1}{1 - D}$$

Where

V_o is the output voltage

V_i is the input voltage

D is the duty cycle, defined as

$$D = 1 - \frac{V_i}{V_o}$$

Step 3:

The load resistance is placed at the output, and the output is obtained as a variable dc voltage.

Step 4:

The simulation result is shown at the output.

Result Analysis

Figure 1.9 (a) Input Voltage waveform

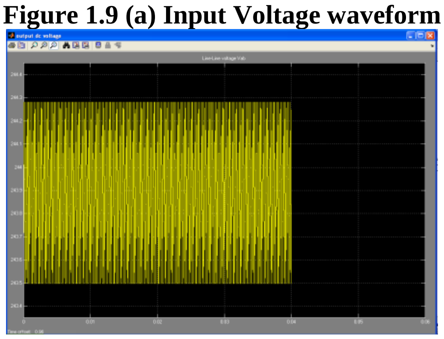


Figure 1.9 (b) Output Voltage Waveform

Figure (a) shows the input voltage from the PV module. Input voltage of 42.956 V is provided at the input. The output from the load resistance after being boosted up is shown in Figure (b).

The entire system has been modeled on MATLAB R 2006a and Simulink. The inputs to the solar PV panel are the current and temperature. The simulation is favorable out for series connection of PV cells.

The Boost Converter consisting of an IGBT instead of diode is controlled using the pulse generator. At the output various values of voltages can be obtained by varying the pulse width of the pulse generator.

If we vary the pulse width of the pulse generator various voltage range at the output can be obtained, as listed in the table below in Table 1.

Conclusion

The results shown in this paper are the basic requirements for the MPPT. As mentioned above amongst the various methods the study shown here will be extended by opting Perturb and Observe Method (P&O).

The main contribution of this thesis is tracking the maximum power point using a closed loop system consisting of some power electronic devices such as boost converter, rectifier and PV module as input device. Instead of using semiconductor devices live diodes IGBT's will be used.

Future scope of the work

In future, this approach can be applied for tracking the Maximum Power Point without using any type of controller.

Hence, reducing the cost and increasing the efficiency of the system.

The basic advantage of only using Perturb and Observe method is that when it is properly optimized it can offer very high Maximum Power Point Tracking efficiency, which is highly competitive against other Maximum Power Point Tracking algorithms.

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