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PV Cells Powered Home Based On MPPT

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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. Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation. In order to continuously harvest maximum power from the solar panels, they have to operate at their MPP despite the inevitable changes in the environment. The main hindrance for the penetration and reach of solar PV systems is their low efficiency and high capital cost. One very common MPPT technique is to compare the PV array voltage with a constant reference voltage, which corresponds to the PV voltage at the maximum power point, under specific atmospheric conditions. The resulting difference signal (error signal) is used to drive a power conditioner, which interfaces the PV array to the load. In this paper, maximum obtainable solar power from a PV module is developed and the energy is used for powering a home which comprises of mostly AC applications.

KeyWords: Solar PV cell, Standalone PV system, MPPT, Incremental Conductance.

1. INTRODUCTION

The photovoltaic (PV) domain provide one of the most efficient ways of producing energy, with real perspectives in the future, considering the actual situation of the classical power resources around the world. It becomes a real problem the fact that we have insufficient supplies of this kind of power resources for insuring the world's needs.

Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP. The principle of maximum power point tracking (MPPT) is to place a convertor between the load and the PV array, as shown in Fig. 1 [1-4], to regulate the array output voltage (or current) so that the maximum available power is extracted [5]. A power converter is necessary to adjust the energy flow from the PV array to the load [1]. In the method described in [2], the power converter is controlled using the PV array output power [3]. Voltage and current sensing allow measuring the power. If the value of power is available can be decided if go up or down on the power curve [1].

The PV array is an unregulated dc power source, which has to be properly conditioned in order to interface it to the grid. The dc/dc converter is present at the PV array output for MPPT purposes, i.e. for extracting the maximum available power for a given insolation level [5]. The step-down dc/dc converter (buck converter) is used as a dc transformer which can match the PV array optimum load by changing its switching duty ratio (D) [6]. In general, the operation of an ideal buck converter [6-9] is described by (1)

$$V_{out} / V_{in} = I_{in} / I_{out} = D \quad (1)$$

where Vin and Iin are the voltage and current at the PV array
side (i.e. the input of the buck converter), and Vout and Iout are the voltage and current at the load side (i.e. the output of the buck converter).

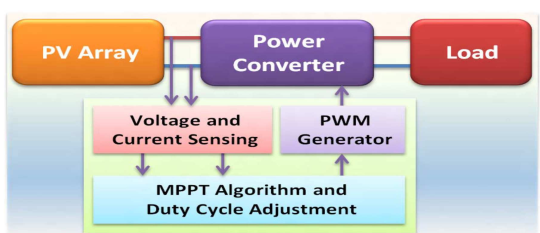

Figure 1: Block diagram of a PV array connected to the load.

2. DESCRIPTION OF PV ARRAY

2.1 Equivalent Circuit of Solar Cell

The equivalent circuit of a PV cell is demonstrated below in Fig.2. 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

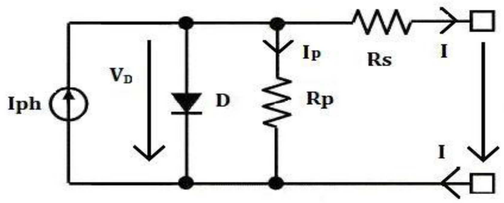

Figure 2: Equivalent Circuit of a PV Cell

of flow of electrons from n to p junction and parallel resistance is due to the leakage current.

In this model we consider a 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 …..………...(2)

Id = Io (eqvd/kT-1)……..(3)

where Io is the reverse saturation current of the diode, q is the electron charge, Vd 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 equations 2 and 3,
I = Isc – Io (eqvd/kT-1)…(4)

2.2 Characteristics of PV Array

For the analysis of Photovoltaic array, two characteristics are most important i.e. Current Voltage (I-V) characteristics and Power Voltage (P-V) characteristics. From Fig. 2, the current generated in the solar cell by the current source (Iph) is proportional to the amount of light falling on it. When there is no load connected to the output Vo almost all of the generated current flows through diode D. The resistors Rs and RSH represent small losses due to the connections and leakage respectively. There is very little change in Voc for most instances of load current. However, if a load is connected to the output then the load current draws current away from the diode D. As the load current increases more and more current is diverted away from the diode D. So, as the output load varies so too does the output current, while the output voltage Voc remains largely constant. That is until so much current is being drawn by the load that diode D becomes insufficiently biased and the voltage across it diminishes with increase in load. This results in I-V curve as shown in Fig. 3.

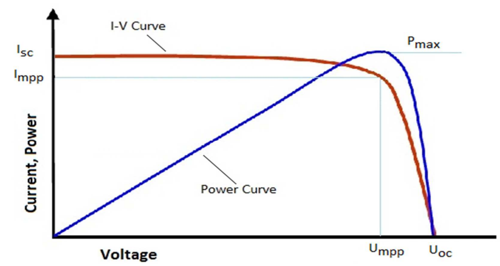

Figure 3: I-V and P-V curve of a solar cell.

3. MPPT METHODS

A MPTT is used for extracting the maximum power from the solar PV module and transferring maximum power from the solar PV module to the load. There are a large number of algorithms which are able to track the MPPs. Some of them are simple such as voltage and current feedback based and some are more complicated such as perturbations and observations (P&O) or incremental in conductance method, fuzzy logic method etc.

A particular MPPT technique is chosen based on the factors like simplicity, cost, quick tracking under varying atmospheric conditions, small power output locations etc. MPPT techniques which automatically find the voltage or current at which maximum power point at which a PV module should operate. Under partial shading conditions, it is possible to have multiple local maximum at the same points so maximum power point shifts according to it. Most MPPT techniques would automatically respond to changes in both irradiance and temperature.

So the most suitable technique for the application to power a home consisting AC loads will be Incremental Conductance since power output obtained from incremental conductance method is high us compared to other methods under varying atmospheric conditions. The goal when using PV arrays in residential areas is to minimize the payback time and to do so, it is essential to constantly and quickly track the MPP. Since partial shading (from trees and other buildings) can be an issue, the MPPT should be capable of bypassing multiple local maxima. Therefore, Incremental Conductance is found to be suitable.

3.1 Incremental Conductance Algorithm

The incremental conductance algorithm is based on the differentiation of the PV array power versus voltage curve as in (5) [1, 9].

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} = I + V\frac{dI}{dV} \quad \text{.......(5)}$$

$$\frac{dP}{dV} = 0 => I + V\frac{dI}{dV} = 0 => -\frac{I}{V} = \frac{dI}{dV} \quad \text{........(6)}$$

where I/V represent the instantaneous conductance of PV array and dI/dV is the incremental conductance (instantaneous change in conductance). The comparison of those two quantities tells us on which side of the MPP we are currently operating.

The analysis of the derivative, presented in (7), can determine whether the PV array is operating at MPP or far from it, as is shown in Fig. 4 [9, 10].

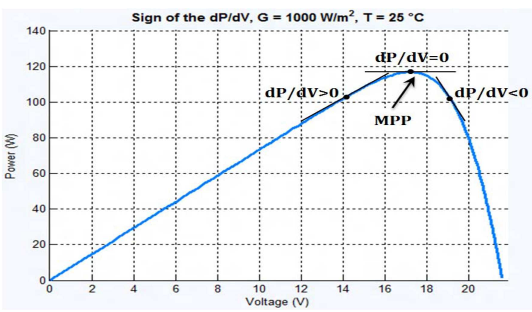

Figure 4. Sign of the dP/dV at different positions on the P-V characteristic curve of PV array

dP/dV>0,for V<Vmpp
dP/dV=0,for V=Vmpp
dP/dV<0,for V>Vmpp ....(7)

The principle of this algorithm [1, 9, 11, 12] is described in Flow chart presented in Fig. 5, where the triangle represent decision making.

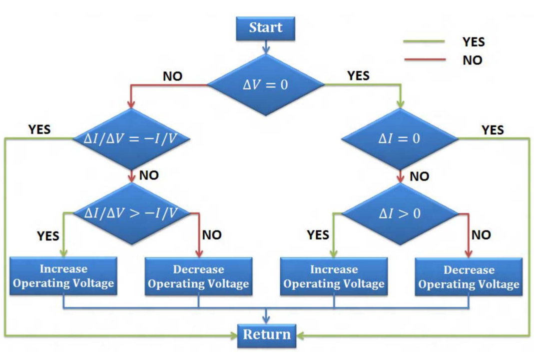

Figure 5.Flow chart of the incremental conductance algorithm.

4. POWER CONVERTER

When proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. The efficiency of switch-mode dc–dc converters is widely discussed in [1]. Most switching-mode power supplies are well designed to function with high efficiency. Among all the topologies available, both Cuk and buck–boost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. Although the buck–boost configuration is cheaper than the Cuk one, some disadvantages, such as discontinuous input current, high peak currents in power components, and poor transient response, make it less efficient. On the other hand, the Cuk converter has low switching losses and the highest efficiency among non isolated dc–dc converters.

It can also provide a better output-current characteristic due to the inductor on the output stage. Thus, the Cuk configuration is a proper converter to be employed in designing the MPPT. Fig. 6 and 7 show a Cuk converter and its operating modes, which is used as the power stage interface between the PV module and the load. The Cuk converter has two modes of operation. The first mode of operation is when the switch is closed (ON), and it is conducting as a short circuit. In this mode, the capacitor releases energy to the output. The equations for the switch conduction mode are as follows:

$vL1 = Vg$ ....(8)
$vL2 = -v1 - v2$...........(9)
$ic1 = i2$ ....(10)
$ic2 = i2 - v2\ R$.......... (11)

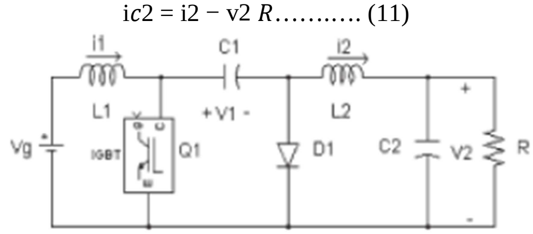

Figure. 6 Electrical circuit of the Cuk converter used as the PV power-stage interface

On the second operating mode when the switch is open (OFF), the diode is forward-biased and conducting energy to the output. Capacitor C1 is charging from the input. The equations for this mode of operation are as follows:

$vL1 = Vg - v1$........(12)
$vL2 = -v2$............(13)
$ic1 = i1$................(14)
$iC2=i2-v2/R$.........(15)

The principles of Cuk converter operating conditions state that the average values of the periodic inductor voltage and capacitor current waveforms are zero when the converter operates in steady state.

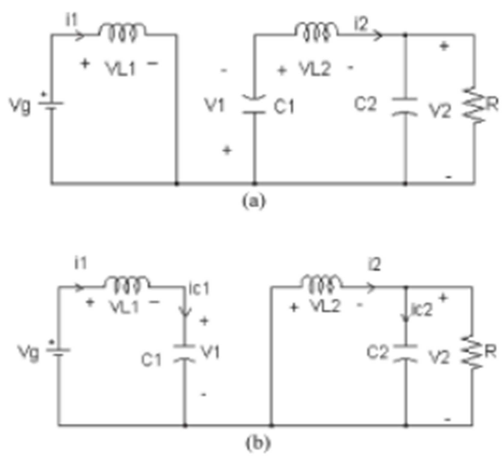

Figure. 7 Cuk converters with (a) switch ON and (b) switch OFF

The relations between output and input currents and voltages are given in the following:

$$\frac{\text{Vo}}{\text{Vin}} = -\left(\frac{\text{D}}{1-\text{D}}\right)\ldots\ldots(16)$$

$$\frac{\text{Iin}}{\text{Io}} = -\left(\frac{\text{D}}{1-\text{D}}\right)\ldots\ldots.(17)$$

5. ADVANTAGES AND DISADVANTAGES

There has always been debate about whether or not PV systems are more suitable on a smaller scale, providing power directly to users from on-site systems. The advantages and disadvantages of solar energy which powers PV system can be enumerated as follows:

5.1 Advantages of Solar Energy:

1. Solar energy is one of the energies that is abundantly available and will last forever whereas it is estimated that the world's oil reserves will last for 30 to 40 years.
2. Once a solar panel is installed, solar energy can be produced free of charge.
3. Solar energy causes no pollution.
4. A silent energy provider as the solar cells do not create sounds while extracting heat from the sun and producing electricity.
5. The solar energy system can work independently without any connection and can be utilized and installed in remote areas too where there is no sign of electricity.
6. Very little maintenance is needed to keep solar cells running. There are no moving parts in a solar cell which makes it impossible to really damage them.
7. In the long term, there can be a high return on investment due to the amount of free energy a solar panel can produce, it is estimated that the average household will see 50% of their energy coming in from solar panels.

5.2 Disadvantages of Solar Energy:

1. Solar panels can be expensive to install resulting in a time-lag of many years for savings on energy bills to match initial investments.
2. Electricity generation depends entirely on the area's exposure to sunlight; this could be limited by its weather like sunny, rainy, cloudy, etc. So, there is no consistency because the incident solar energy from sun on earth is intermittent.
3. Solar power stations do not match the power output of similar sized conventional power stations; they can also be very expensive to build.
4. Solar power is used to charge batteries so that solar powered devices can be used at night. The batteries can often be large and heavy, taking up space and needing to be replaced from time to time.
5. The solar panel produces an output that is DC (direct current) and the power supply in homes usually runs on AC (alternating current), so additional circuitry for DC-AC conversion is required if AC loads are to be connected .
6. Installation of solar panels require large area so that the system can provide good amount of electricity. This is a great disadvantage in places where the area is small.
7. Pollution can be a hindrance to solar panels as pollution can degrade the efficiency of the photovoltaic cell.

6. CONCLUSION

Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. There are different techniques for MPPT but amongst 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.

In this paper, incremental conductance, a MPPT technique is used to electrify a remote location. Standalone system can be used at any location to harness electricity from solar energy, even at any remote place which is quite away from electrification.

7. SCOPE FOR FUTUREWORK

- When the electricity is generated it is stored in the batteries for small period this consumption period is less, so it should be improved for longer time.
- Maintainance cost should be minimized
- Production of electricity in cloudy days should be increased.
- Costing of overall system is more so it is to be minimized.

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