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Maximum Power Point Tracker for PV Solar Panels Using SEPIC Converter

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Abstract: ***Photovoltaic (PV) energy is one of the most important renewable energy sources. Maximum Power Point Tracking (MPPT) techniques should be used in photovoltaic systems to maximize the PV panel output power by tracking continuously the maximum power point which depends on panel's temperature and on irradiance conditions. Incremental conductance control method has been used as MPPT algorithm. The methodology is based on connecting a pulse width modulated dc/dc SEPIC converter, which is controlled by a microprocessor based unit. The SEPIC converter is one of the buck boost converters which maintain the output voltage as constant irrespective of the solar isolation level. By adjusting the switching frequency of the converter the maximum power point has been achieved. The main difference between the method used in the proposed MPPT systems and other technique used in the past is that PV array output power is used to directly control the dc/dc converter thus reducing the complexity of the system. The resulting system has high efficiency, low cost and can be easily modified. The tracking capability has been verified experimentally with a 20 W solar panel under a controlled experimental setup. The SEPIC converter and their control strategies has been analyzed and simulated using Simulink/Matlab software.***

Keyword: Maximum Power Point Tracking, Microprocessor, PV Module, SEPIC Converter.

1. Introduction

Significant progress has been made over the last few years in the research and development of renewable energy systems such as wind, sea wave and solar energy systems. Among these resources, solar energy is considered nowadays as one of the most reliable, daily available, and environment friendly renewable energy source.

Solar panel is the fundamental energy conversion component of photovoltaic (PV) systems. It has been used in many applications, such as aerospace industries, electric vehicles, communication equipment, etc. As the solar panels are relatively expensive, much research work has been conducted to improve the utilization of solar energy. Physically, the power supplied by the panels depends on many extrinsic factors, such as insolation (incident solar radiation) levels, temperature, and load condition. Thus, a solar panel is typically rated at an insolation level together with a specified temperature, such as 1000 W/m at 25C. Its electrical power output usually increases linearly with the insolation(incident solar radiation) and decreases with the cell/ambient temperature.

However, solar energy systems generally suffer from their low efficiencies and high costs. In order to overcome these drawbacks, maximum power should be extracted from the PV panel using different MPPT techniques to optimize the efficiency of overall PV system. MPPT is a real-time control scheme applied to the PV power converter in order to extract the maximum power possible from the PV panel.

A Maximum Power Point Tracking algorithm is required to increase the efficiency of the solar panel. MPPT is a method that compensates for that changing voltage and current characteristic of solar panel and maximum utilization of solar energy from panel. MPPT is point where power is drawn from solar panel maximum, then efficiency of solar cell will be increase. Many maximum power point tracking algorithm are developed.

2. Maximum Power Point Tracking Algorithms

As we know power conversion efficiency of solar module very low. To increase efficiency of solar module proper impedance matching requires to increase efficiency of solar module. MPPT algorithms are vary due to simplicity, efficiency, tracking speed, sensor required and cost. It is seen that the V-I characteristics of the solar module is nonlinear and extremely affected by the solar irradiation and temperature. To maximize the output power of solar module, it has to be operated at fixed value of load resistance. This requires a separate power converter circuit for the MPPT. In our design, a SEPIC type DC-DC converter is used to extract the maximum power from solar module. Following algorithms for maximum power point tracking are listed below.

- Constant voltage MPPT
- Fractional open circuit voltage MPPT
- Fractional short circuit current MPPT
- Perturb and observe (P&O) MPPT
- Incremental conductance (INC) MPPT

2.1 Constant voltage MPPT

The Constant Voltage (CV) algorithm is the simplest MPPT control method. The operating point of the PV array is kept near the MPP by regulating the array voltage and matching it to a fixed reference voltage *Vref*. The *Vref* value is set equal to the *VMPP* of the characteristic PV module (see Table 1)or to another calculated best fixed voltage. This method assumes that individual insulation and temperature variations on the array are insignificant, and that the constant reference voltage is an adequate approximation of the true MPP.

2.2 Fractional open circuit voltage MPPT

Fractional open circuit (FOCV) fast and simple way of MPPT tracking. This algorithm not able to track exact maximum power point. Reason is that when irradiation level and temperature of module changes correspondingly MPP point change but this algorithm work on fixed value of voltage at MPP. This algorithm work on principle that voltage at MPP is nearly equal to open circuit voltage of module by factor N.$Vmpp = N * Voc$ Where N is fixed and its value getting from data sheet of PV module. Value of N basically braying from .68 to .80 that depend on type of module used. Fractional open circuit voltage only require sensing of panel voltage that also we can sense by using simple voltage divider circuit across the panel. So fractional open circuit basically require no voltage sensor by using voltage divider circuit we can directly sense module voltage and apply to microcontroller. So we can conclude that implementation cost of fractional open circuit quit low but it is not capable for tracking exact MPPT

2.3 Fractional short circuit current MPPT

This method also work on same principle of fractional open circuit voltage (FOCV). Similar to (FOCV) it is also not capable to track exact MPPT because it is also work on fixed value of current. Imp not change according to irradiation level and temperature changes. $Imp = N * Isc$ Where value of N calculated according to data sheet of panel. Values of N normally vary from .82 to .94 that is depend on type of panel used. Fractional short circuit current (FSCC) require sensing of panel current. Current we cannot sense directly across the panel so current sensor is require to sense panel current. Generally hall effect based current sensor are used for MPP tracking due to its accuracy and transient response that use of current sensor make system cost effective. So we can conclude that implementation cost of fractional short circuit high and it is not capable for tracking exact MPPT

2.4 Perturb and Observe (P&O) MPPT

Perturb and observe (P&O) is one of the famous algorithm due to its simplicity used for maximum power point tracking. This algorithm based on voltage and current sensing based used to track MPP. In this controller require calculation for power and voltage to track MPP. In this voltage is perturbed in one direction and if power is continuous to increase then algorithm keep on perturb in same direction. If new power is less than previous power then perturbed in opposite direction. When module power reach at MPP there is oscillation around MPP point. However, this approach is unsuitable for applications in rapidly changing atmospheric conditions.

2.5 Incremental Conductance (INC) MPPT

In this technique, the controller measures incremental change in module voltage and current to observe the effect of a power change. This method requires more calculation but can track fast than perturb and observe algorithm (P&O). Under abruptly change in irradiation level as maximum power point changes continuously, P&O receipts it as a change in MPP due to perturb rather than that of isolation and sometimes ends up in calculating incorrect MPP. However this problem get avoided by incremental conductance (INC).In this method algorithm takes two sample of voltage and current to maximize power from solar module. However due to effectiveness and complexity of incremental conductance algorithm very high compare to perturb and observe. Like the P&O algorithm, it can produce oscillations in power output. This study on realizing MPPT by improved incremental conductance method with variable step-size . So these are two advantage of incremental conductance method. So in our implementation to achieve high efficiency this method utilize incremental conductance (dI/dV) of the photovoltaic array to calculate the sign of the change in power with respect to voltage (dP/dV). The controller maintains this voltage till the isolation changes and the process is repeated. Flow chart of incremental conductance is shown in Figure2.1

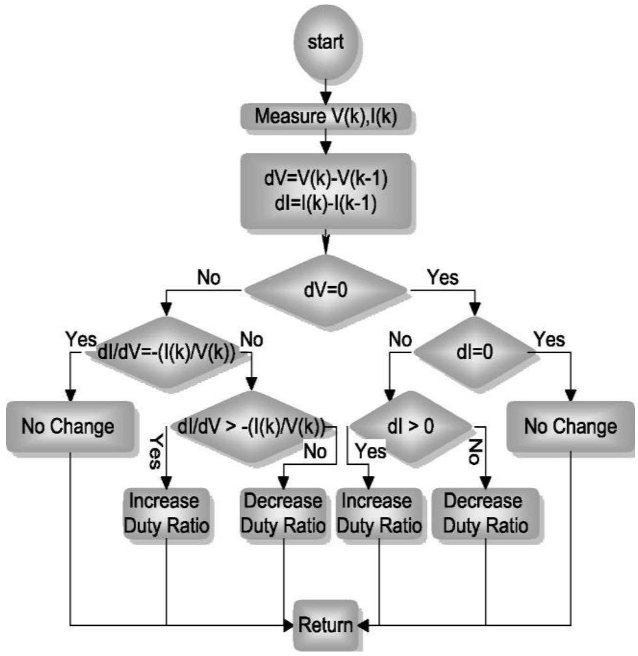

Figure 2.1: Flow chart of Incremental Conductance (INC) algorithm

3. Proposed System

This proposed work focuses on SEPIC dc-dc converter as voltage level control using Incremental conductance MPPT method for solar PV systems

The solar power which can be obtained from solar cell cannot be utilized directly. It is usually stored in the battery and inverter circuit and further it can be used as AC. But the output voltage as well as power from the solar cell depends upon the illumination and intensity of the light. If the light intensity is very low it may produce very low output voltage. The lower output voltage from the solar cell may not charge the battery and the power is wasted. Here an intermediate stage of converter called SEPIC is used to boost the lower output voltage from the solar cell and also buck the voltage if the light intensity is high. The block diagram of proposed system is shown in Figure

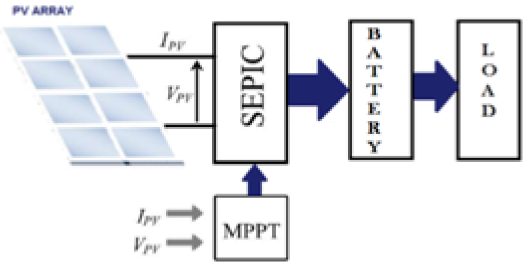

Figure 3.1: Block diagram of proposed system

A DC-DC converter with simpler structure and higher efficiency has been an active research topic in the power electronics. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output. Non-inverting buck-boost topologies require more active components. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. In this proposed system, a prototype SEPIC converter is designed to Charge the battery from the solar panel.

In solar cells, a number of PV modules are arranged in series and parallel to meet the energy requirements. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on 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. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors. Fig3.2. shows the single diode model of PV cell

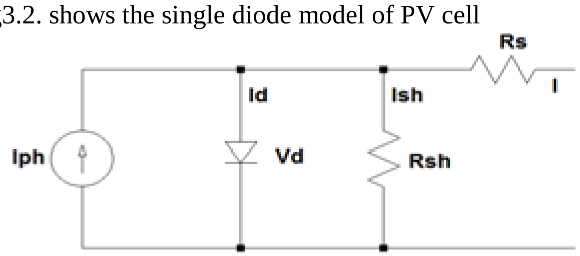

Figure 3.2: Single diode model of a solar cell

Where **I**ph = Photon Current, Id = Diode Current, I = PV Current .V = PV Voltage ,Vd=Diode Voltage,Rs = Series Resistance ,Rsh = Shunt Resistance Rsh is very high compared with Rs and has a negligible effect in the output current. The output current from the photovoltaic array is Id=Isat*[exp(Vd/VT) -1] where:Id = diode cuurent (A) Vd = diode voltage (V) Isat = diode saturation current (A) ,VT = temperature voltage = k*T/q*Qd*Ncell*Nser,T = cell temperature (K),k = Boltzman constant = 1.3806e-23 J.K^-1 ,q = electron charge = 1.6022e-19 C,Qd = diode quality factor,Ncell= number of series-connected cells per module,Nser = number of series-connected modules per string.

3.1Characteristics of a PV cell

In a PV characteristic there are basically three important points viz. open circuit voltage (), short circuit current () and maximum power point (). The maximum power that can be extracted from a PV cell are at the maximum power points. Usually manufacturers provide these parameters in their datasheets for a particular PV cell or module. By using these parameters we can build a simple model but for more information is required for designing an accurate model

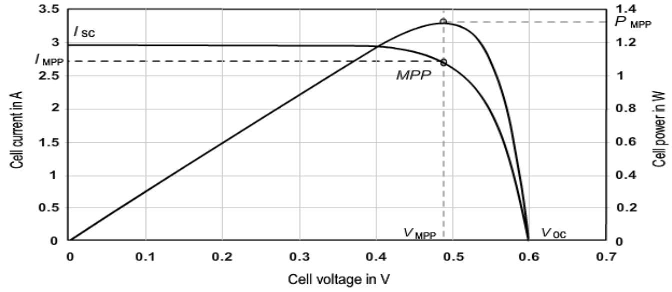

Figure 3.3: characteristics of a PV cell

The VI characteristics of a typical solar cell are as shown in Fig.3.3. The PV characteristics are obtained by the voltage and the current characteristics as shown in below Fig.3.4. The point indicated as MPPT is the point at which the panel power output is maximum.

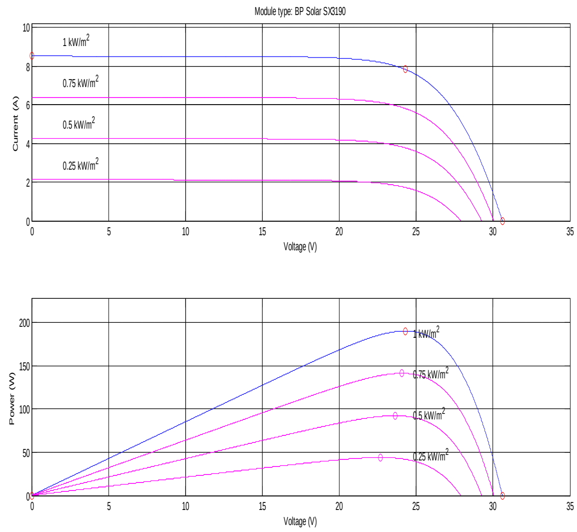

Figure 3.4: VI and P V characteristics of a one model at25^{0}C

4. SEPIC Converter

Single-ended primary inductor converter (SEPIC) is a type of DC-DC converter, that allows the voltage at its output to be more than, less than, or equal to that at its input. The output voltage of the SEPIC is controlled by the duty cycle of the MOSFET. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output, by means of coupling energy from the input to the output is via a series capacitor. When the switch is turned off output voltage drops to 0 V. SEPIC is useful in applications like battery charging where voltage can be above and below that of the regulator output.

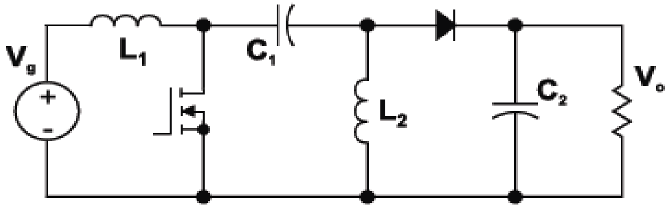

Figure 4.1: Circuit diagram of SEPIC Converter

DC-DC converter used in maximum power point tracking system to interface load and PV system SEPIC (Single Ended Primary Inductance Converter) is modelled, output voltage of SEPIC converter can be step-up or step-down then input voltage. In MPPT SEPIC converter work in continuous conduction mode. PWM controlled with switching frequency of 50KHz. Power flow of circuit controlled by using ON/OFF duty ratio threw switching MOSFET.

4.1 MPPT Using SEPIC

A novel technique for efficiently maximizing the output power of a solar panel supplying to a load or battery bus under varying meteorological conditions is presented. MPPT algorithms are vary due to simplicity, efficiency, tracking speed, sensor required and cost. It is seen that the V-I characteristics of the solar module is nonlinear and extremely affected by the solar irradiation and temperature. To maximize the output power of solar module, it has to be operated at fixed value of load resistance. This require a separate power converter circuit for the MPPT. In our design, a SEPIC type DC-DC converter is used to extract the maximum power from solar module.

Maximum power point tracking by incremental conductance method + Integral regulator
Maximum power point is obtained when dP/dV=0

$$\text{where } P = V*I$$
$$d(V*I)/dV = I + V*dI/dV = 0$$
$$dI/dV = -I/V$$

The integral regulator minimizes the error (dI/dV + I/V) Regulator output = Duty cycle correction, Maximum power point is obtained using incremental conductance method. So in our implementation to achieve high efficiency this method utilize incremental conductance (dI/dV) of the photovoltaic array to calculate the sign of the change in power with respect to voltage (dP/dV). The controller maintains this voltage till the isolation changes and the process is repeated. Flow chart of incremental conductance is shown in above Figure2.1.

5. Simulink Modelof SEPIC Converter Using INC MPPT Method and Results

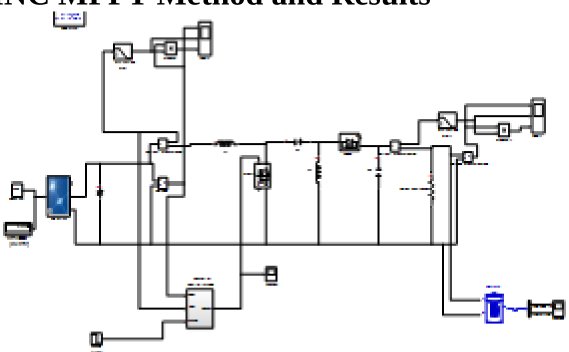

Figure 5.1: Simulation Of SEPIC Converter Using Inc MPPT Method

Simulations have been performed to confirm the above analysis. And below Figs.5.1 and 5.2,5.3 are shows the Simulation of SEPIC Converter and simulation result of SEPIC Converte.

Figure 5.2: output waveform of solar panel for 600w/m^2 irradiance

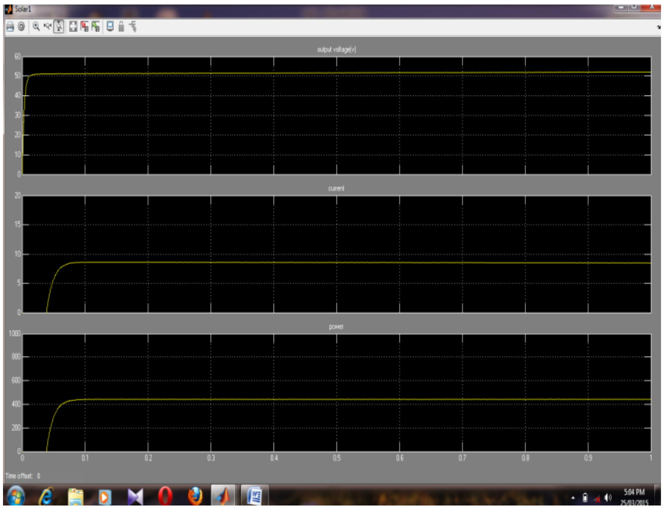

Figure 5.3: output waveform of SEPIC converter for 600w/m^2 irradiance

6. Advantages

- Low cost of the system.
- Higher Efficiency.
- Simpler structure and control
- It removes the unwanted noise through capacitor.
- It gives non inverted output voltage and Ripple free continuous output and input current
- .It reduces the complexity of the system.

7. Applications

- Grid supply system.
- Stand alone PV system for residential application.
- Used in small scale Industrial UPS.

8. Conclusion

A novel technique using a SEPIC converter to efficiently track the maximum power point of a solar panel has been presented. The technique is simple and elegant and does not require complicated mathematical computation. The tracking capability of the proposed technique has been verified experimentally with a 12V, 2A converter with input voltages (different radiation levels) .MATLAB/Simulink software has been used to simulate SEPIC converter. Compared to many existing methods, the proposed technique is unnecessary to

1) Perform digital sampling of the converter parameters.
2) Perform sophisticated mathematical computations of the panel output power.
3) Approximate the panel output characteristics.

Hence, it can be used under a wide range of meteorological conditions.

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