ISSN 2278 - 8875
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 1, Issue 4, October 2012

Development of Solar MPPT System Using Boost Converter with Microcontroller

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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 Gig watts 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. In this project, we examine a schematic to extract maximum obtainable solar power by using the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system.This project work introduces an approach to design a boost converter for photovoltaic (PV) system using microcontroller. As irradiation and temperature level changes rapidly, solar panel voltage fluctuates and becomes inconstant. The converter is designed to step up solar panel voltage to produce a stable 24V output without storage elements such as battery. Solar panel voltage is controlled by a microcontroller unit using constant voltage or voltage-feedback technique. Microcontroller PIC16F877A is used to perform tasks in the proposed design. Boost converter output is continuously tracked and measured and the values are sent to the microcontroller unit to produce pulse-width-modulation (PWM) signal. These signals are used to control the duty cycle of the boost converter. A maximum power point tracker (MPPT) is a system that directs the converter to track the maximum power of a solar panel and deliver it to load.

KEYWORDS: maximum power point traking, boost converter,

I.INTRODUCTION

In recent years, attention towards renewable energy such as wind and solar power has increased dramatically. As more people are concerned with the power generation using fossil fuel which brings environmental problems, societies and conferences are being held to find solutions to slow down the world climate change caused by power generation. Photovoltaic (PV) sources are used today in many applications such as satellite power systems, battery charging, home appliances and many more. PV is becoming more famous in the world of power generation because they have the advantages of free pollution, low maintenance, and no noise and wear due to the absence of moving parts.

The power produced by solar panel depends on two factors which are irradiation and temperature. As irradiation and temperature level changes rapidly, the voltage produced fluctuates and becomes inconstant. A converter is therefore implemented to produce a constant voltage and deliver maximum power from solar panel to load. A maximum power point tracker (MPPT) is a system that directs the converter to track the maximum power of a solar panel and deliver it to load. MPPT is not a mechanical tracking system that moves the solar panel to point more directly to the sun but it is an electronic system that varies the electrical operating point so that it will deliver a maximum output power.

Within this context, this work presents the design of a converter using high efficiency boost converter operating in continuous conduction mode (CCM). It is implemented with a control technique based on voltage-feedback control. In this design, the proposed control algorithm will be much simple compared to other MPPT control algorithms such as Perturbation and Observation (P&O) and Incremental Conductance. Voltage-feedback control algorithm is implemented using PIC16F877A microcontroller. It continuously tracks the output voltage of the boost converter and sets a duty cycle of a pulse-width-modulation (PWM) signal for the boost converter as an output signal. As the output voltage changes, the duty cycle will change accordingly. Therefore, the converter will be able to provide a constant output voltage by using this control technique. As the converter produces constant output voltage, it can be coupled with a voltmeter to show we get constant voltage.

II.SYSTEM MODEL AND ASSUMPTIONS

System Block Diagram

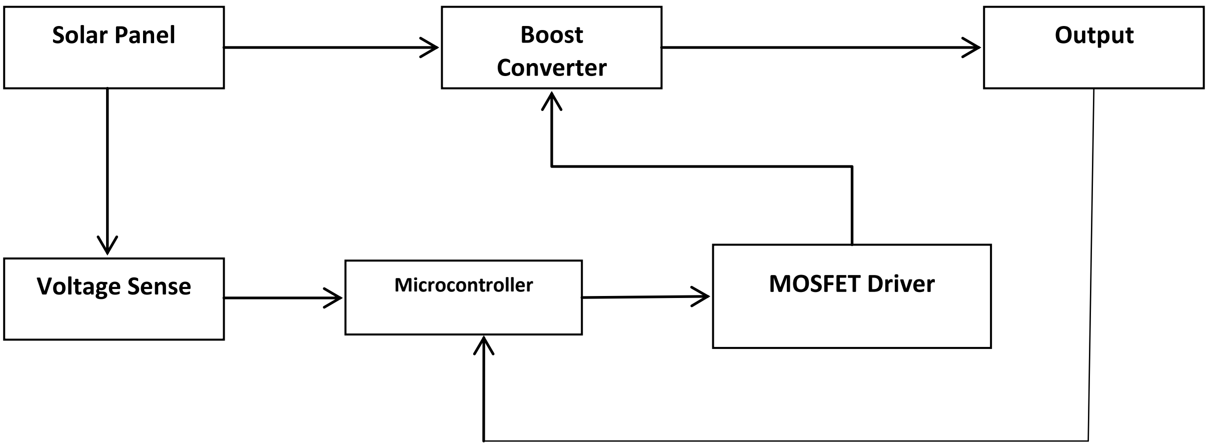

Fig 2.1: System Block Diagram

Complete block diagram of our project is illustrated in the fig 2.1. Output of the solar panel is given to the boost converter. And also solar panel output voltage is reduced to 0-5 Volts using a voltage divider and supplied to the microcontroller because microcontroller operates with a voltage of 0-5 Volts. Output of the microcontroller which is a PWM signal is given to the switch of boost converter (MOSFET) through MOSFET driver for smooth and fast switching. Output of the boost converter is given to load. Detailed description of each block is explained below.

Voltage Sensing

The voltage generated by the solar panel can range anywhere between 0 and 24 Volts. This voltage range needs to match that of the maximum input voltage range of the microcontroller chip, which is 0 to 5 Volts. A simple voltage divider connected in parallel with the solar panel will easily reduce the 24 Volts maximum output from the solar panel to match the 5 Volts maximum analog input of the microcontroller.

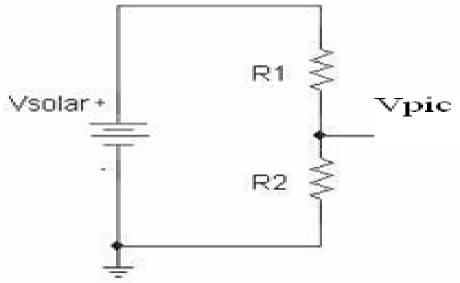

Fig 2.2: Voltage Divider

The values R1 and R2 must be specified in order to achieve a one quarter drop in voltage to the microcontroller. From fig 2.2, the equation describing the voltage divider in the system is:

$$V_{PIC} = V_{SOLAR} (R2 / (R1 + R_2))$$

If 24 Volts are emitted from the solar panel, then the voltage at the microprocessor should be five volts. Plugging in these values in the equation above and solving for R1 yields the following expression.

$$R_1 = 3R_2$$

As long as this resistor ratio is kept true, the voltage generated by the solar panel will always lie in the range of 0 to 5 Volts, which is essential in order to prevent any damage to the microprocessor chip.

The impedance for the two resistors needs to be large in order to minimize the current drawn by the voltage divider. However, the impedance cannot be too large due to the requirement of an RC filter in order to filter out the rippling voltage generated by the solar panel. If the impedances of the RC filter and the voltage divider are relatively close, than the RC filter will draw too much current from the voltage divider causing the voltage divider to drop a factor that is not equivalent to one quarter..

Boost Converter

The boost converter is one of the most important components to the Maximum Peak Power Tracker. To achieve maximum power from the solar panels, we must operate the panels at their optimum power point. By opening or closing a switch, the output of the solar panel will either be shorted or open circuited. The switch discussed will actually be a MOSFET. The digital controller will control this MOSFET. To understand the boost converter, the MOSFET is modelled with a simple ideal switch. The switch will open and close to control the voltage level over the inductor, which will essentially set the solar panels to their optimum power level.

As the switch is closed the voltage drops as the current increases towards its maximum short circuit current. If the switch is closed for a long enough period of time the voltage will eventually drop to zero and thus the power at this point is zero. If the switch is open, the voltage will rise to its open circuit voltage and no current flows out of the solar panel. Again the power will be zero watts. Due to the inductor’s presence in the boost converter, current and voltage transients will not happen instantly but instead take some time. Therefore the power cannot instantly move from optimum to zero, but instead takes some time constant. By opening and closing this switch at fast speeds, it is possible to pick a place such as the peak power point and operate close to this point.

Specific Diagram

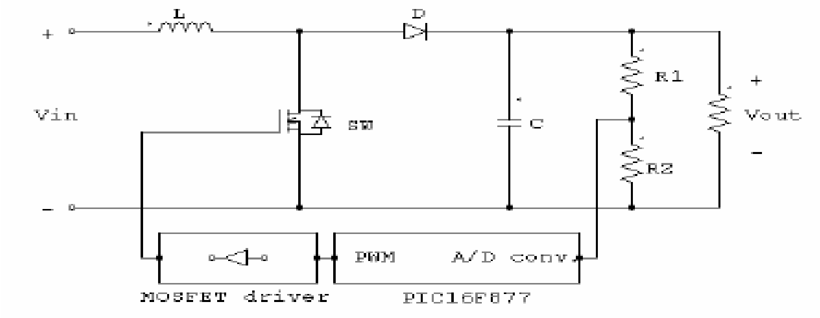

Fig 2.3: Specific Diagram

Proposed System

- The proposed boost converter is implemented in between a solar panel and load as illustrated in fig 2.4.
- This system is able to deliver power with a constant output voltage of 24V without storage elements such as battery.
- Therefore, the converter is small and light weight. In addition to that, the system is able to attach directly to the solar panel as a single unit.
- The power stage includes switch SW which may consist of one or more parallel connected power MOSFET, a fast switching type fly back diode D, an inductor L wound on ferrite core with air gap to prevent core saturation, and output capacitor.
- The controlling stage consists of a PIC16F877 microcontroller with built-in analog-to-digital converter (ADC), a power MOSFET driver, and a voltage divider.
- Voltage divider resistors R1and R2 will divide the output voltage to a suitable voltage range which is acceptable by the built-in ADC in the microcontroller.
- PIC16F877A will then perform calculation based on the control algorithm and produce a PWM signal with a set of duty cycle.
- The PWM signal is then transmitted to power MOSFET in power stage through a power MOSFET driver to perform on and off state.
- The PIC16F877A microcontroller unit features an eight-bit, successive approximation ADC, used by the control program to measure signals required for the power flow control. The 10-bit resolution is adequate for the proposed design.
- Also, it features two PWM outputs with program-controlled duty cycle and 208.3 kHz maximum frequency when driven by the 20 MHz clock of the unit.

III. BOOST CONVERTER

A boost converter has been employed in this application to regulate the power output to the load. A step up, also known as a boost converter, is capable of providing an output voltage that is greater than the input voltage. The operation of a boost converter can be divided into two modes- the Continuous Current Mode and the Discontinuous Current Mode.

DC-DC Converters

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. The minimum oscillator frequency should be about 100 times longer than the transistor switching time to maximize efficiency. This limitation is due to the switching loss in the transistor. The transistor switching loss increases with the switching frequency and thereby, the efficiency decreases. The core loss of the inductors limits the high frequency operation. There are four topologies for the switching regulators: buck converter, boost converter, buck-boost converter, cuk converter. However my project work deals with the boost regulator and further discussions will be concentrated towards this one.

Circuit Diagram

One of the aims of our project is to design the boost converter. Complete design of boost converter is illustrated in the fig 4.6. Selection of all components like inductor, diode, capacitor, MOSFET and MOSFET driver are discussed below. Solar panel output is given to the boost converter. Output of the MOSFET driver is given as input to the switch of the boost converter. For smooth and quick switching MOSFET driver is used in between microcontroller and the boost converter.

Output of the boost converter is taken as a feedback and a voltage divider is used to reduce the voltage to a prescribed level and given as one of the inputs to the microcontroller.

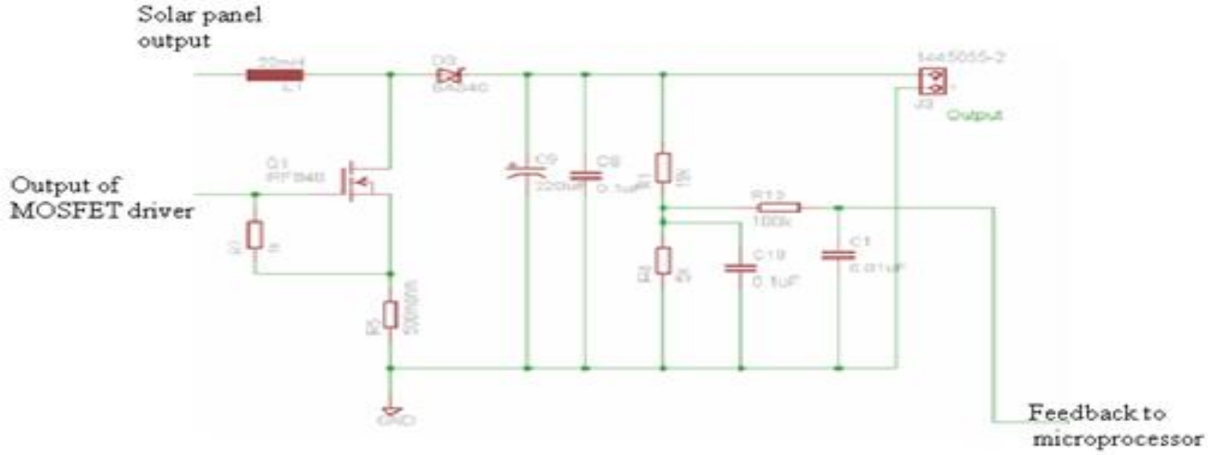

Fig 3.1: Boost Converter Design

IV. MAXIMUM POWER POINT TECHNIQUES

MPPT

MPPT or **Maximum Power Point Tracking** is used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and **solar cell** temperature.

For any given set of operational conditions, cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V / I as specified by Ohm's Law. The power P is given by P=V*I. A photovoltaic cell has an approximately exponential relationship between current and voltage. From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the slope) dI/dV of the I-V curve is equal and opposite theI/V ratio (where dP/dV=0). This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve.

Fig 5.1 illustrates the V-I and P-V characteristics of a 12V solar panel and the maximum power point at the bend of the V-I curve.

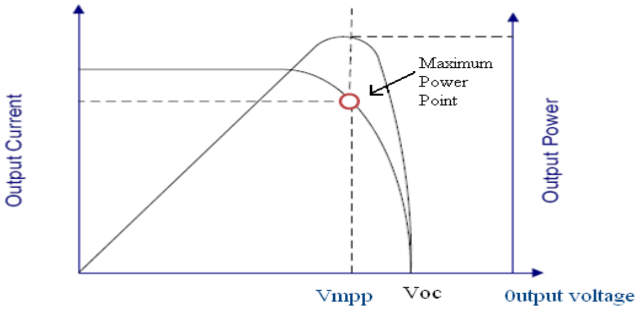

Fig 4.1: Maximum Power Point of a Solar Panel

MPPT Techniques

The MPPT techniques are:

1. Perturbation and Observation (P&O) method.
2. Incremental Conductance (InC) method.
3. Constant Voltage method.
4.

Perturbation and Observation (P&O) method:

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. It is often referred to as **hill climbing** method, because they depend on the fact that on the left side of the MPP, the curve is rising (dP/dV> 0) while on the right side of the MPP the curve is falling (dP/dV< 0). 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. This process works by increasing or decreasing the duty cycle of a buck or boost DC to DC converter.

One of the major drawbacks of perturb and observe method is that under steady state operation, the output power oscillates around the maximum power point. This algorithm can track wrongly under rapidly varying irradiation conditions. 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.

Incremental Conductance (InC) method:

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). InC computes the maximum power point by comparison of the incremental conductance (ΔI/ΔV) to the instantaneous conductance (I/V). When the incremental conductance is zero, the output voltage is ascertained to be the MPP voltage and fixed at this voltage until the MPP encounters a change due to the change in irradiation conditions. Then the process is repeated until a new maximum power point is reached.

The drawback of this technique is that it can produce oscillations and can perform erratically under rapidly changing atmospheric conditions. The computational time is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method.

Constant Voltage Method:

In the constant voltage method, the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage, which has empirically been determined as the estimated maximum power point. 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 maximum power point voltage of the characteristic PV module or to another calculated best fixed voltage.

One of the approximations of this method is that variations of individual panels are not considered. The constant reference voltage can be considered as the maximum power point voltage. The data for this method varies with geographical location and has to be processed differently for different geographical locations. The CV method does not require any input. It is important to observe that when the PV panel is in low isolation conditions, the CV technique is more effective than either the P&O method or any other method. CV is sometime combined together with other MPPT techniques.

V. RESULT

Simulation Diagram

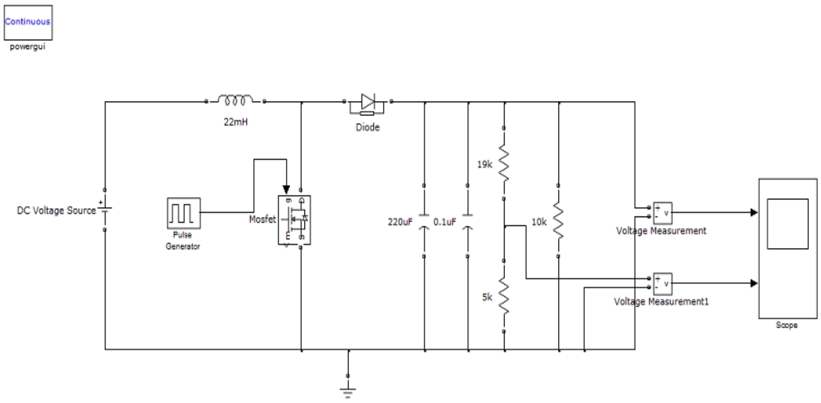

Fig 5.1: Simulation Diagram

Basic simulation diagram of our project is illustrated in the fig 6.1. DC voltage source instead of solar panel and a Pulse Generator instead of microcontroller are used in simulation because main aim of our project is to get a constant voltage of 24V by developing a boost converter where duty cycle is being varied by the programme in the microcontroller.

The boost converter design includes an inductor, capacitor, resistors and a switch (MOSFET) are used. Voltage measurement block is used to measure the output voltage of the boost converter. Feedback voltage measured from Voltage Measurement 1 that is to be given to the microcontroller is reduced using a voltage divider that is obtained by adding two resistors in parallel with the boost converter.

The switch (MOSFET) of the boost converter is controlled by pulse signal of the Pulse Generator where the amplitude and pulse width are varied manually by trial and error method we found that, to generate a 24V constant output voltage for a DC input voltage of 12V amplitude and pulse width were 5 and 51.7 respectively. Accordingly resistor, inductor and capacitor values are set.

Simulation Result

Constant output voltage of 24V measured from the boost converter through Voltage Measurement block is illustrated in the fig 6.2. Feedback output voltage of 5V measured from the boost converter through Voltage Measurement 1 block as an input to the microcontroller is illustrated in the fig 5.2.

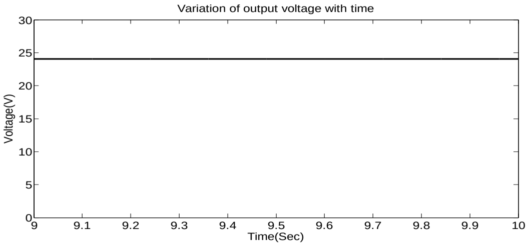

Fig 5.2: Constant Output Voltage of Boost Converter – 24V

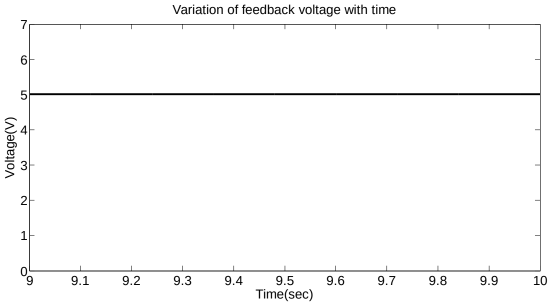

Fig 5.3 Feedback Voltage to Microcontroller – 5V

VI.CONCLUSION

To complete this project in an effective manner a thorough understanding of solar technology and important aspects of it is essential. The sun has the ability to give off lots of energy; however solar panels can only convert a small amount of solar energy to electrical energy due to inefficiency in solar panel technology. Simply connecting a solar panel to a battery or a load can further decrease the available efficiency. Solar power systems benefit from an MPPT device in order to extract the maximum available power from the solar panels in the system. The MPPT is a charge controller that compensates for the changing Voltage vs. Current characteristic of a solar cell. By monitoring the voltage and current output of the solar panel, the MPPT tracks the always-changing operating point in order to draw the maximum amount of power available during all periods of the day. A circuit that would monitor the solar panel's power output and adjust the operating conditions based on a control system in order to maximize the power output was successfully designed. Over the course of this project a number of practical problems were encountered. This form of project gave us a unique experience that would not be available in a typical classroom.This project can be further developed to include both buck and boost functionalities to get different levels of voltage as per our requirements. Also modifications can be made to adjust the system for applications where multiple panels are used. If panels of higher rating are used, we can even design a system to that can be tied to the power grid.

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