IJIREEICE
ISSN (Online) 2278-1021
ISSN (Print) 2319-5940
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering
REPSE-17
National Conference on Sustainable Development in Renewable Energy Sources and Power System Engineering
Sri Venkateshwara College of Engineering, Bengaluru
Vol. 5, Special Issue 3, May 2017

Maximum Power Point Tracking and Programmable Output Voltage Controller for PV Systems

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Abstract: The power obtained from the Photovoltaic (PV) system keeps on changing with solar radiation and ambient temperature because of the nonlinear voltage current characteristic, exhibited by the PV system. However, with the advancement in technology, it is now possible to obtain maximum power from the PV cell and thus overall efficiency can be improved. In this paper, Maximum Power Point Tracking (MPPT) based on Perturb and Observe (P & O) algorithm and programmable output voltage controller for PV systems has been presented. P & O algorithm improves the overall efficiency of MPPT and provides faster response, particularly during fast changing environmental conditions. The single stage buck and boost converter has been hardware modelled and by adjusting the duty cycle, constant output voltage can be obtained.

Keywords: Maximum Power Point Tracking, Open Circuit Voltage, Short Circuit Current, Perturb and Observe Algorithm, Buck Converter, Boost Converter.

I. INTRODUCTION

Due to the increase in industrialization and technology, need and demand for electrical energy is increasing day by day. At present, we are mainly depending on fossil fuels as a main source of energy because of its higher efficiency and availability. But fossil fuels are non-renewable resource and more usage of fossil fuels leads to global warming. In contrast with other renewable energy resource, solar energy has proved to be the suitable alternative for fossil fuels due to its abundant availability and less cost. But the availability of solar power will not be there throughout the year and the conversion efficiency and losses will be more compared to other resources. By applying the concept of Maximum Power Point Tracking (MPPT) into the PV system, the efficiency of the PV system can be increased. Many authors have proposed different algorithm such has Perturb and Observe algorithm, Incremental Conductance algorithm, Constant Voltage algorithm, Current Sweep algorithm and different methods of output controller for implementing MPPT. In this paper, Perturb and Observe algorithm has been used because of its simpler structure and faster response, especially during faster changing environmental conditions to track Maximum Power Point (MPP).

II. METHODOLOGY

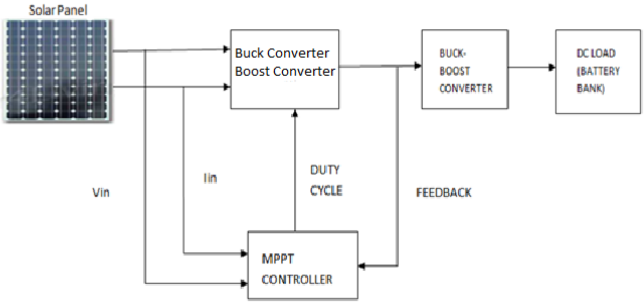

Fig. 1. Block diagram of the proposed system.

The Fig. 1 shows the block diagram of proposed system. The voltage and current obtained from the solar panel is given as input to both buck and boost converter and MPPT controller. The output voltage of buck and boost converter is given as feedback to MPPT controller. The output voltage of buck and boost converter is kept constant by continuously

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monitoring the input and output voltage and the impedance matching between load side and source side is done by continuously varying the duty cycle of the buck and boost converter. The constant voltage obtained is given as input to second stage DC-DC buck boost converter, which is used to obtain the variable voltage ranged from 6-36 V. The output voltage obtained can be used for charging DC load or supply for resistive load.

A. PV System

PV system is used to convert light energy to electrical energy and the phenomenon in which conversion takes place is called as photovoltaic effect. Typical solar cell consists of a current source in parallel with a diode, a series and parallel resistance as shown in Fig. 3. The open circuit voltage and short circuit current for solar panel TBP1200 is measured under constant irradiance and I-V curve is plotted. The result obtained is tabulated as shown in Table1.

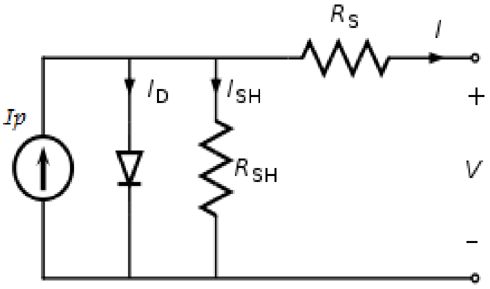

Fig. 2.Equivalent circuit of PV cell.

The total current produced by solar cell is

$I = I_P – I_D - I_{SH}$ (i)

Where,

I = Total Current output from the PV Panel.

I_P = Photovoltaic Current generated from PV Panel.

I_D= Current Flowing Through Diode.

I_{sh} = Current Flowing Through Shunt Resistor.

TABLE I. ELECTRICAL PARAMETERS OF SOLAR PANEL (TATA BP SOLAR TBP1200)

Electrical Characteristics	
Open Circuit Voltage (V_{OC})	18.72V
Short Circuit Current (I_{SC})	2.16A
Voltage at Maximum Power	14.3V
Current at Maximum Power	1.85A
Maximum Power	26.45W

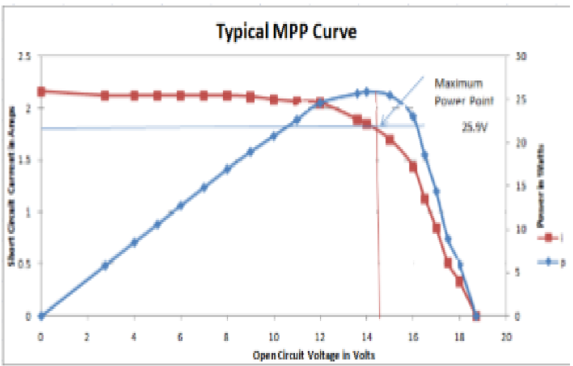

Fig. 3. Typical MPP curve for solar panel TATA BP SOLAR TBP1200

B. Perturb and Observe Algorithm

When uniform irradiance is falling on the PV system, then Maximum Power Point (MPP) obtained from the PV system will be constant. But, because of the I-V characteristic of the PV cell and variation in atmospheric conditions, MPP will also vary. Therefore, in order to operate PV system at MPP, Perturb and Observe algorithm has been proposed for this project.

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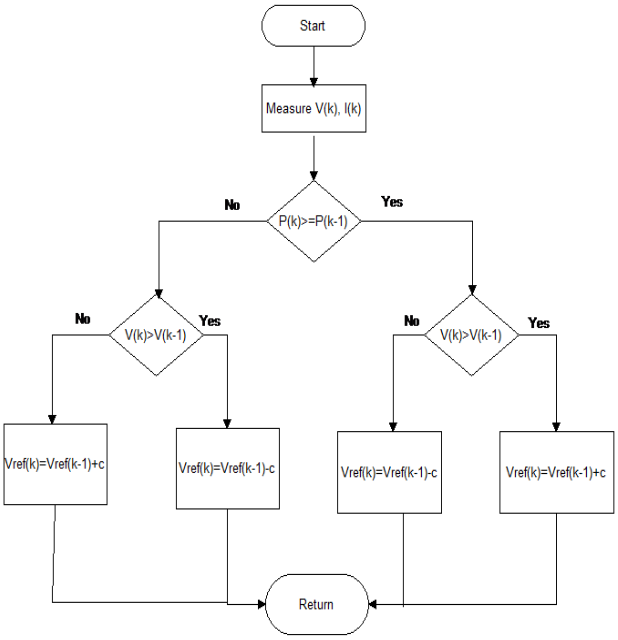

Fig. 4. Perturb and Observe algorithm.

Fig. 4 shows the flow chart of Perturb and Observe algorithm. In this algorithm, the output and input voltage and current have been measured and Power is calculated. If the present power is greater than previous power, then the perturbation is continued in the same path. If the present power is lesser than that of the previous power, then perturbation is reversed.
The perturbation of the PV panel is obtained by varying the duty cycle. When the duty cycle is varied across the load through MPPT block, the source impedance will also be varied. The duty cycle will be continuously varied until source impedance is equal to the load impedance.

C. MPPT Controller Block

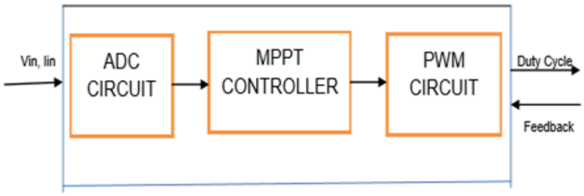

Fig. 5. Block diagram of MPPT controller block.

MPPT controller block is shown in Fig. 5. It consists of ADC circuit, MPPT Controller and PWM circuit. The sampled voltage and current is given to the ADC block of MPPT controller through resistor divider network. Resistor divider network is used to reduce the voltage obtained from the PV cell to a maximum voltage rating of microcontroller. In ADC block, the analog value is converted into digital value. MPPT controller block compares the input and output voltage and based on the value obtained, the duty cycle is adjusted such that constant voltage is obtained across the output. The MPPT controller block and duty cycle adjustment is done through C programming and implemented through PIC16F877A microcontroller.

D. Buck and Boost Converter
In this paper, single stage buck and boost converter is designed to obtain a required voltage of 12V and 24V at the output through PWM control method. A buck converter is designed as shown in Fig. 6. The gate voltage to the MOSFET of buck converter is adjusted by varying the duty cycle from MPPT controller. Buck converter works in two modes. In mode1, when MOSFET is turned on (closed), the current will flow through the inductor and it produces an opposing voltage, which causes the voltage drop across the inductor and the output voltage will be lesser than that of the input. When MOSFET is turned off (open), then no current will flow through the inductor and inductor starts discharging until inductor current goes to zero.

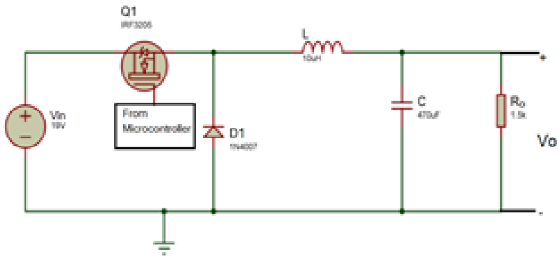

Fig. 6.Circuit diagram of buck converter

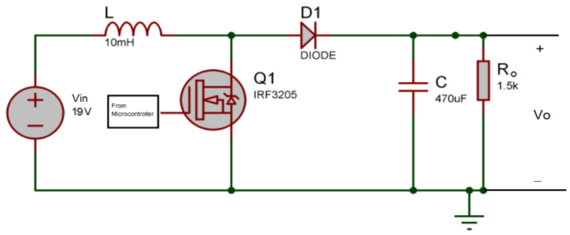

Fig. 7.Circuit diagram of boost converter

In boost converter, the output voltage is more than that of the input. In this paper, boost converter is designed as shown in Fig.7, such that output voltage will remain constant at 24V for varying input voltage. Boost converter works on two modes. In mode1, when the MOSFET is turned on (closed), the inductor gets charged by the current flowing through the circuit. In mode2, when the MOSFET is turned off (open), the input current along with inductor current flows through the diode and capacitor, which tends to increase the output voltage.

E. XL6009 Buck Boost IC

The another stage of buck-boost converter is designed as shown in Fig. 8, using XL6009 IC and is used to obtain the variable output voltage across the load. The input for this circuit is given as 12V, which is obtained from the previous stage buck converter circuit and the output is varied from 6V to 36V, by varying the potentiometer across the load.
The circuit diagram for XL6009 buck-boost IC is taken from XL6009 data sheet and it is been hardware modeled as shown in Fig. 8.

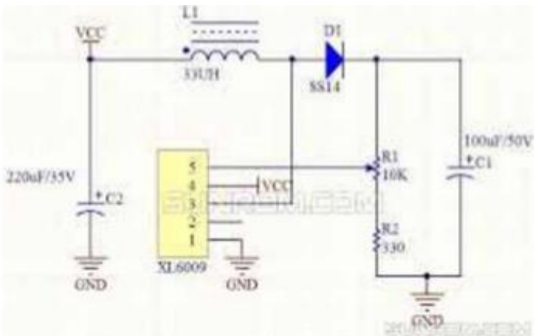

Fig. 8. Circuit diagram of XL6009 IC[13].

The required output voltage is obtained by varying the potentiometer R1. The formula for output voltage is,

$$V_{out} = 1.25 * (1+ (\frac{R_1}{R_2}) \qquad \text{ii}$$

Where,
Vout = Output voltage
R1 = Potentiometer used for varying resistor.
R2= Fixed resistor.

F. Circuit Diagram of MPPT Controller with Buck and Boost Converter

The circuit diagram of MPPT controller is shown in Fig. 9. In this circuit, the feedback voltage from the buck and boost converter is given to the ADC pins of the PIC16F877A microcontroller through voltage divider network.

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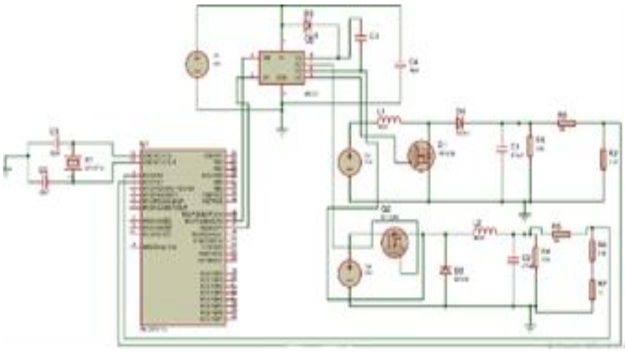
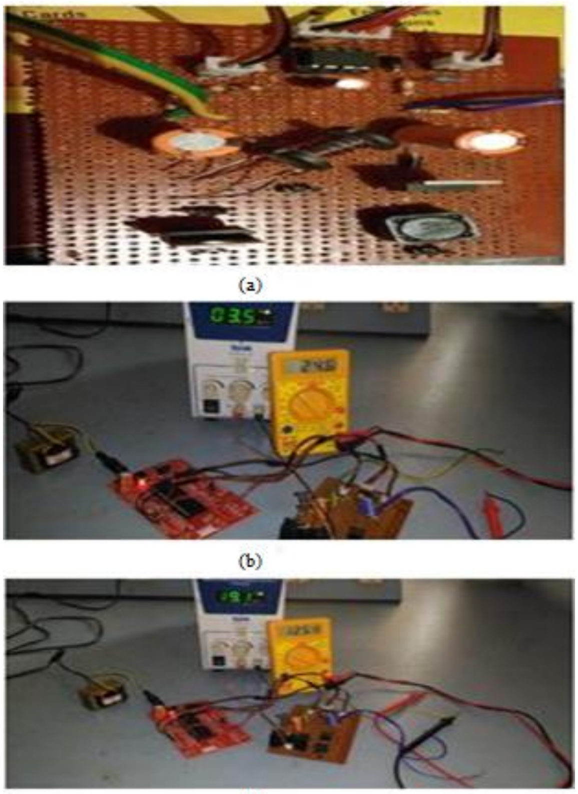


Fig. 9.Circuit Diagram of Buck Boost MPPT Controller.

The output voltage is monitored and based on the output voltage obtained, the duty cycle adjusted and the gate voltage is given to MOSFET IRF3205. IR2101 gate driver IC is used to drive the gate voltage. The PWM pins of PIC16F877A microcontroller is given to the high side and low side input pins of IR2101 IC. Based on the input given to either buck or boost converter, the output will be switched according to the input. Because of the high current requirement, toroid core type inductor is chosen for this project.

III.RESULTS

The MPPT concept is used to obtain the maximum power from the PV system. The hardware model has been developed and bench tested using regulated power supply from laboratory. The output voltage obtained is monitored using multimeter. The MPPT controller is developed using PIC16F877A microcontroller and by writing the suitable C program, the duty cycle is adjusted to get constant voltage at the output. The XL6009 IC has been hardware modeled and tested.



(c)

Fig. 10.MPPT buckboost converter. (a) Hardware model of buck and boost Converter. (b) Boost converteroutput voltage 24V for input voltage 3.5V. (c) Buck converter output voltage for input voltage 19V.

The results obtained from the MPPT buck and boost converter is shown in Fig. 10. The hardware model is designed using PCB board as shown in Fig. 10(a).The minimum input voltage (3.5V) is required to obtain the boost converter constant output voltage of 24V is shown in Fig. 10(b) and the output will remain constant up to 19V input, which is the maximum voltage obtained from the solar panel TBP1200. Fig. 10(c) shows the buck converter output for maximum input voltage of 19V. The results are bench tested by using regulated power supply as a source.

Fig. 11. Hardware model of XL6009 buck boost converter.

The XL6009 IC is hardware modeled using PCB board as shown in Fig. 11. Toroid type inductor is used for high current range. Potentiometer of 10KΩ range is used for the required output voltage of 6-36V. The hardware model is bench tested using regulated power supply.

IV. CONCLUSION AND FUTURE SCOPE

Maximum Power Point Tracking is one of the effective ways of obtaining maximum power from the DC source with high efficiency. In this paper, P&O algorithm is used because of its fast switching and high reliability property. We can obtain the constant voltage during changing irradiance and environmental conditions from the PV system. The proposed system is designed for a maximum power of 25W. If we use this technique for low voltage DC transmission, then we can reduce the losses obtained in AC transmission, due to corona effect, high voltage surges, etc. Because of the less insulation in DC, we can save cost and it is one of the environmental friendly ways of power generation and transmission.

ACKNOWLEDGMENT

Author owes an intellectual debit to the reference materials, which helped to achieve sound knowledge about the topic and it would also make an excellentcompilation for further reading on the topic.Author would like to thank **Mr. Anil Kumar Bhat**, Assistant Professor, Department of Electronics and Communication Engineering, NMAMIT, Nitte, for his guidance on conducting this study. I sincerely acknowledge the encouragement and impetus given to me by my HOD, **Dr. Rekha Bhandarkar,** Professor & Head, Department of Electronics and Communication Engineering, NMAMIT, Nitte, for their constant encouragement and support
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