Design of an Efficient Photovoltaic System using MPPT and P&O Algorithm

Rajeev Kumar[1] Minali Gupta[2]
[1,2]Department of Electronics Design & Technology
[1,2]NIELIT, Gorakhpur, India

Abstract— Among all renewable energy sources solar energy is the most acceptable solution as it is available in abundant and free of cost worldwide. A typical solar generation system consists of a solar array and a DC-DC converter. DC-DC converters are applied between the source and the load as power conditioning unit to regulate and boost up photovoltaic voltage to desired output voltage. This paper presents a low capacity photovoltaic system suitable for residential purpose. The hard switching method has a large overlapping area between voltage and current of the switch. This area causes switching losses because the power is a product of voltage and current. Switching losses are proportional to the switching frequency. Thus, it is unable to increase the switching frequency. On the other hand, the soft switching method including ZVS and ZCS minimizes the overlapping area. This paper presents maximum power point tracking (MPPT) simulation for a photovoltaic (PV) system. The MPPT is used to find and maintain operation at the maximum power point. Algorithm used is perturb and observe (PO).

Key words: Photo Voltaic, MPPT, Boost Converter, ZVS Matlab, PSIM

I. INTRODUCTION

Tracking the maximum power point (MPP) of a photovoltaic array is an essential stage to increase the efficiency of most PV systems. It is a technique that is used to obtain the maximum power by measuring and sampling the output voltage and/or current of the solar array, and then controlling a power converter or adjusting the load to ensure maximum power is delivered to the load system for any given atmosphere condition. Many MPPT[1] methods have been introduced and numerous variants of each method have been proposed to overcome specific disadvantages. The solar cell is the basic element of the photovoltaic panels. It converts solar energy directly to electricity. The non-linear current voltage characteristic (I-V) is a major challenge in the utilization of solar PV panel; therefore the power voltage curve (P-V) presents a unique maximum power point in particular conditions. A DC-DC converter[2], in this work is boost which converts the DC voltage to other DC voltage higher than input one. The converter is coupled to the output of the PV array to achieve the optimum voltage and for implementing maximum power point tracking (MPPT).

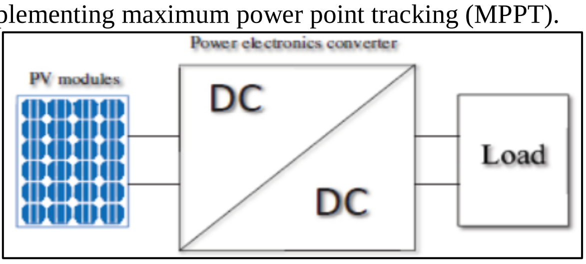

Fig. 1: Block diagram of PV system

II. MODELING OF PV CELL

The modeling of solar photovoltaic (PV) cell can be done as both current and voltage source, hence the series as well as parallel both combinations are possible in solar cell, but the solar cell characteristic is more similar to current source. The double diode modeling of solar PV system [3] is given in Fig.2.

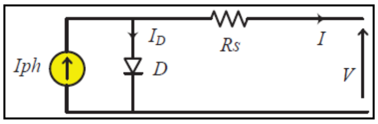

Fig. 2: Electrical equivalent circuit of PV cell

The I-V curve of a PV cell obtained under a uniform solar radiation and given temperature conditions can be expressed asT

$$\boxed{I = I_{ph} - I_D = I_{ph} - I_0(e^{\frac{q(V+IR_s)}{mkTc}} - 1)}$$

Where Iph is the current of the PV source, ID is the diode current, m is the idealizing factor, k is the Boltzmann's gas constant, Tc the absolute temperature of the cell, q the electron charge and I0 is the dark saturation current which depends on the temperature.

III. CONVENTIONAL BOOST CONVERTER

DC DC converters [4] work to transform input DC voltages to output DC voltages at a desired level, and have two modes of operation: continuous current mode operation and discontinuous current mode operation. In some applications, the converter can operate in both modes of operation with different characteristics associated with each.

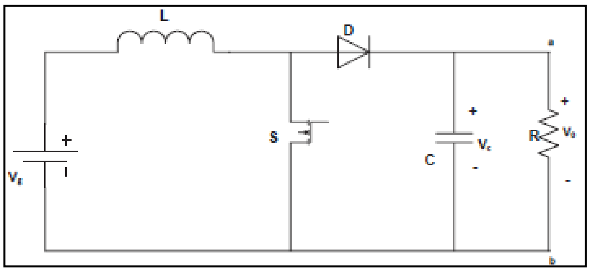

Fig. 3: DC- DC Conventional boost converter

IV. MPPT CONTROLLER

PV generator exhibits nonlinear characteristics, its maximum power point varies with the solar insolation, and there is a unique operating point of the PV generator at which its power output is at a maximum. Therefore, for maximum utilization efficiency, it is necessary to use a maximum power point tracking algorithm to generate all available PV panel maximum power under different insolation to the load. Perturbation and observation (P&O) algorithm[5][6] has been used for tracking the maximum power point.

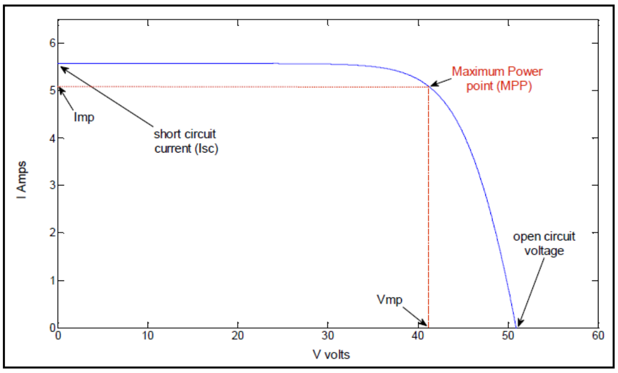

Fig. 4: I-V characteristics of a PV cell with MPPT control

The P&O algorithm is chosen due to its ease of implementation in its basic form and its advantages compared to other methods. It operates by periodically perturbing (incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changes and power increases, the control system moves the PV array operating point in that direction, otherwise the operating point is moved in the opposite direction. In the next perturbation cycle the algorithm continues in the same way[8]. The main advantage of this method is the relative simplicity of the algorithm.

V. PI CONTROLLER

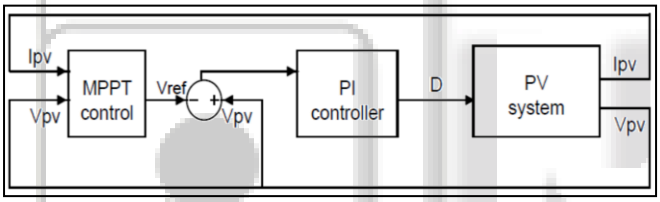

Fig. 5: Block diagram of a PV panel with PI controller and MPPT control

The maximum power point tracker MPPT takes measurement of the PV module current and voltage and calculates the reference voltage (Vref) where the PV operating voltage should move to. The task of the MPPT control is to set reference voltage only and it is repeated periodically with a slow rate 1-15 samples per second. Then there is another control loop that is the proportional-integral (PI) control[7] that regulates the input voltage of the DC-DC converter. The PI control job is to minimize the error between the measured voltage of PV and reference voltage that is calculated by the MPPT algorithm by adjusting the duty cycle. The digital PI control operates rapidly and provides a good dynamic system response. Digital PI controller use sample and hold circuitry to convert analogue signal to digital signal and vice versa. To tune the discrete PI controller, there are many stability-analysis tuning techniques available; such trial and error tuning, Ziegler Nichols, pole placement, and so on. This research had used the trail-and-error tuning method to tune the discrete PI control in the system, due to its simple yet effective approach.

VI. PERTURBATION AND OBSERVATION (P&O) ALGORITHM

The P&O algorithm shown below in Fig operates by increasing or decreasing the array terminal voltage, or current, at regular intervals and then comparing the PV output power with that of the previous sample point. If the PV array operating voltage changes and power increases (dP/dVpv>0), the control system adjusts the PV array operating point in that direction; otherwise the operating point is moved in the opposite direction. The main advantage of this approach is the simplicity of the technique. Furthermore, previous knowledge of the PV panel characteristics is not required. In its simplest form, this method generally exhibits good performance provided the solar irradiation does not vary too quickly [9].

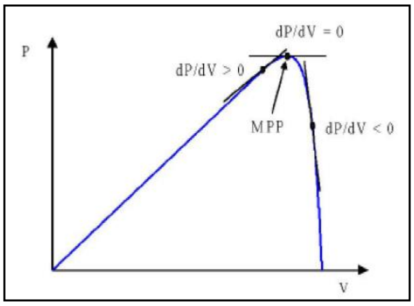

Fig. 6: dP/dV at different positions

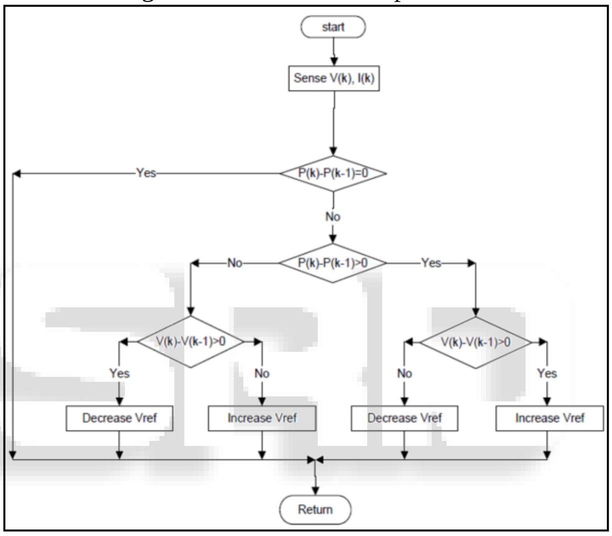

Fig. 7: Flowchart of Perturbation and Observation algorithm

VII. SIMULATION AND RESULT

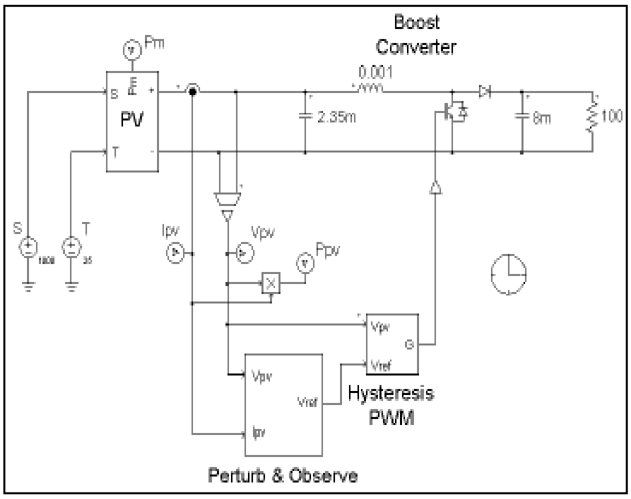

Fig. 8: Simulation of PV boost converter

The simulation is carried out by PSIM 9.0.3[10]. Table I shows the electrical characteristics of PV modules used for simulation when the Standard Test Condition (STC). This PV module parameters obtained from the technical data of PV modules. The number of PV modules used is 200 units (10 series and 20 parallel)

A. *Irradiation Variation*

For this case, solar irradiation (S) varies between 200 - 1000 W/m2. The temperature (T) remains constant at 25°C. Figure.9 shows the output of the PV when irradiation 200 W/m2 and temperature 25°C. It is shown in Figure9(a) that the power output of the PV can track the maximum available power at t= 0.15 s. The power of the PV is 10.6 kW. Figure9(b) and Figure9(c) show voltage and current of the PV at maximum power are 328.5 V and 32.3 A.

Maximum power	P_{MAX}	250 Wp
Open circuit voltage	V_{OC}	37,8 V
Voltage at maximum power	V_{MPP}	31,1 V
Short circuit current	I_{SC}	8,28 A
Current at maximum power	I_{MPP}	8,05 A
*STC : 1000 W/m^2, 25°C, AM 1.5		

Table 1: The Electrical Characteristics of PV Modules at STC

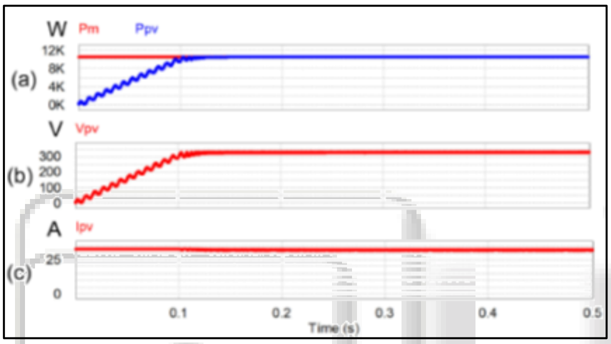

Fig. 9: Outputs of the PV when S = 200 W/m2 and T = 25°C

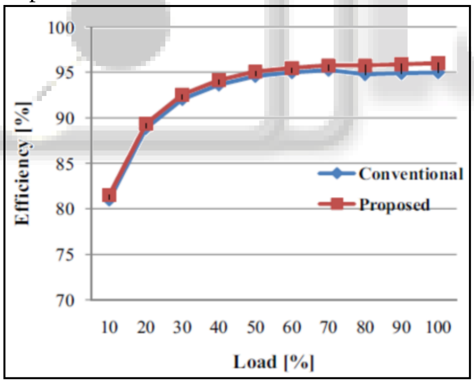

Fig. 10: Efficiency of the proposed PV cell

Figure is the graph of efficiencies with load variation. To compare efficiencies of the conventional converter with proposed soft switching boost converter[11], all of the condition is fixed except the load. The result is given at 0.2 of a duty ratio under 30kHz of a switching frequency. The conventional converter and proposed converter have the highest efficiency when the load is 100%. And compared with conventional converter, the efficiency of the proposed converter is higher than that of the conventional converter in all cases.

VIII. Conclusion

Perturb and observe (PO) algorithm can be used as the maximum power point tracking (MPPT) for photovoltaic system to find and maintain operation at the maximum power point. The increase in irradiation causes PV power generated will be increased. But the increase in temperature will cause the generated PV power decreased slightly.

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