

Simulation of Perturb and Observe MPPT algorithm for FPGA

Vinod Kumar M. P.¹PG Scholar, Department of Electrical and Electronics Engineering, NMAMIT, Nitte, Udupi, India¹

ABSTRACT: The generation of electricity from the PV energy has less efficiency. This is improved by impedance matching between PV panel and load by connecting DC-DC converter in between and controlling the switching of DC-DC converter, according to variations in Panel's output power thus achieving maximum power. Out of Many software algorithms to achieve maximum power, one of the simplest and efficient is Perturb and Observe algorithm. This paper presents simulation of P and O MPPT algorithm and PWM generation based on the algorithm output using Verilog HDL language. This is helpful for using FPGA as MPPT controller in PV applications.

KEYWORDS: PV energy, DC-DC converter, MPPT, FPGA.

I. INTRODUCTION

With the modernizing and fast growing world, the demand for energy is increasing every day. Fossil fuel was the main source of electricity beside hydro energy for very long time. Fossil fuels are non-renewable energy. Extensive use of fossil fuels also leads to global warming. As an alternative to this, many green and clean energy such as tidal, wind and solar energy are becoming main source of electricity to satisfy the increasing demand of energy and to reduce the cost of the electricity generation and dependency on conventional source of energy. Solar energy uses photovoltaic effect to generate electricity. It is also called as Photovoltaic (PV) energy. Electricity generation from PV energy involves less wastage, very less pollution during manufacturing of PV components.

The utilization of amount of solar energy falling on earth is very less. Lesser than this is the amount of PV energy converted into electric energy. To increase this conversion efficiency, many methods are used. Physical tracking of sun as it moves from east to west. Rather than physical tracking and changing the axis of the PV panel, there are many methods which use software algorithms to deliver maximum power to the load from PV panel. These algorithms are MPPT algorithms. There are many MPPT algorithms available. Each of which has both the advantages and disadvantages over one another. Some of the MPPT algorithms are incremental conductance, Perturb and Observe method, fractional open circuit voltage, fractional short circuit voltage.

Irradiation and temperature are different at different geographical locations, time of the day and season of the year. These variations results in variation of PV panel output power. Irrespective of these changes in the irradiance and temperature, MPPT algorithms keep track of panel's output power to ensure that PV system always operates at a point where maximum power is achieved. These software MPPT algorithms are implemented on a hardware controller. In this paper, Perturb and Observe MPPT algorithm, which is simpler and easier to implement is used to track MPPT [1]. The hardware could be a microcontroller or digital signal processor. These hardware controllers pose a certain points of disadvantages in real time tracking. Compared to microcontrollers and digital signal processor, Field programmable gate array (FPGA) has advantages of speed, concurrency and effective real time implementation [3].

II. PV SYSTEM WITH MPPT

The PV system consists of PV module, load and DC-DC converter in between. The load line curve of this system doesn't gives the maximum efficiency all the time. According to maximum power transfer theorem, maximum power is transferred when there is an impedance match between source and the load. This is possible by controlling the

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switching of DC-DC converter switch. With the MPPT controller integrated with the PV system, efficiency can be improved.

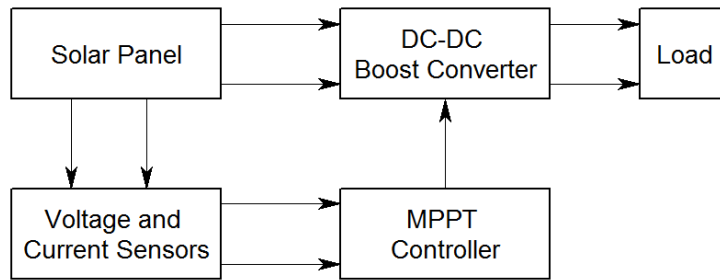


Figure 1: Block diagram of PV system with MPPT.

The block diagram of PV system with the MPPT controller is shown in the Figure 1. It consists of a PV module, DC-DC boost converter, load and the MPPT controller. The current and the voltage from the PV module is given as input to the MPPT controller. As there are changes in the voltage and current input to the controller, corresponding changes are made in the duty ratio of PWM signal and given as input the DC-DC converter switch. Thus the impedance between source and load is matched by varying the duty ratio of boost converter which acts as a variable impedance [2]. The MPPT controller can be based on any hardware controller such as microcontroller, digital signal processor or FPGA. However FPGA has some advantages over other as a MPPT controller.

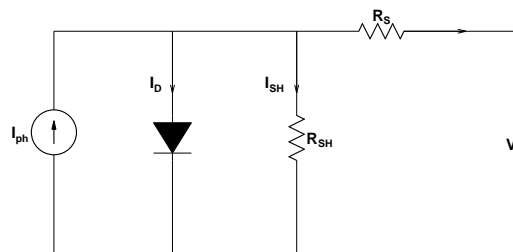


Figure 2: Single diode model of a solar PV cell.

The equivalent circuit of a single diode model of a PV cell is shown in the Figure 2. To describe this circuit, the equation is given by

$$I = I_{ph} - I_0 \left(e^{\frac{q(V+IR_s)}{KT}} - 1 \right) - \frac{(V + IR_s)}{R_{sh}} \quad (1)$$

Where,

- I is the Current of a PV cell (A).
- I_{ph} is the photocurrent (A).
- I_0 is the saturation current of a diode (A).
- Q is the electron charge (coulombs).
- K is the Boltzman constant (J/K).
- T is the temperature of a cell (K).
- R_s and R_{sh} are the series and shunt resistance (Ω).
- V is the output voltage of a cell (V).

The single diode model shown in the Figure 2 has an ideality factor of 1. The I_{ph} is the current generated when the photon from the sunlight is incident on the cell. The electron hole pairs will be generated. As the intensity of light increases, more electron hole recombination will occur and the resulting photocurrent will be increased. I_{ph} also varies

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with the temperature variations. The simulated results of Solarex MS-60 PV module in Matlab Simulink with the P-V and I-V curves are shown in the Figure 3. These curves helps in determining the characteristics of a PV module such as maximum power point, I_{SC} , V_{OC} , V_m and I_m . [8].

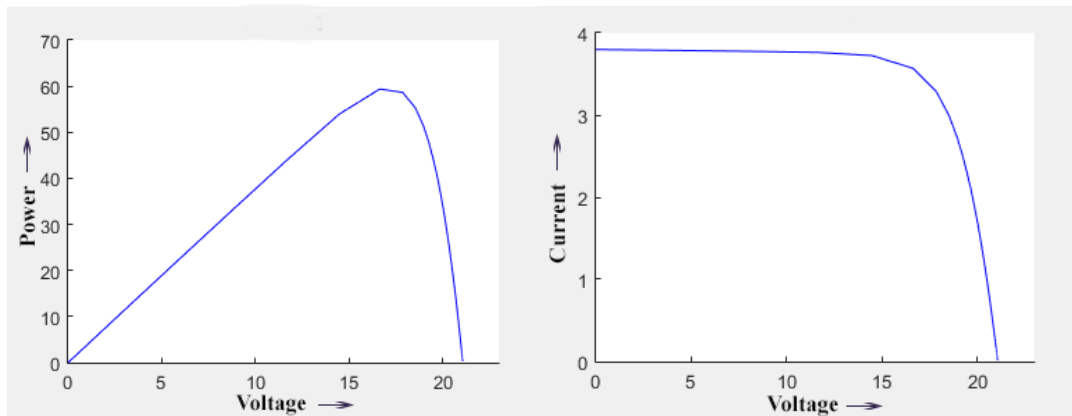


Figure 3: PV and IV characteristics of solar module.

III. PERTURB AND OBSERVE MPPT TECHNIQUE

The power v/s Voltage plot of a V panel consists of a curve. At only one point, the power is maximum. This maximum power occurs at maximum power point voltage, V_{MPP} and maximum power point current I_{MPP} . In this algorithm, calculation of power is done by sensing the panel's output voltage and current. The calculated power changes with the change in the ambience conditions. Based on these changes, the algorithm processes the data and corresponding change in the duty cycle is given as the output.

The Perturb and observe MPPT technique flow chart is shown in the Figure 4. The PV panel output voltage and current are measured continuously with time. The measured voltage and current are read by the P & O MPPT algorithm. Power is calculated from the measured values. The difference in the power measured at current time and the power measured at previous time gives the change in the power, power delta. If the change in the power is positive, sign change in voltage is looked. If the change in the voltage between current time and previous time is positive duty ratio is increased further and changes in the power is observed. If there is positive power change and change in voltage is negative, duty ratio is decreased. If the change in power is negative and the voltage change from current time to previous time is also negative, then the duty ratio is decreased or if change in voltage is positive, then the duty ratio is decreased.

The code for this algorithm is written in different languages depending on the type of hardware in which it is to be implemented. As the hardware controllers such as microcontrollers and digital signal processors have some disadvantages in large scale and real time implementation, Field Programmable Gate Array (FPGA) is opted in this paper [9][10]. FPGA has large set of logic blocks which can be configured to perform many functions in parallel and also it is faster, which is the main requirement in real time implementation [7]. FPGA can be programmed using HDL language. It has two types, Verilog and VHDL. In this paper, the code for P and O MPPT algorithm is written in Verilog HDL language. Case statements are used in the code to read the voltage and current readings from the sensors. Then the case number is incremented after each case. The current and the previous voltage and current readings are stored in the separate registers. Multiplication program is used to get the product of voltage and current readings. Under the 'if' statement, the difference in the previous and current tie power reading is checked to proceed as per the algorithm.

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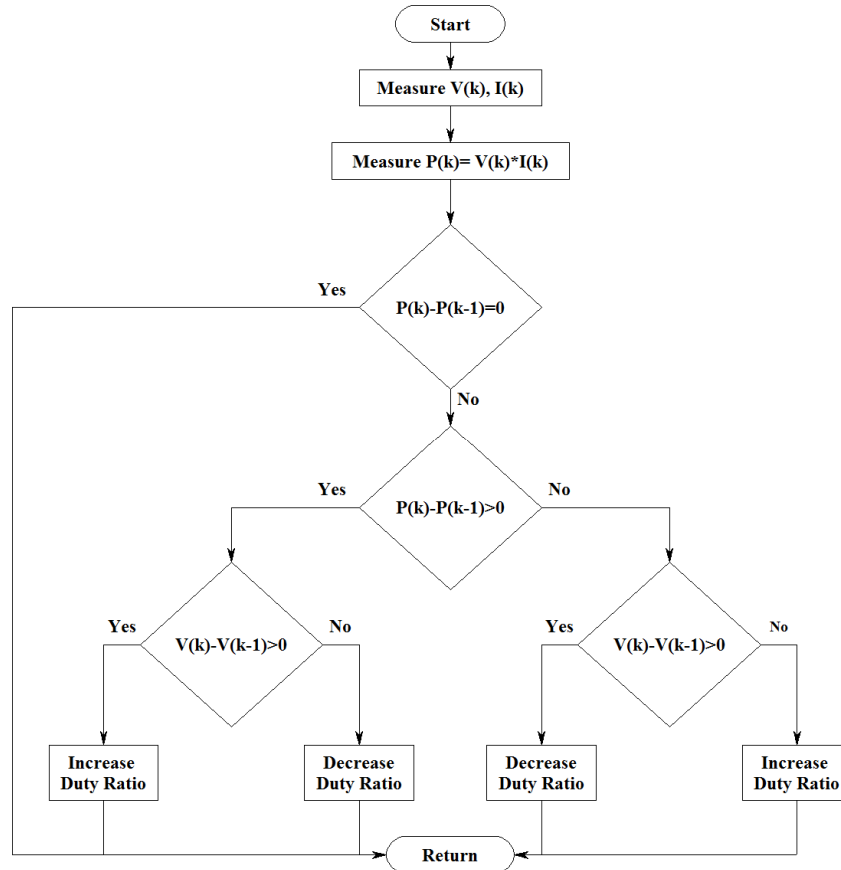


Figure 4: Flow chart of Perturb and Observe MPPT algorithm.

The code for the PWM generation is written in the Verilog. A clock of 1MHz is used here to get a PWM gate signal of 50 KHz to Mosfet switch of DC-DC boost converter. The formula to generate a PWM signal is given by the equation (2).

$$F_{PWM} = \frac{F_{CLK}}{2^N} \quad (2)$$

The principle used here to generate PWM signal using a counter and the input value. Input value is compared with the counter value. The counter keeps on counting, input value is compared with the counter value. When the value of the input is higher than the value of the counter, PWM output is high or else when the counter value exceeds input value, PWM output is low [11]. The duty ratio of the PWM signal can be controlled by controlling the input value to the comparator. PWM module is called inside the P and O algorithm program, the output of this program is given as the input to the PWM comparator. With the changes in the panel's output power, corresponding changes are made in the output of P and O code according to the algorithm. From this, as the input to the P and O code changes, PWM gate signal is generated with the required changes in the duty ratio. Thus the maximum power point tracking is achieved by Perturb and Observe MPPT algorithm. The simulation results are as shown in the Figure 5 to 8.

IV. SIMULATION RESULTS

These are the simulation results of the P and O algorithm Verilog code. These results are obtained from the Modelsim simulation software. Figure 5 shows the simulation of P and O Verilog code. This is with the 1MHz clock reference. V_ref is the output of this algorithm which is based on the changes in the input from the voltage and current sensors.

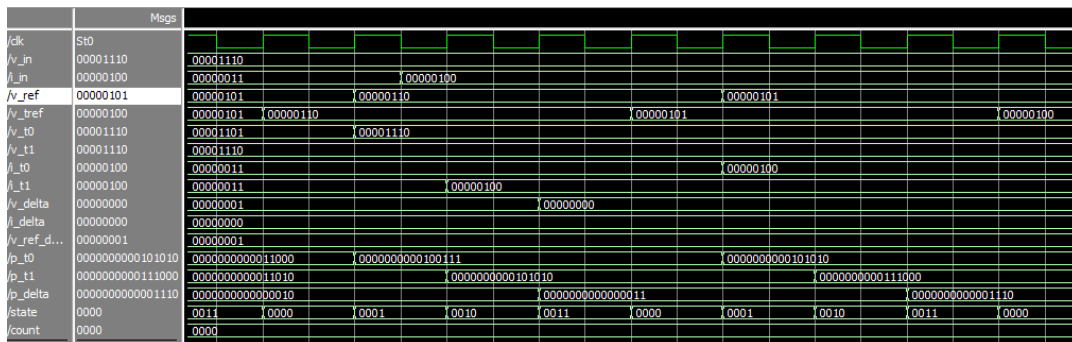


Figure 5: P and O MPPT algorithm simulation.

The output V_ref is input to the PWM comparator, which compares with the counter value to generate PWM gate signal. With the variations in the value of V_ref, PWM gate signal duty ratio is varied. The below Figures shows the PWM signals with a duty ratio of 25%, 50% and 75% generated with the changes in V_ref.

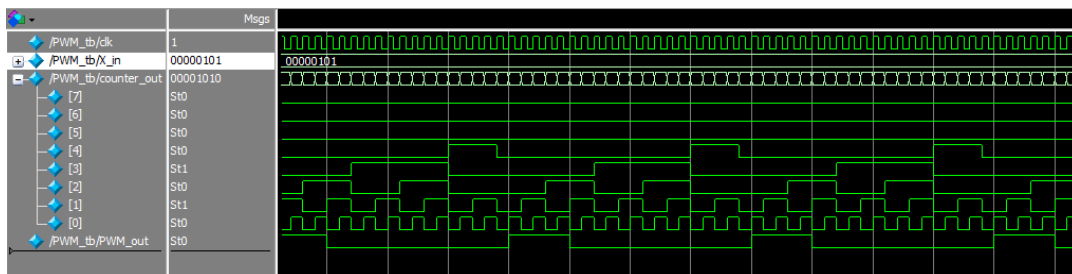


Figure 6: PWM gate signal with a duty ratio of 25%.

With a reference clock of 1MHz, pwm signal of 10 kHz is generated. Here 7bit counter is used with a counter value limited to 100. When the input to pwm comparator from V_ref output is 24(convert 24 to 7bit binary and replace 24 with that binary value), the duty ratio of generated pwm signal is 25% as shown in the figure 6.

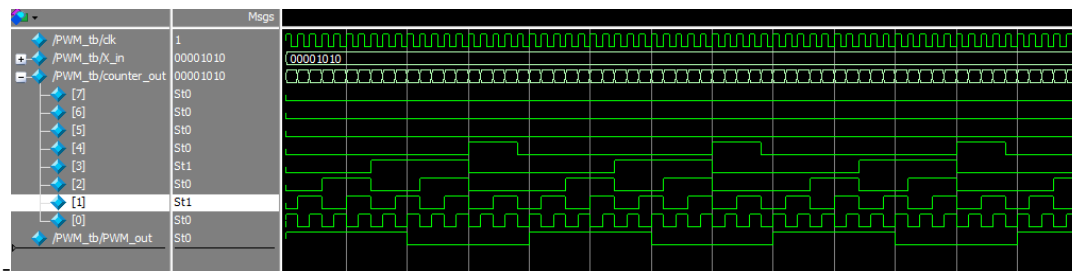


Figure 7: PWM gate signal with a duty ratio of 50%.

When the comparator input is 49(convert and replace with binary), pwm signal with 50% duty cycle is generated as shown in the figure 7.

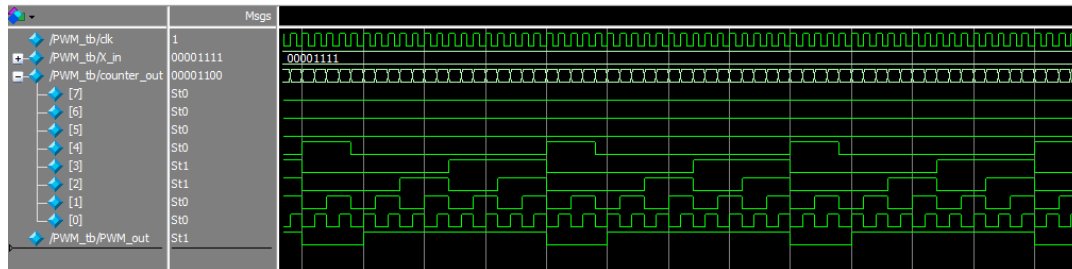


Figure 8: PWM gate signal with a duty ratio of 75%.

Pwm signal with 75% duty cycle is generated when the P& O algorithm V_{ref} output to Pwm comparator is 74(convert and replace with binary) as shown in the figure 8.

V. CONCLUSION

In this paper, the use of MPPT to vary the duty ratio DC-DC converter switch to match the impedance and transfer maximum power from PV module to load is shown. The flow of P and O MPPT algorithm with changes in the output reference responding to the input changes is shown. The code for this algorithm, written in Verilog HDL language is simulated and corresponding PWM signal generation for DC-DC converter switch is shown. By this it is helpful for implementation of FPGA as a MPPT controller based on Perturb and Observe MPPT algorithm in PV systems.

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