Microcontroller-Based Intelligent Boost Converter for Solar Photovoltaic Module Maximum Peak Power Tracking

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Abstract — In order to guarantee quick maximum power point operation under all rapidly changing environmental conditions, the study aims to provide an innovative, cost-effective, and efficient microcontroller-based MPPT system for solar photovoltaic systems. The MPP must be tracked using the proper techniques because it fluctuates depending on the irradiation and cell temperature. Maximum power point tracking is the term for this. Various MPPT algorithms have been proposed in the literature, each with a unique performance. Numerous factors, including complexity, convergence time, hardware implementation, cost, range of efficacy, sensors needed, and parameterization requirements, distinguish these methods from one another.

Keywords: Maximum Power Point Tracking (MPPT), Solar Photovoltaic Systems, Microcontroller-Based Control, MPPT Algorithms, Irradiance and Temperature Variation, Power Optimization

I. INTRODUCTION

Energy derived from natural resources including sunshine, wind, rain, tides, and geothermal heat is referred to as renewable energy. These resources can be naturally renewed and are renewable.

Therefore, unlike depleting traditional fossil fuels, these resources can be practically regarded as limitless [1]. The expansion and advancement of clean and renewable energy sources have been revitalized by the world's energy crisis. Organizations worldwide are embracing Clean Development Mechanisms (CDMs) [2]. Aside from the quickly depleting fossil fuel reserves.

The pollution that results from burning fossil fuels is another significant factor opposing them globally. In contrast to their traditional equivalents, renewable energy sources are believed to be far cleaner and to generate energy without the negative impacts of pollution.

These energy sources can all be used to varied degrees and at different prices. Since uranium is a finite resource and its supplies are depleted via use, nuclear energy shall be considered a non-renewable energy source for the purposes of this article even though it is not a fossil fuel.

It's critical to keep in mind that every energy producing process has some impact on the environment. One extremely inefficient energy source is solar energy. Earth receives a vast quantity of sunshine every day, but solar panels and other solar power technologies are not efficient enough to make the most of it. More electricity is produced when efficiency is improved. We need suitable solar storage techniques to guarantee the dependability of solar-generated energy as the sun is an intermittent energy source.

Before solar energy becomes a significant player in the global energy market and becomes cost-competitive with fossil fuels, there are still a number of difficulties that need to be handled.

II. MPPT CONTROL ALGORITHM

A. Perturb And Observe (P&O)

According to the Perturb & Observe algorithm, if a slight increase in the PV panel's operating voltage results in a positive change in power _P, we are moving in the direction of MPP and will continue to perturb in that direction.

If _P is negative, we are deviating from the MPP direction and the given perturbation sign needs to be altered.

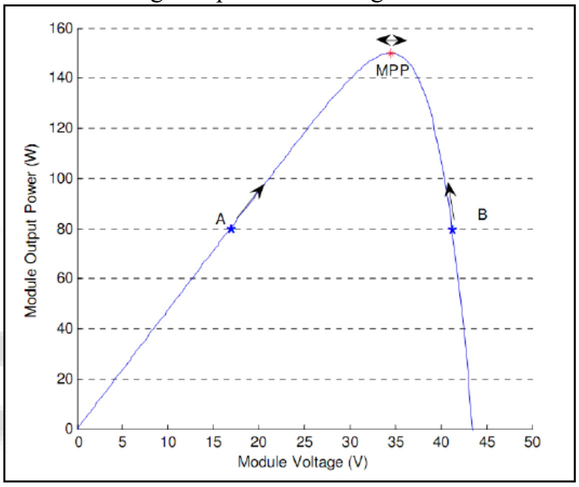


Fig. 1: Module Voltage and Output Power

The perturbation continues in the same direction if it causes an increase in power [7]. When the peak power is reached, and the power subsequently decreases, the perturbation reverses. Upon reaching steady state, the algorithm oscillates around the peak power point. To minimize power variation, the perturbation size is kept very small. The algorithm sets a reference voltage for the module corresponding to its peak voltage, and a PI controller adjusts the operating point to this voltage level. However, some power loss occurs due to the perturbation, and the algorithm struggles to accurately track power under rapidly changing atmospheric conditions.

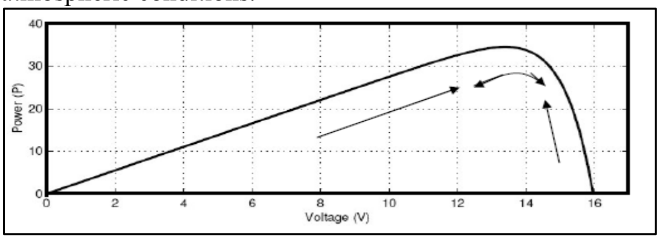


Fig.2 Module Voltage and Output Power

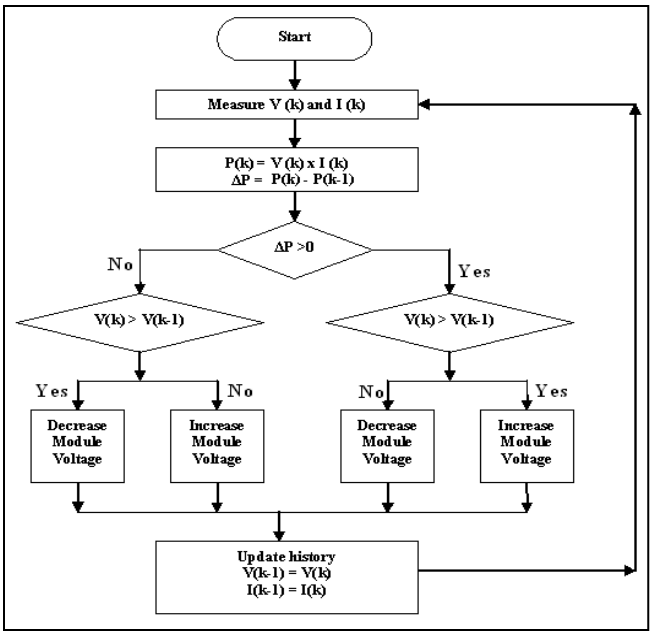


Fig. 3: Flow Chart of Perturb and Observe Grapf of power vs voltage for perturb and observe

B. Incremental conductance

Incremental conductance is a technique used in maximum power point tracking (MPPT) that leverages the characteristic that the slope of the power-voltage (P-V) curve is zero at the maximum power point (MPP). To the left of the MPP, the slope of the P-V curve is positive, while to the right, it is negative. When the MPP is found, the solar module maintains operation at this point unless there is a change in the current (I). Such changes typically occur due to variations in the MPP or ambient conditions, such as irradiance or temperature. When these changes happen, the algorithm adjusts the operating voltage to track and reach the new MPP.

This can be written in the following simple equations:

$$dp/dV = 0 \text{ at the MPOP}$$

$$dP/dV > 0 \text{ to the left of the MPOP}$$

$$dP/dV < 0 \text{ to the right of the MPOP}$$

C. Parasitic Capacitances

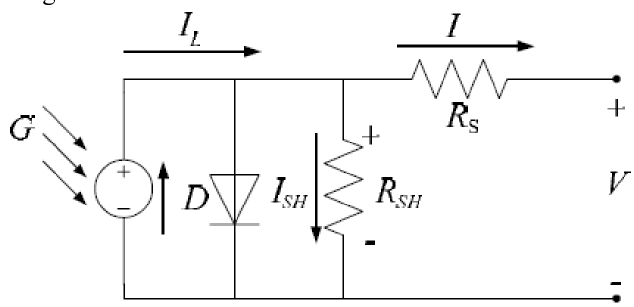
The parasitic capacitance method is an improved version of the incremental conductance method. It considers the small capacitances that naturally exist in the solar cells of the PV array. This method uses the switching ripple from the MPPT to make small changes in the array. To account for these capacitances, the average ripple in the array's power and voltage, created by the switching frequency, is measured using filters and multipliers. These measurements help calculate the array's conductance. Then, the incremental conductance algorithm is used to decide which way to adjust the MPPT's operating point. One problem with this method is that each module's parasitic capacitance is very small, so it only becomes noticeable in large PV arrays where multiple module strings are connected in parallel. Also, the DC-DC converter has a big input capacitor that helps reduce small ripples in the array's power. This capacitor might hide the overall effect of the PV array's parasitic capacitance.

D. Voltage control maximum point tracker

It is assumed that a maximum power point of a particular solar PV module lies at about 0.75 times the open circuit voltage of the module. So by measuring the open circuit voltage a reference voltage can be generated and feed forward voltage control scheme can be implemented to bring the solar PV module voltage to the point of maximum power. One problem of this technique is the open circuit voltage of the module varies with the temperature.

E. Modeling the solar cell

The simplest way to represent a solar cell is by using a current source connected in parallel with a diode. The current from the source depends directly on the amount of light hitting the cell, which is called the photocurrent (Iph). When there is no light, the solar cell acts like a regular diode, which is a p-n junction. In this situation, it does not produce any current or voltage. However, if you connect it to a strong external power source, it will create a current known as the diode current or dark current (ID). This diode is what controls the current-voltage behaviour of the solar cell.



$$I = I_L - I_0\left(e^{\frac{q(V+IR_s)}{nKT}} - 1\right)$$

The model included temperature dependence of the photocurrent *IL* and the saturation current of the diode *I0*.

$$\mathrm{I_L = I_L\,(T_1) + K_0(T - T_1)}$$

$$I_L(T_1) = I_{SC}(T_{1,nom})\frac{G}{G(_{nom})}$$

$$K_0 = I_{SC}(T_{1,nom})\frac{G}{G(_{nom})}$$

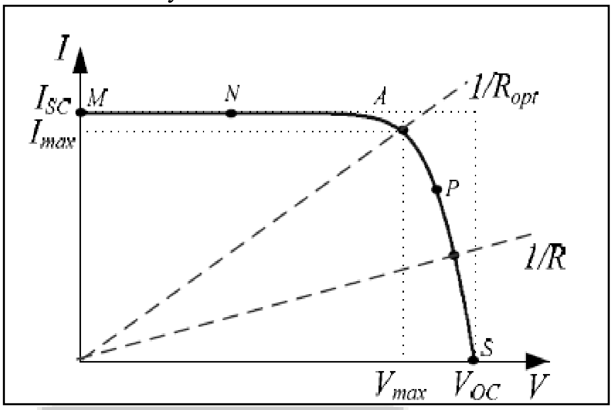
$$K_0 = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{(T_2 - T_1)}$$

$$I_0 = I_O(T_1)\left(\frac{T}{T_1}\right)^{\frac{3}{n}} e^{\frac{qV_q(T_1)}{nk\left(\frac{1}{T}\right)\left(\frac{1}{T_1}\right)}}$$

$$I_0(T_1) = \frac{I_{SC}(T_1)}{e^{\frac{qV_{oc}(T_1)}{nkT_1}} - 1}$$

F. *Current-Voltage I-V Curve for A Solar Cell*

A typical I-V characteristic of the solar cell for a certain ambient irradiation *G* and a certain fixed cell temperature *T*, is shown in Fig 2. For a resistive load, the load characteristic is a straight line with scope *I/V*=1/*R*. It should be pointed out that the power delivered to the load depends on the value of the resistance only.



the load R is small, the cell works in the M-N part of the curve (Fig 2), and it acts like a current source, almost the same as the short circuit current. But if the load R is large, the cell works in the P-S part of the curve, and it behaves more like a voltage source, almost the same as the open-circuit voltage.

G. *Perturb And Observe Algorithm*

The graph shows how the power output of a solar panel changes with its voltage when there is a certain amount of sunlight. The point labeled MPP is the Maximum Power Point, which is the highest power the solar panel can produce. Let's say there are two points, A and B. Point A is to the left of the MPP. So, if we slightly increase the voltage, we can move closer to the MPP. However, point B is to the right of the MPP. If we increase the voltage again, the power output goes down, which means we need to decrease the voltage instead to reach the MPP.

III. BOOST CONVERTER

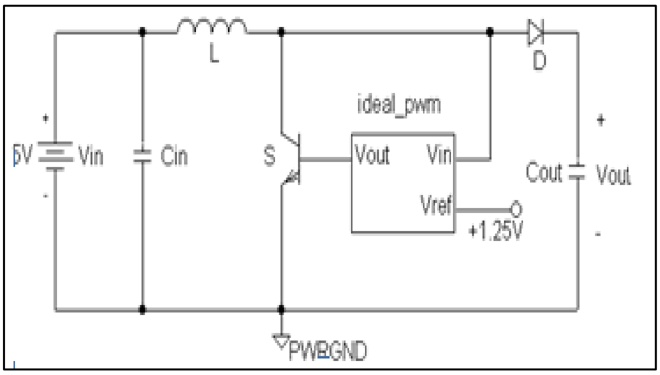
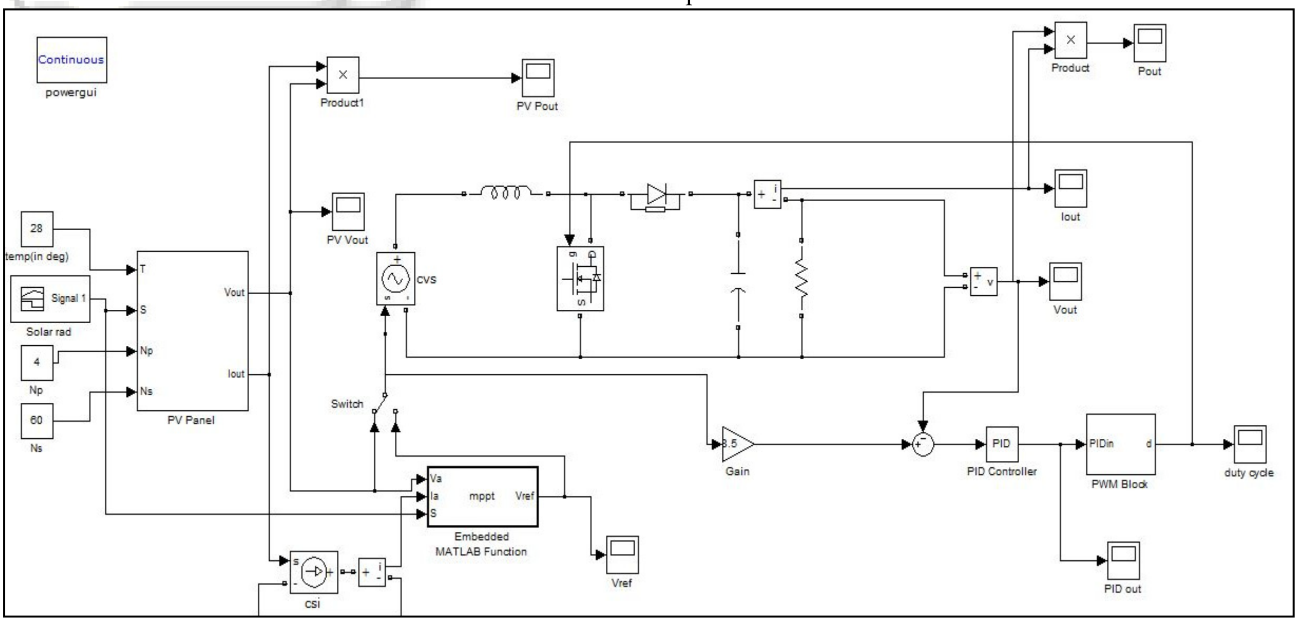


Fig. 4: Boost Converter

When the switch is closed, the inductor charges using the battery and saves the energy. In this stage, the current through the inductor increases quickly, but for easier understanding, we act as if the charging and discharging of the inductor happen in a straight line. The diode stops the current from going through, so the load current stays the same, and it comes from the capacitor discharging.

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation.



IV. SIMULATION RESULT

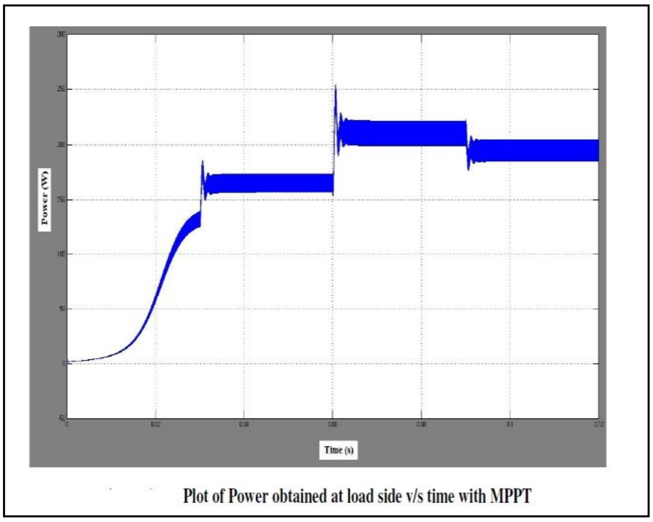


Fig. 5: Plot of power obtained at load side v/s time with MPPT

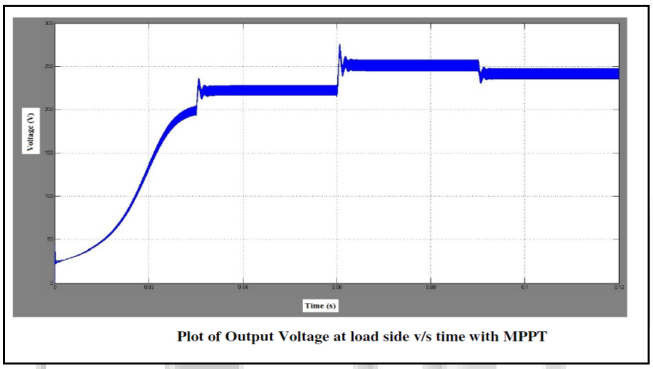


Fig. 6: Plot of Output Voltage at load side v/s time with MPPT

V. CONCLUSION

The simulation was first run with the switch set to no MPPT mode, which skipped the MPPT algorithm in the circuit. It was observed that when the MPPT algorithm wasn't used, the power delivered to the load was about 95 Watts for a solar irradiation level of 85 Watts per square centimeter. It should be noted that the PV panel was producing around 250 Watts under these conditions. This means the conversion efficiency was quite low. The simulation was then run with the switch set to MPPT mode. Under the same solar irradiation levels, the PV panel still generated about 250 Watts. However, in this case, the power delivered to the load was higher the load side was found to be around 215 Watts thus increasing the conversion efficiency of the photovoltaic system as a whole. The loss of power from the available 250 Watts generated by the PV panel can be explained by switching losses in the high frequency PWM switching circuit and the inductive and capacitive losses in the Boost Converter circuit. Therefore, it was seen that using the Perturb & Observe MPPT technique increased the efficiency of the photovoltaic system by approximately 126% from an earlier output power of around 95 Watts to an obtained output power of around 215 Watts.

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