

Development of a Novel Robust Differential Maximum Power Point Tracking (MPPT) Method

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Abstract- The use of photovoltaic (PV) systems is increasingly growing in importance since they involve an exploitation of solar radiation constituting an energy source which is renewable, available in most places, and pollution-free. Despite their numerous advantages, PV systems have two major drawbacks: low energy conversion efficiency and loss of energy due to variations in meteorological conditions; for this reason, Maximum Power Point Tracking (MPPT) control techniques play a key role in exploiting the maximum energy caught by PV modules. The output characteristic of a photovoltaic array is non-linear and changes with solar irradiation and the cell's temperature. Therefore, a Maximum Power Point Tracking (MPPT) technique is needed to draw peak power from the solar array to maximize the produced energy. In this study we have analyzed the Maximum Power Point Tracking (MPPT) method and finding out a new and easier way to track maximum power point (MPP) and also our study is focused to overcome the drawbacks of MPPT. This research paper presents a novel MPP tracking method for tracking exact Maximum Power Point (MPP) if the irradiation or load changes.

Index Terms- Irradiance, MPP, MPPT, PO, PV

I. INTRODUCTION

Maximum Power Point Tracking (MPPT) is a technique which is used commonly with photovoltaic (PV) solar systems to maximize power extraction under all conditions [1]. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power.

As PV solar panel efficiency is low, so it is very important that load works in maximum power. Otherwise power losses occur. In PV solar system, it is not necessary that the load works in the maximum power. That is why it's necessary to track the maximum power point so that load can work at that point for reducing power losses. In this study we have considered the challenge to minimize the power losses of existing solar systems and another challenge to track the maximum power.

Due to changes in irradiation the load characteristics also changes as a result the efficiency of the whole system is also variable.

Our main focus of this study is as follow:

- To investigate and track the maximum power point in present solar system and find the suitable and stable way for tracking MPP.
- To learn and study about algorithms for tracking maximum power point.

II. METHODOLOGY

A. MPP Tracking Methods

Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation. Some popular MPPT algorithms are Perturb and Observation, Incremental Conductance, Fractional Open Circuit Voltage, Fractional Short Circuit Current etc.

Perturb and Observation MPPT Algorithm: This algorithm is an iterative technique and very simple one. It measures the panel operating voltage and current periodically and calculates the instantaneous power $p(n)$. This instantaneous power compares with the previous output power $P(n)-P(n-1)$, then the operating voltage $X(n+1)$ is determined and changed by changing the duty ratio of the converter $X(n+c)$ or $X(n-c)$. The sign of change of output power is also observed to track the MPP. This method has some drawbacks as well: The operating point continues to oscillate around the MPP, resulting in PV power losses, The P&O fails to work properly under a sudden increase in insolation level, exhibiting erratic behavior, It lacks accuracy in finding whether the MPP is reached.

Incremental Conductance Algorithm (INC): This is a most popular MPPT algorithm and widely used. The disadvantages of the P&O MPPT algorithm is overcome and eliminated by this INC technique but it is more complex and very difficult to implement. The theory of the incremental conductance is to determine the variation direction of the output terminal voltage of the PV modules by measuring and comparing the incremental conductance and instantaneous conductance of PV modules.

III. PROPOSED METHOD

A. Proposed MPP Tracking Technique:

Analyzing all popular algorithms and technique we have proposed a robust optimization 1st order close loop differential MPP tracking method which is controlled by PI controller. We have developed this method to track MPP whether the radiation or load changes. Here is the block diagram of our proposed method

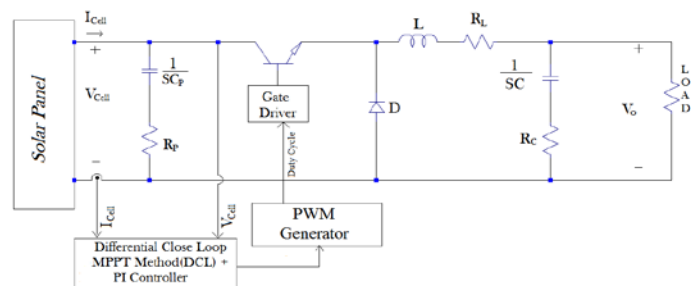


Figure 1: Model of MPPT using block diagram

The Figure 1 shows PV system block diagram with MPPT Technique. It consists of PV array, Buck converter, MPPT block, and finally load. Combination of Series and parallel solar cells constitute PV array. Series connection of solar cells boost up the array voltage and parallel connection increases the current. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. Buck converter is used to obtain more practical uses from solar panel. The input of buck converter is connected to PV array and output is connected to load [12]. MPPT block receives VPV and IPV signals from PV array. The output of MPPT block is going to the PI controller. Then from PI controller these pulses are given to buck converter. Converter works based on these pulses to make the PV system operate at Maximum power point (MPP) [3]. The heart of the model is MPPT block which is working through the PI controller helps in finding the maximum operating point of the solar panel. This can be done by using a robust 1st order close loop differential MPPT method

B. Modeling of MPPT

The proposed circuit needs independent dc source which is supplied from photovoltaic cell. The inputs are fed by voltage and current of the PV terminals, while the output provides duty cycle for the buck converter. Buck converter controls the output voltage by varying the duty cycle k, of the switch. This is calculated using the formula

$$V_0 = KV_S.$$

If we vary the pulse width of the pulse generator various voltage ranges at the output can be obtained. Once the buck converter injected the power from the PV panel and the PI controller starts function, it varies the value of duty cycle which will change the input value that is sensed by the PI controller. By using the PI controller the error has been minimized in the system and the efficiency is improved [12].

C.MPPT implementation

MPPT implementation is a close loop system. Here $\frac{dP}{dV} = 0$ goes to dc/dc buck converter. From PV array I_{cell} and P_{cell} is goes through the differentiator and PI controller forcefully maintain that $\frac{dP}{dV}$ is equal to zero (0). The controlling block diagram is given bellow:

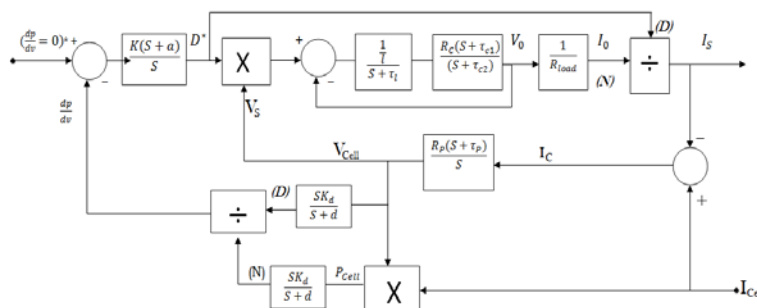


Figure 2: MPPT block diagram using buck converter and PI controller

IV. ANALYSIS AND SIMULATION

A. Simulation Circuit diagram of MPPT tracking in PSIM

In this paper, the simulation model is developed with PSIM. The proposed circuit needs independent dc source which is supplied from photovoltaic cell. The inputs are fed by voltage and current of the PV terminals, while the output provides duty cycle for the buck converter. Buck converter controls the output voltage by varying the duty cycle k, of the switch. Which is calculated using the formula $V_0 = KV_S$. If we vary the pulse width of the pulse generator various voltage ranges at the output can be obtained. Once the buck converter injected the power from the PV panel and the PI controller starts function, it varies the value of duty cycle which will change the input value that is sensed by the PI controller. By using the PI controller the error has been minimized in the system and the efficiency is improved [12].

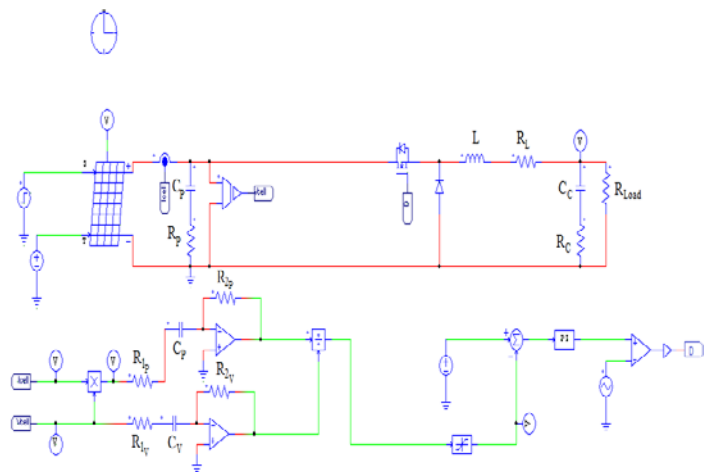


Figure 3: Simulation circuit of solar panel with MPPT block

The model shown in figure 3 represents a PV solar panel connected to resistive load through a DC/DC Buck converter. The DC-Buck boost system specifications are given as follows_

Load Resistance, $R_{Load} = 1.5\Omega$.

Buck inductance, $L = 500\mu H$; Resistance, $R_L = 10m\Omega$

Buck capacitor, $C_c = 47\mu F$; Resistance, $R_c = 1m\Omega$.

Here in the block there are two differentiator. One is connected to the PCell and another is connected to the VCell.

Now the specifications are given_

Power diff. resistor, $R_{1P} = 20\Omega$; $R_{2P} = 100\Omega$

Power diff. capacitor, $C_P = 10nF$

Voltage diff. resistor, $R_{1V} = 20\Omega$; $R_{2V} = 100\Omega$

Voltage diff. capacitor, $C_V = 10nF$

PI controller gain (K)= 10000 and $a = 0.1$

Now here is the panel parameter below_

Table 1: The parameters of 60w solar panel

60W Solar Panel		
Sr. no	Parameter	Value
1	Number of cell	$N_s = 36$
2	Standard radiation	$1000w/m^2$
3	Series resistance	$R_s = 0.008\Omega$
4	Shunt resistance	$R_{sh} = 1000\Omega$
5	Short circuit current	$I_{sc} = 3.8A$
6	Open circuit voltage	$V_{oc} = 21.1V$

B. Irradiance Effect

Effect of Decreasing Irradiance:

In solar panel irradiance is not constant, it is changeable. If it is cloudy day then irradiance effect is decreasing. Then it is very important to track that MPP. On that condition $\frac{dP}{dV} = 0$ is required. The output power of the solar panel varies with the irradiance. Solar power is high at high value of solar irradiance & it starts decreasing as the solar irradiance value decreases.

After simulation using the circuit diagram 3

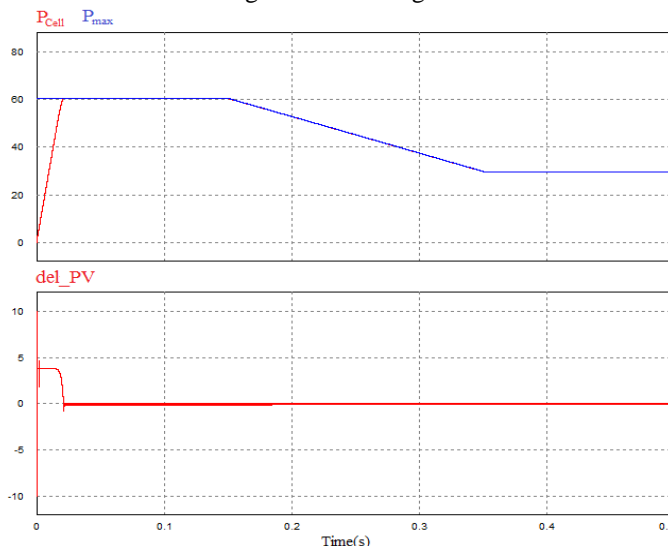


Figure 4: MPP track when the irradiance is low

Here in the figure, when irradiance is low then on the upper portion PCell track the Pmax and in lower portion $\frac{dP}{dV}$ track the zero(0) point. If $\frac{dP}{dV} = 0$ then power will be maximum. That mean PCell track the Pmax. It is clear from waveform that even though solar irradiance varies output remains constant. This is because of PI controller and novel robust differential MPPT method. It is also necessary that Load can work at that maximum power. This is shown in below simulation figure.

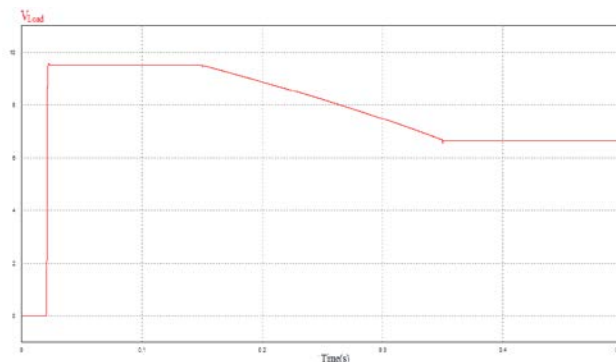


Figure 5: Load is working in maximum power point

Increasing Irradiance Effect: When it is sunny day then irradiance effect is high. Then it is also necessary to track MPP for minimize power loss. On that condition $\frac{dP}{dV} = 0$ is require.

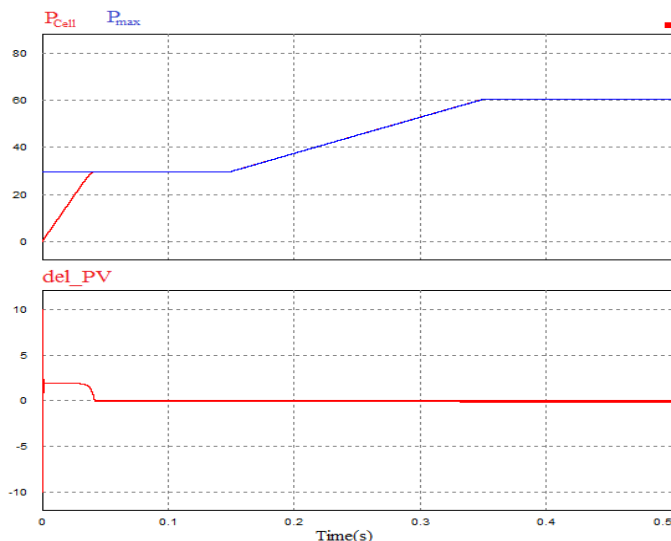


Figure 6: MPP track when the irradiance is high

Here in the figure, when irradiance is high then on the upper portion P_{Cell} track the P_{max} and in lower portion dP/dV track the zero(0) point. If $dP/dV = 0$ then power will be maximum. That mean P_{Cell} track the P_{max}. Load must have to work at that maximum power when the irradiance is high. This is shown in below simulation figure.

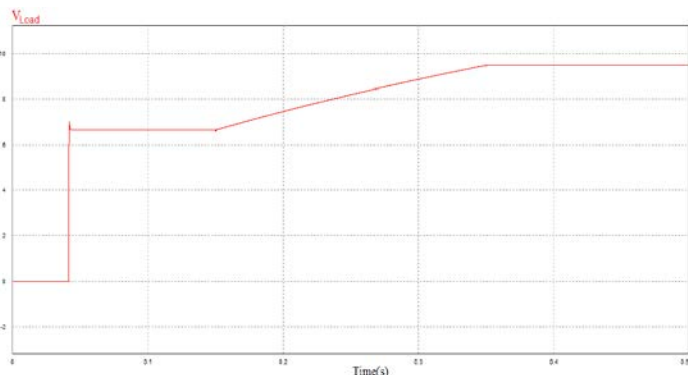


Figure 7: Load is working in maximum power point

C. Load Changing Effect

It is very difficult to track MPP when load is changed. Because when load is changed power consumption fluctuate at instant. That is why is too difficult to track MPP. But using PI controller and 1st order close loop differential MPPT method can easily track maximum power point.

Here is the changing load is
 $R_{load} = 1\Omega$

Now load changing effect is shown in the below figure _

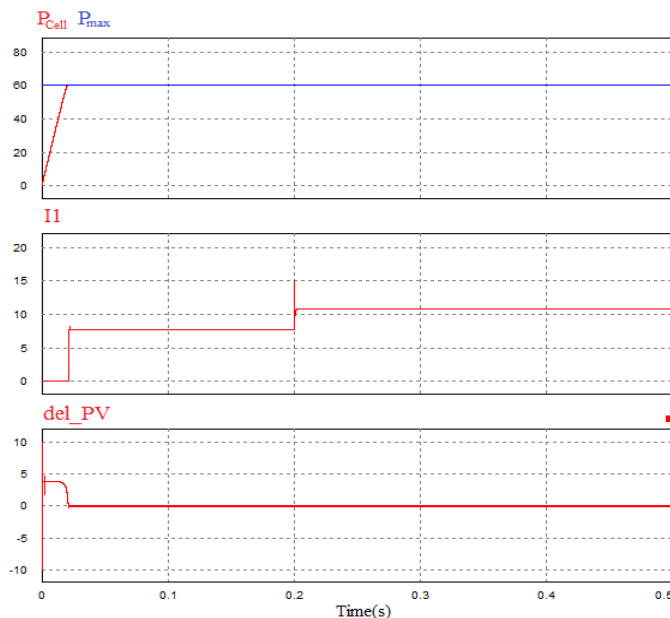


Figure 8: MPP is tracked when the load is changing

Here in this figure.....though load is changed on the upper portion P_{cell} easily track the P_{max} and also dP/dV is equal to zero (0) is shown in the lower portion.

V. RESULT ANALYSIS

We have found a new MPP tracking method which is controlled by PI controller. This new method name is “**Novel Robust Differential MPP Tracking Method**”. Using this method through the PI controller we can easily track the maximum power point.

A. Irradiance Effect

The output power of solar panel with MPPT block with respect to solar irradiance level is as shown in the figure 4 and 6. It is clear from the figure that the output power of the solar panel varies with the irradiance. Solar power is high at high value of solar irradiance & it starts decreasing as the solar irradiance value decreases.

Now here is the result justifying table_

Table 2: Result justification on irradiance varies

Sr.No	X-axis (Time in second)	Y-axis(Power in watt)
1	0.0	0.0
2	0.0066	20
3	0.0133	38
4	0.02	60
5	0.10	60
6	0.15	58
7	0.20	48
8	0.30	38
9	0.35	31
10	0.40	30

From the table 2 it is shown that at X-axis when time is between 0(zero) s to 0.2 s Pcell couldn't track the Pmax. This is the error of this method. But on the other side 0.02 s is very small time. So this small time couldn't create any effect on the output result. After that small time maximum power point is tracked exactly by Pcell. That mean it takes time 20ms to track maximum power point.

B. Load Changing Effect

Output power of solar panel of with MPPT block varies with respect to the changing of load. By using PI controller to track maximum power Pmax in MPPT method while the load is changing, as shown in figure 8

PI controller forcefully create $\frac{dP}{dV}$ is equal to 0(zero) and that is why load can track the maximum power point. This is shown in figure 8

Now here is the result justifying table

Table 3: Result justification on changing load

Sr.No	Time in s(X-axis)	Pcell(Y-axis)W	I1(Y-axis)A	□PV(Y-axis)
1	6.66ms	10	0	3.5
2	13.33ms	40	0	3.4
3	20.00ms	60	8	0
4	26.66ms	60	8	0
5	33.33	60	8	0
6	200ms	60	11	0
7	300ms	60	11	0
8	400ms	60	11	0
9	500ms	60	11	0

From the table 3 it is clear that from time 0 (zero) to time 0.02 there is some error. On that time Pcell,I1 and ΔPV is not expected value. But after that point all three Pcell,I1 and ΔPV is expected value. That mean system takes 20ms to track maximum power point. After that small time load can easily track the maximum power point and PI controller forcefully create $\frac{dP}{dV}$ is equal to 0(zero).

VI. CONCLUSION

Power generation method using solar photovoltaic module is a foremost effective technique of using the solar energy. In this method solar panel directly convert sunlight irradiation into electricity by the photoelectric effect. It is clean and pollution-free. MPPT algorithms used in PV systems are one of the most important factors affecting the electrical efficiency of system. As a result of cost optimization, after decided to use an MPPT system, it is important to decide which technique or method will be used in application [10]. After studying MPPT techniques , it is clear that it can be very difficult to choose the best; each MPPT method has its own advantages and disadvantages and the choice is highly application dependent. That's why MPPT algorithms are not suitable for tracking MPP [11]. Analyzing these methods we find out an easier new method

which is controlled by PI controller. The name of this method is "Novel robust differential maximum power point tracking method".

The output power of the solar panel varies with the irradiance. Solar power can be high when irradiance is high or power can be low when irradiance is low. So it is difficult to track MPP. One the other hand when load is varying the output is varying at instant. That is why it is more difficult to track maximum power point than irradiance varying. So it is important to use a robust and cost effective method. Using this Novel robust differential maximum power point tracking method through PI controller, we can track maximum power point perfectly whether it is irradiance effect or load change effect or temperature effect on PV panel.

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