

Analysis of Variable Step Incremental Conductance MPPT Technique for PV System

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Abstract : Now a days the tracking of maximum power point techniques are mostly used for photovoltaic (PV) array systems, to track the peak power output which is greatly depends on environmental condition (mainly irradiance & temperature) and load variation. There are many MPPT methods have been proposed. Among all, the incremental conductance (IC) method is largely used, because this method is less complicated and having good tracking accuracy. But in IC method the tracking speed is less. So this paper represents a variable step incremental conductance (VSIC) method. This paper improves both tracking speed as well as tracking accuracy with wide range of operating conditions. The paper also provides the detail analysis and simulation results for the proposed VSIC method under different environmental conditions. The variation in the output characteristics with the proposed MPPT and without MPPT are shown in the paper.

Keywords : photovoltaic (PV); maximum power point tracking (MPPT); variable step incremental conductance (VSIC).

I. Introduction

In recent days the electricity generated by solar energy system has gained its popularity. Because it has very less impact on the environment and have many advantages when compare to the fossil fired fuel energy system. Input to the solar system (irradiance and temperature) are highly depends on the environmental conditions. Due to which, the generation of electricity from the solar panel is affected and unstable. Instability of production in solar energy causes decrease the efficiency [11]. To eradicate this problem the MPPT controller is required. Because of the MPPT controller the system can supply maximum power with different environmental weather conditions as well as with varying load condition [10].

There are many MPPT techniques have been proposed, such as hill climbing method, fractional open circuit voltage (FOCV), fractional short circuit current (FSCC), perturb and observation (P & O) method [9], incremental conductance (IC) method, fuzzy logic control, neural network control. Among all of these techniques, FOCV and FSCC having simplest algorithms [7 and 9]. But these methods require disconnections of PV system at a regular interval, to obtain both current in short circuit condition (I_{sc}) and voltage across open circuit (V_{oc}). For which, there is a power loss and decrease in overall efficiency of the system. Hill climbing method and P & O technique are used in most cases, due to simple control strategies and can be implemented easily. But these methods may give erroneous tracking of peak power point for quick change in the environmental conditions. So these methods are not efficient for area with frequently changing irradiance and temperature. Fuzzy logic control and neural network controls have good response under changing atmosphere, due to its ability for taking care of the non-linearity. But these controllers should have to train accurately for a particular PV system, as the PV array characteristics changes with time. So parameters of algorithm have to be updated.

In IC method, the slope of power versus voltage at MPP is zero. The slope is not zero on the either side of the MPP. In this method the tracking speed is less, because a constant iteration step has been used. So the tracking accuracy can be improved by using this method, but the tracking speed is affected. To overcome this problem, in this paper the VSIC technique is proposed [10 and 14]. Approach to this method is same as that of the IC method except the step size variation. In this method the step size will change automatically according to the change in power to voltage output characteristics of the PV system. If the operating power point on the PV curve is far from the MPP, then step size will increase to enhance the tracking speed. If the operating power point on the PV curve is near MPP, then step size will decrease to enhance the accuracy of the tracking.

II. Proposed Scheme

For the proposed scheme, the generated current obtained from PV system module is fed to DC-DC boost converter. As per the maximum power point theorem, the output power of the system is attains its maximum value, when the source impedance is equal to load impedance. So, to get the maximum power we have to match the source impedance with load impedance [14]. This can be achieved by varying the DC-DC

converter duty cycle. It is difficult to control the duty cycle manually with load variation or variation in the input levels.

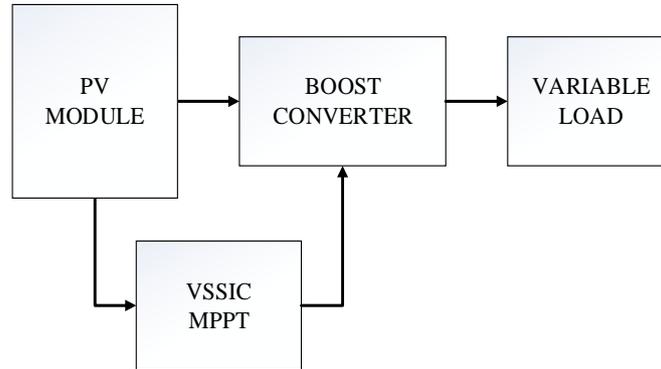


Fig. 1. Block diagram of proposed scheme.

To control the duty cycle, usually MPPT methods are used. Further to have an efficient control, here the VSIC method is used. The MPPT controller interface the PV module with the DC-DC converter and is shown in Fig. 1 and tracks the peak point.

2.1 PV module design

Basically the PV cell can be described as a semiconductor device, which produce electricity when exposed to light. A typical solar cell produce 0.5 to 0.8 volts. To have high voltage, the PV cells has to be connected in series and for high current the cells are to be in parallel as shown in Fig. 2. In this paper the solar module developed with the help of mathematical model [2 and 3]. Here the single diode model have been proposed. To have better accuracy, in single diode model the series as well as shunt resistance are also considered [6]. The equivalent cell current equation is given as

$$I = n_p * (I_{pv} - I_d - I_{sh}) \tag{1}$$

$$\text{Where, } I_{pv} = G/G_{stc} [I_{pv,stc} + \mu_{sc} (T_c - T_{stc})] \tag{2}$$

$$I_d = I_0 \left[\exp\left(\frac{(V/n_s + I * R_s) * q}{akT}\right) - 1 \right] \tag{3}$$

$$I_{sh} = \frac{(V + I * R_s)}{R_{sh}} \tag{4}$$

Here I is output current of cell, V is cell output voltage. I_{pv} is the generated current, I_d is current trough the diode, I_{sh} is the current through the shut resistance. G and T_c are irradiance and temperature at operating condition. G_{stc} and T_{stc} are irradiance and temperature for standard test condition (STC). μ_{sc} is the short circuit current coefficient, q is electron charge and k is Boltzmann's constant. 'a' is diode ideality factor, n_s is number of series connected PV cells and n_p is number of parallel connected cells. I_0 is saturation current of diode.

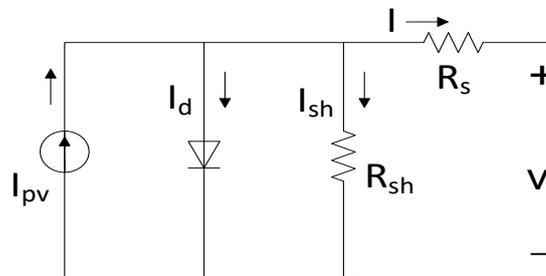


Fig. 2. Single diode PV cell model.

As given in [1 and 4], the change in temperature and irradiance, directly affect the short circuit current (I_{sc}). But the diode reverse saturation current is mainly affected by temperature only. The power obtained from PV module is depends on temperature and irradiance. PV module characteristics are shown is Fig. 3, where 36 series connected cells are considered.

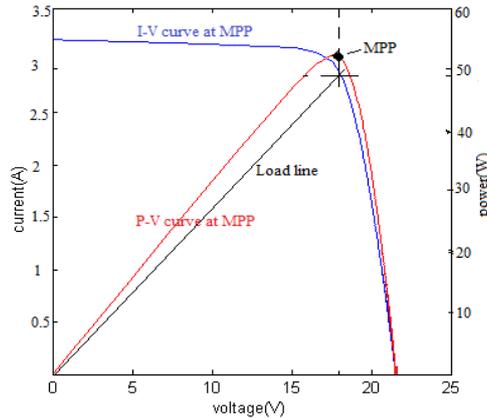


Fig. 3. Output characteristics of PV array.

Peak power of the module can be determined by load line shown in Fig. 3. As the load line depends on the load impedance of the system. At the point where the I-V curve and load line intersect each other, the value of power is simply the multiplication of voltage and current value at that particular point. DC-DC converter is required for determination for positioning of load line. Duty cycle of the converter should be regulated in a proper manner, so that the load line must intersect the I-V curve to get the peak power. The proper regulation of the duty cycle can be obtained with the help of MPPT method.

2.2 Proposed MPPT Technique

In this paper the VSIC method has been proposed. Basically the slope of P-V curve is determined by the VSIC algorithm. As the main aim of the tracker to track the peak point of P-V curve, so the algorithm should be designed to track the peak point of power curve. The variable step size introduced in the incremental conductance method to have a better tracking accuracy and speed. Because in conventional incremental conductance method, the tracking steps are constant. If tracking steps are small, then tracking speed decreases but accuracy increases [12 and 13]. If tracking steps are large then speed increases but accuracy decreases. So, by considering both cases the VSIC method have advantages over IC method. The comparison of step sizes are shown in Fig. 4. In IC method the instantaneous conductance (I/V) value of the system and incremental conductance (dI/dV) value are useful to determine the maximum power point on the P-V curve.

The power to voltage derivative of PV module is used as the parameter for the variable step increment or decrement of VSIC MPPT technique and is given as

$$D(n) = D(n - 1) \pm d \tag{5}$$

Where, $d = N * \left| \frac{dP}{dV} \right|$

D(n) is Duty cycle, d is variable step size depends on the change in the power to voltage derivative and N is the adjusted scaling factor and that decides the performance of MPPT.

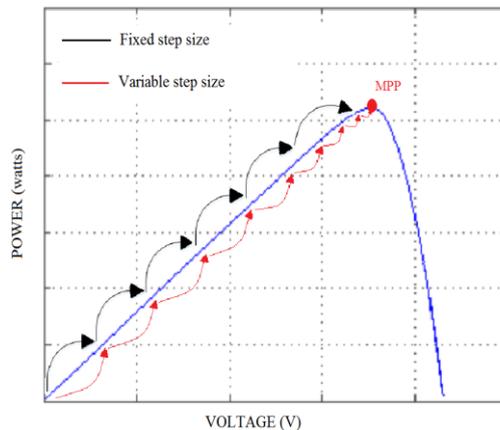


Fig. 4. Fixed and variable step MPPT operation.

At the peak point, slope of P-V characteristic curve is zero. The slope on left side of MPP is positive and on right it is negative.

$$\left. \begin{aligned} \text{At MPP: } (dP/dV) &= 0 \\ \text{On left of MPP: } (dP/dV) &> 0 \\ \text{On right of MPP: } (dP/dV) &< 0 \end{aligned} \right\} \quad (6)$$

The power to voltage derivative is

$$\frac{d}{dV} P = \frac{d}{dV} (VI) = I + V \frac{d}{dV} I \quad (7)$$

From (6) it can be written as

$$\left. \begin{aligned} \text{At MPP: } (dI/dV) &= -(I/V) \\ \text{On left of MPP: } (dI/dV) &> -(I/V) \\ \text{On right of MPP: } (dI/dV) &< -(I/V) \end{aligned} \right\} \quad (8)$$

By using (8), the algorithm is designed for proposed MPPT technique and is shown in Fig. 5. If change in incremental conductance is zero, then there is no change in the duty cycle. If the power to voltage derivative is more than zero, then duty cycle has to be increased and for less than zero the duty cycle has to be decreased. Then the duty cycle is adjusted by the scaling factor and the decrement and increment in the duty cycle is decided by power to voltage slope. To increase the tracing speed the scaling factor has to be increased. Fig. 6 and Fig. 7 shows variation in module power for constant and variable step size respectively. In Fig. 6, the step size is constant so near MPP variation is more as compare to the variable step [8 and 14]. In variable step size IC method the near to MPP there is decrease in step but gradually increases when tracking occurs at far from MPP. In fig. 6 the peak power is 109.015 and the variation near the MPP is more and the difference of power levels the two duty cycle is around 0.005. But in fig. 7 the peak power tracked is 109.232 and the variation is less and the difference in power is very less near MPP and gradually increases.

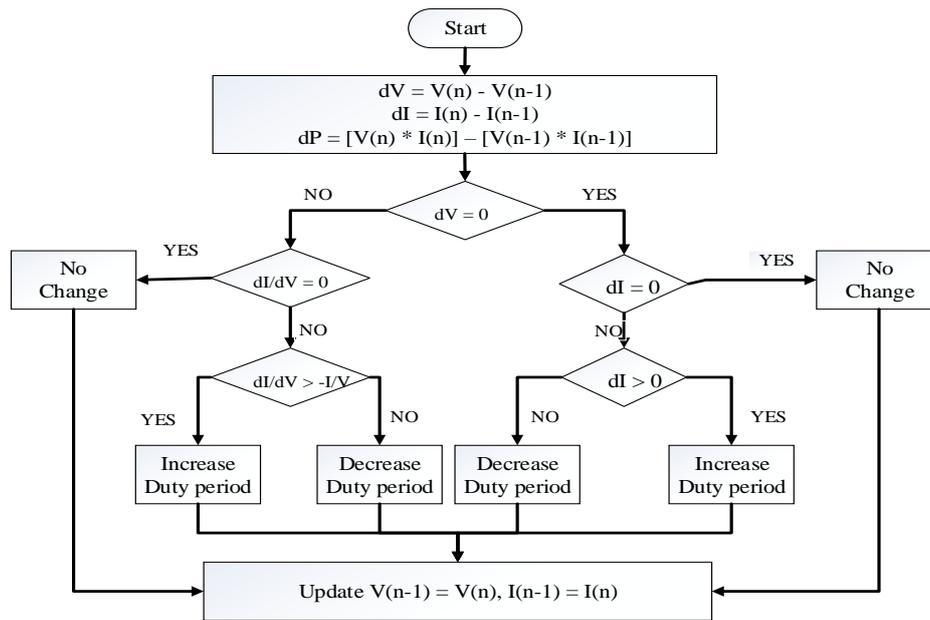


Fig. 5. Flow chart of VSIC MPPT technique.

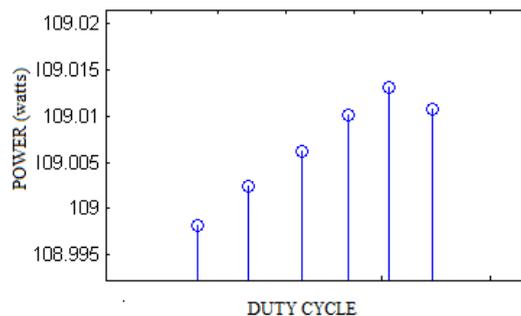


Fig. 6. PV power near MPP (at STC) for constant step size of 0.06.

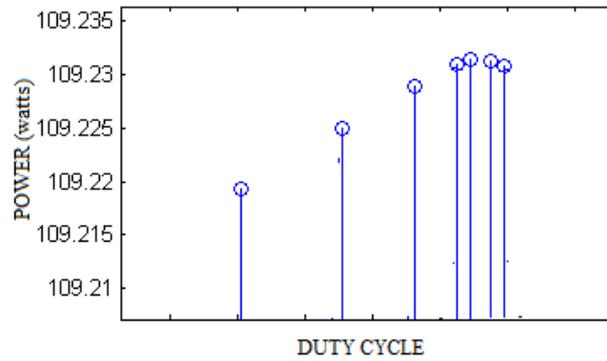


Fig. 7. PV power near MPP (at STC) for variable step size with .06 scaling factor.

2.3 DC Boost Converter Specification

To track maximum power, DC-DC converter is one of the essential power electronics device. In this paper the DC boost converter is used to achieve the proper load line for maximum power tracking and to boost the input voltage. The specification of DC boost converter are listed in Table I.

TABLE I
DC Boost Converter Specification

PARAMETERS	VALUES
Input side capacitance	350 μ F
Boost converter inductance	300 μ H
Output side capacitance	110 μ F
Converter switching frequency	50 kHz

TABLE II
Parameters of BP SX- 110 PV Module at STC

PARAMETERS	VALUES
V_{oc}	41.2 V
I_{sc}	3.69A
Temp coefficient of I_{sc}	(0.065 \pm 0.015)% A/ $^{\circ}$ C
V_{mp}	17.5 V
I_{mp}	3.34A
P_{max}	110 W

III. Simulation Results And Discussion

To verify the performance of proposed variable step size IC MPPT method, simulation model is developed using MATLAB/Simulink. The solar module parameters are adopted from the datasheet value of BP SX-110 PV module. The specification of this module are given in Table II. Output variation of the model is considered for changing irradiance level. The change of levels are shown in Fig. 8. The maximum power obtained at STC, where irradiance level is 1000 watts/m² and ambient temperature is of 25°C. Here the irradiance is changes rapidly at .3 second, from 1000 W/m² to 700 W/m² and again at .6 sec the irradiance level changes. By considering this variable input condition, the variation in the power due to the IC and VSIC methods are discussed in this paper.

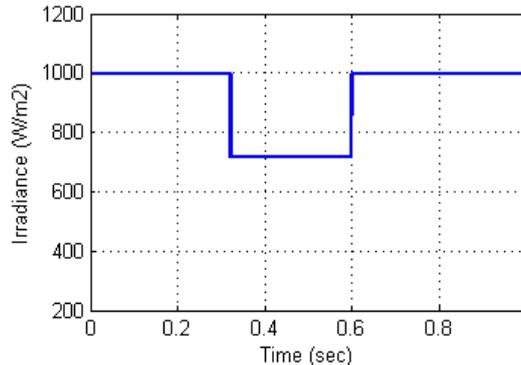


Fig. 8. Variation in the input irradiance level.

3.1 Response with Different Step Size

For the conventional incremental conductance method, two step sizes are considered. Two fixed step sizes of 0.3 and 0.03 are taken. For both cases, exactly same irradiance and the temperature level are given as input to the solar module. It is observed that, for step size of .3 has good dynamic performance. So speed of tracking increases, but steady state oscillation affected severely. At the same time for step size of .03, the tracking speed decreases but the impact on the steady state operation is very less. The comparison of both cases are shown in Table III and the response of performance shown in Fig. 9.

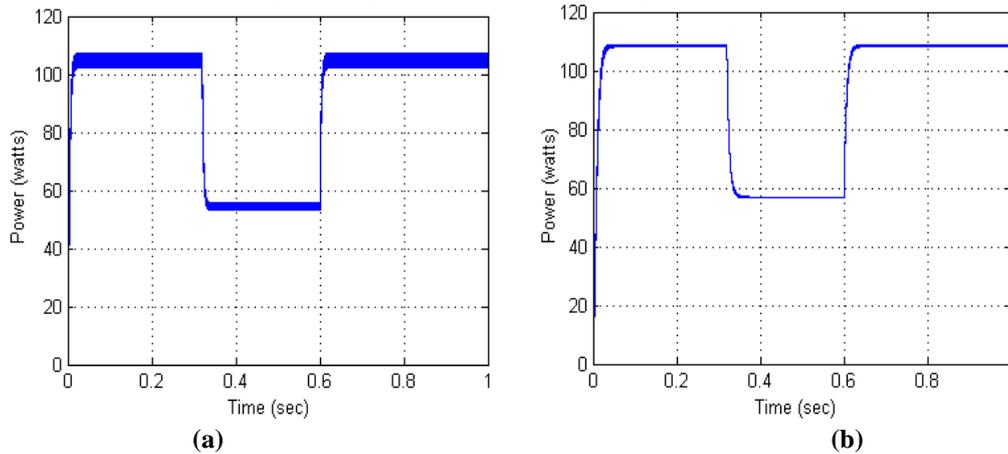


Fig. 9. PV module output variation for constant step IC MPPT with (a) Step size with 0.3. (b) Step size with 0.03.

TABLE III
Tracking Performance of IC MPPT Method

Characteristics	Step size	
	0.3	0.03
Average power (P_{avg})	104.5 W	108.2 W
Voltage ripple	1.5 V	0.15 V
Current ripple	0.14 A	0.018 A
Response time	Fast	Slow

From Fig. 9 and Table III, it can be observed that with change in the size of the step, there is huge variation in the system response. When the step size is more the ripple in the voltage and current more and is directly affect the steady state power response. But in case of lower step size value, though the time of tracking is more, but the steady state operation can be obtained. These problems can be solved by using the proposed VSIC MPPT method. In Fig. 10, for both cases the steady state oscillation is less. The output power of the system is more (109 W). With change in the value of scaling factor (which decides the step size), there is a very small variation in the system responses. In this case a faster dynamic response is achieved when compared to the constant step size. Also for scaling factor of 0.2, the speed of operation increases. In addition to that, there is a very system output response variation with change in the scaling factor value. Variations are shown in Table IV.

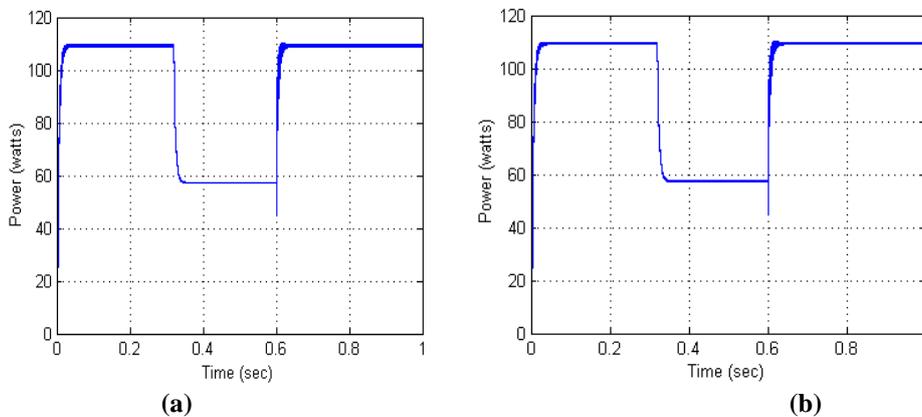


Fig. 10. PV module output variation with variable step size IC MPPT (a) Scaling factor of 0.2. (b) Scaling factor of 0.06.

TABLE IV
Tracking Performance of VSIC MPPT Method

Characteristics	Step size	
	0.2	0.06
Average power (P_{avg})	109.3 W	109.5 W
Voltage ripple	0.16 V	0.15 V
Current ripple	0.006 A	0.005 A
Response time	Fast	Slow

3.2 Response with Change in Load

To analyze the system variation with change in the load, the resistive load has been changed from 22 ohm to 15 ohm. In Fig. 11, initially the system operates at MPP at STC. But at point A when the resistance decreases, the voltage value decreases and the current increases suddenly as shown in Fig. 11 at point B, for some time. Afterward, the duty cycle decreases to acquire the maximum power by using the MPPT algorithm.

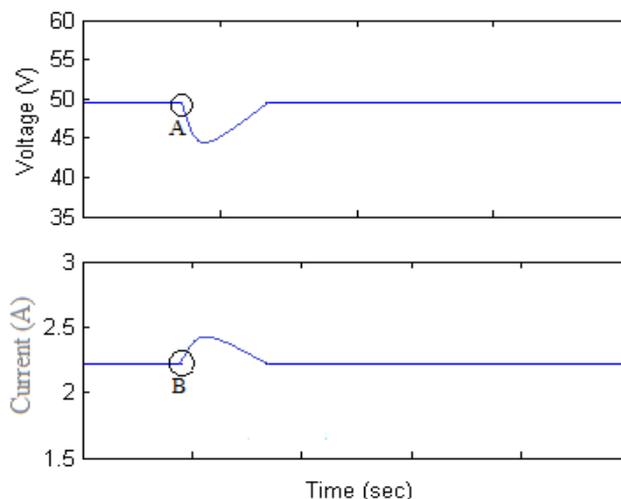


Fig. 11. Output waveform of voltage and current of PV module with change in load.

IV. Conclusion

In this paper, VSIC method is proposed and comparison with conventional incremental conductance method are proposed. The improvements like steady state response and dynamic response of system are achieved by using the proposed MPPT algorithm. Both IC and VSIC method are simulated in MATLAB/Simulink. A simple boost converter is used in the proposed simulation model of PV system. The design analysis of proposed scheme are discussed in the paper. The variations in the output of the system with change in the input levels and load are shown. It is also shown that the proposed method is more efficient with respect to the conventional incremental conductance method and has a better as well as wider range of operation.

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