MAXIMUM POWER POINT TRACKER FOR PHOTOVOLTAIC SYSTEM BY CONSTANT VOLTAGE METHOD

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ABSTRACT

Energy, especially alternative source of energy is vital for the development of a country. In future, the world anticipates to develop more of its solar resource potential as an alternative energy source to overcome the persistent shortages and unreliability of power supply. In order to maximize the power output the system components of the photovoltaic system should be optimized. This paper describes the design of a constant voltage based maximum power point tracker (MPPT) for photovoltaic (PV) applications. Of the various MPPT methods, the voltage based method is considered to be the simplest and cost effective. The major disadvantage of this method is that the PV array is disconnected from the load for the sampling of its open circuit voltage, which inevitably results in power loss. To overcome this disadvantage a pilot PV panel is used to measure the open circuit voltage, which has characteristics similar to that of the main PV panel, is kept at no load condition. The main PV panel is never disconnected from the load. This method will increase energy output. The simulation results indicate that panel tracks the MPP under changing atmospheric and load conditions.

Keywords: Maximum power point tracker, PV array, dc-dc boost converter.

I. INTRODUCTION

Sustainable energy sources like solar, wind, and fuel cells are becoming increasingly important as environmentally friendly alternatives to the traditional energy sources such as fossil fuels. However, these environmentally friendly sources are difficult to tap, store, and use. Successful application of these sustainable sources depends on being able to maximize efficiency in both conversion and energy storage. Maximum power point (MPP) tracking techniques are employed in solar array powered systems to optimize the power from the array output that depends on solar insolation, cell temperature, and load levels. Many different techniques have been proposed and implemented to various degrees of success. There are at least nineteen distinct methods with many variations [1]. The general diagram of MPPT with PV system is shown in figure 1. However, in practice, the most commonly implemented methods include perturb and observe (P&O), incremental conductance (IncCond), constant current, and constant voltage methods.

The P&O is the most widely used method [2, 3]. The technique uses an iterative process that perturbs the operating point of the solar power system in order to find the direction of change for maximizing power. Periodically, the operating voltage of the solar module is changed to move it towards the maximum power point using power feedback and/or feed forward control. The method has been shown to work well when insolation does not vary quickly with time. Under rapidly changing conditions, the P&O method quickly fails due to a divergence from the MPP. Improvements have been made to this method.

The shortcomings of the P&O method can be improved by using the incremental conductance method. The incremental conductance algorithm makes use of the fact that the slope of the solar module P-V curve is zero at the MPP, positive on the left of the MPP, and negative on the right of the MPP [4]. The IncCond method has the advantage over the P&O of not oscillating around the MPP under rapidly changing environmental conditions, but has a more complex circuitry. The accuracy of the method depends on the iteration size, which is usually fixed for the conventional IncCond method. There are many improvements to the conventional IncCond.

The MPP tracking algorithm is based on the fact that the MPP current is approximately a fixed percentage of the short circuit current. To implement this algorithm, a switch is placed across the input terminals of the converter and switched on momentarily. The short circuit current is measured the MPP current is calculated, and the PV array output current is then adjusted by the MPPT until the calculated MPP current is reached.

In the proposed constant voltage MPPT, the PV panel is operated at its maximum power point voltage, which is a fixed percentage of the PV panel open circuit voltage. The PV panel is usually disconnected from the load after regular intervals, to record the open circuit voltage. A pilot PV panel is used to measure the open circuit voltage, which has characteristics similar to that of the main PV panel, is kept at no load condition. The main PV panel is never disconnected from the load. This method will increase energy output. The simulation results indicate that panel tracks the MPP under changing atmospheric and load conditions. The constant voltage algorithm is based on the observation from I-V curves that the ratio of the array's maximum power voltage, V_{mp}, to its open circuit voltage, V_{oc} is approximately constant:

$$V_{mp}/ V_{oc}= k < 1 \qquad \textbf{(1)}$$

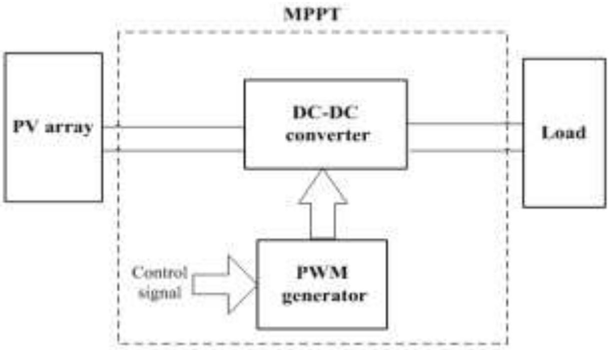

Fig.1 A PV System With A MPPT

II. DESCRIPTION OF MODEL

2.1 PV Array Model

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. A PV cell is usually represented by an electrical equivalent one-diode model shown in fig.2.

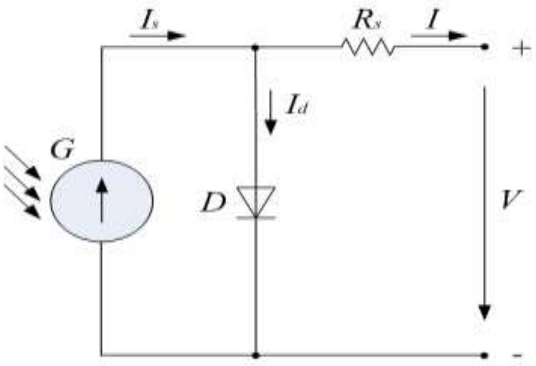

Fig 2. Solar Cell With Single-Diode And Series Resistance

The SIMULINK model equation for determining the diode reverse saturation current at the reference temperature which given in equation (2) [5]:

$$I_o = \frac{I_{sc,n} + K_i \Delta T}{\exp\left(\frac{V_{oc,n} + K_v \Delta T}{nVt}\right) - 1} \quad \textbf{(2)}$$

Where 'n' in all equations is for nominal condition Ki (usually 25ºC and 1000w/m^2), is the current coefficient, Kv is the voltage coefficient, $_\Delta$T=T-Tn [being T and Tn the actual and nominal temperature (K)], Io-diode saturation current (A), Isc,n is the light generated current at nominal condition (usually 25ºC and 1000W/m^2), Voc,n is the open circuit voltage at nominal condition (usually 25ºC and 1000W/m^2).

The SIMULINK model equation for determining the light generated current of the photovoltaic cell which depends linearly on the influence of temperature and solar radiation as given by:

$$I_{sc} = \left(I_{sc,n} + K_i \Delta T\right)\frac{G}{G_n} \quad \textbf{(3)}$$

$$I_m = I_{sc} N_{pp} - I_0 N_{pp}\left[\exp\left(\frac{V + I\left(\frac{N_{ss}}{N_{pp}}\right) R_s}{m V_t N_{ss}}\right) - 1\right] \quad \textbf{(4)}$$

Where, Im-model current (A), Nss - no. of series connected module, Npp -no. of parallel connected module, Vt - thermal potential of PV array(V), Rs-series resistance (Ω). The values of parameters are used in the PV modelling is given in below table 1[5].

Table 1-

Parameters	**Value**
$V_{OC,n}$	32.9V
$I_{SC,n}$	8.21A
K_i	0.0032A/K
K_v	-0.1230A/K
N_S	54
N_{SS}	2
N_{pp}	1
R_S	0.221Ω
R_P	415.405Ω

I_{mp}	7.61A
V_{mp}	26.3V
n	1.3

In figure 3 point a shows the MPP point which is obtained from I-V characteristics of PV array.

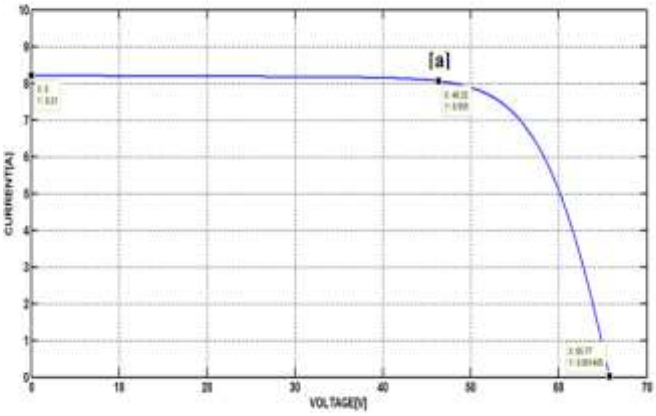

Fig.3 I-V Characteristics At Nominal Condition

2.2 Constant Voltage MPPT

The detail of the CV MPPT block is shown in figure 4. It consists of three parts; the first part is comparator, which obtains the fraction of V_{PV} and V_{OC}, then multiply V_{OC} by 0.81 corresponding to MPPT voltage. These signals, later, are sent to subtracter to produce an error signal. In the next part, error signal increases by a constant gain to increase the speed of the system. The amplified error signal is integrated to get a variable reference signal PWM generator. This part compares the reference signal with high frequency (1111Hz) saw tooth wave to obtain pulse width modulation. The PWM output is used to drive the MOSFET of DC-DC convertor [6]. The duty cycle cycle of the convertor changes untill the PV panel voltage equal to the MPP voltage.

If $V_{PV} > V_{OC}$, the output of the difference amplifier is positive and the output of the integrator will increase. This output work as the reference signal. The saturation block limits this signal between zero and the amplitude of the triangular signal. The relational operator compares the reference signal with the triangular signal and gives high input for the period when reference signal > saw tooth signal. An increase in refernce signal results in increased high period of the pulse width modulated (PWM) output of the relational operator. This increase the ON period of the MOSFET resulting in an increased effective load and a decreased output voltage of the PV panel. Under steady state condition, the PV panel voltage becomes equal to the reference voltage that corresponds to the maximum power point (MPP) voltage of the PV panel. Similarly, if the PV panel voltage becomes less than the MPP voltage, the ON period of the MOSFET decrease untill the PV panel voltage becomes equal to the MPP voltage.

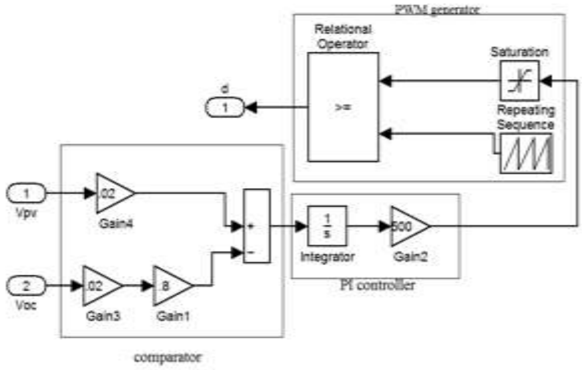

Fig.4 CV MPPT Block Diagram

2.3 DC-DC boost converter

A boost convertor (step-up convertor) is a DC-to-DC power convertor with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the convertor to reduce output voltage ripple. Since power P =VI must be conserved, the output current is lower than the source current. Figure 6 shows the matlab/simulink model of dc-dc boost converter.

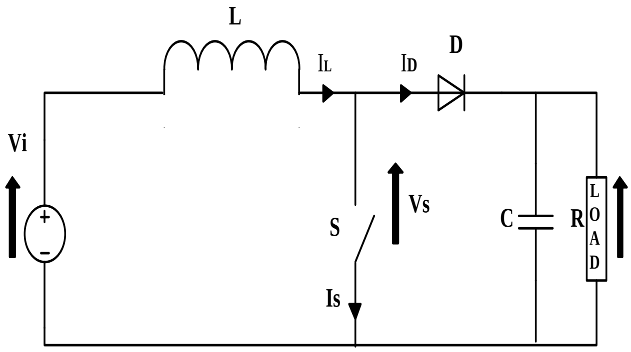

Fig.5 Schematic Diagram of DC-DC Boost Converter

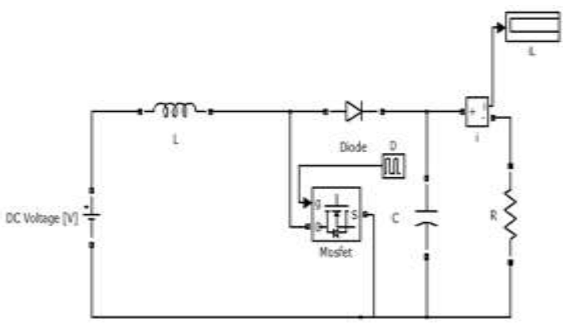

Fig.6 Simulation model of DC-DC boost convertor with dc supply

III. SIMULATION RESULTS

Figure 7 shows a simulation model of PV array by use of the constant voltage algorithm with DC-DC boost convertor and resistant load where the ambient temperature and sun irradiation also is variable in this simulation. The output voltage of the PV array was measured by voltage measurement block and send to MPPT block. Equally, V_{OC} of PV array was measured and sent to CV MPPT block simultaneously and it produce a PWM signal with proper duty cycle for DC-DC converter.

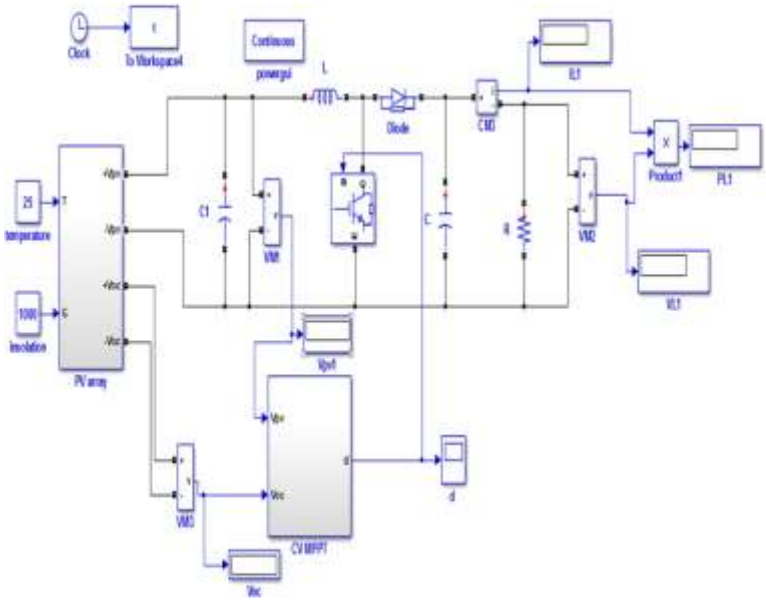

Fig.7 PV array with constant voltage MPPT

Figure 8 shows the PV voltage under condition of G=200W/m^2 , T=25ºC and load value is 100Ω. Initially the input capacitor virtually short circuits the PV source. When the capacitor is charged, the PV voltage reaches to 57.94 V which is near to open circuit value (V_{OC}=59.83 V). At t = 0.704 sec,operation of the MOSFET begins and the PV voltage oscillate around MPP point, finally settles to the MPP voltage ehich is 47.79 V.

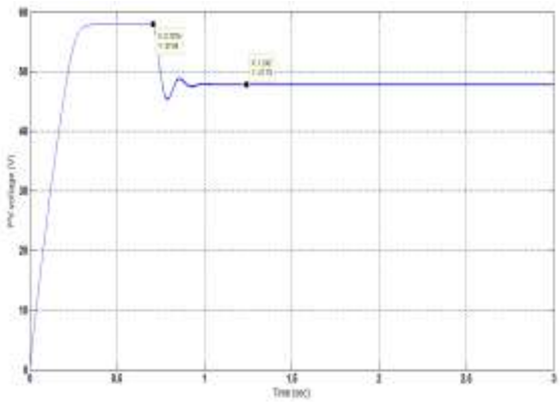

Fig.8 PV voltage for G=200w/m2 and load 100Ω and T=25 ºc for CV method

Figure 9 shows the PV current under condition of G=200W/m^2 , T=25ºC and load value is 100Ω. This figure shows that PV output initially will reach to the short circuit value of current because the capacitor virtually short circuit PV module output. It reaches close to open circuit value of current at t = 0.42 sec, this circuit shows that it is not completely open circuit and it has a leakage current, which is 0.57 A. At t = 0.70 sec MPPT will start and send duty cycle to MOSFET switch and output will star to oscilllation, around MPP point. Finally at t = 1.24 sec final value of current will reach to 1.51 A , which is I_{MPP}.

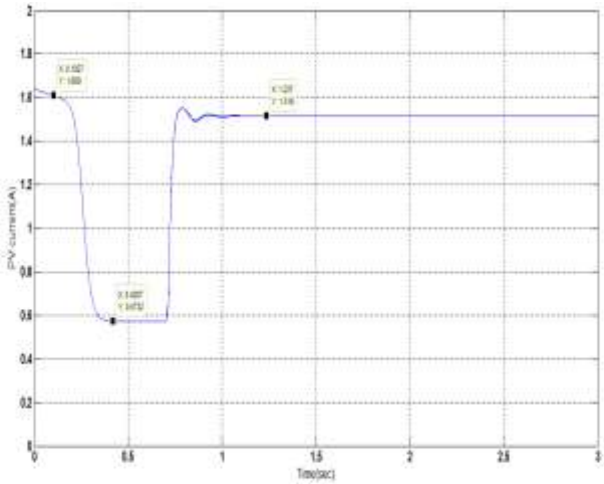

Fig.9 PV current for G=200w/m2, R=100Ω and T=25ºc for CV method

Figure 10, curve [b] shows that Ppv-Ipv plot. In this curve maximum power point (MPP) value is 399.9 W and in the next curve [a] which represent Ppv-t , final value of power which can be tracked with CV method is 399.9 W, figure shows that CV method can track exact MPP. These curves clearly shows that matching between MPP and PV output power in CV method.

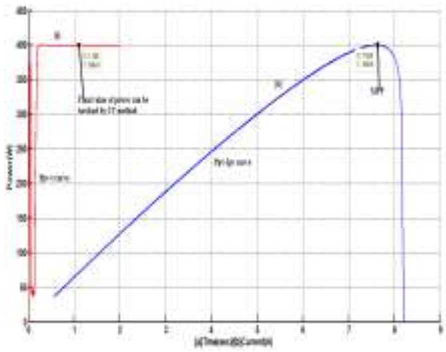

Fig.10 Comparing Result Between A) Ppv-T & B) Ppv-Ipv For Ideal Condition & R=100Ω

Figure 11 & 12 shows a small variation on the output of PV voltage curve and PV current curve under ideal condition,by sudden change in load at t=0.6 sec from 1000 Ω to 100 Ω voltage variation is approximately 1 volt and current 19 mA but after 175msec MPPT track MPP which is same to the value of output before load changing in the curve.

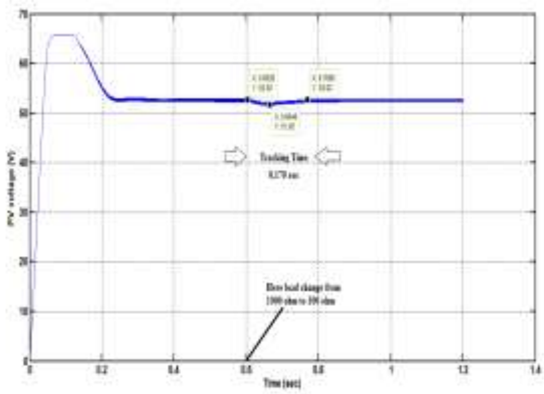

Fig. 11 Change In Load For CV Method At 0.6 Sec From 1000Ω To 100Ω Under Ideal Condition

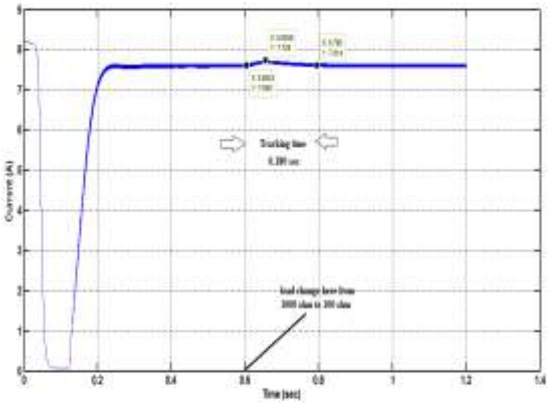

Fig.12 PV Current When Change In Load For CV Method At 0.6 Sec From 1000Ω To 100Ω Under Ideal Condition

IV. CONCLUSION

A simple and cheap analog MPPT has been simulated. The MPP tracking algorithm is based on the fact that the MPP voltage is approximately a fixed percentage of open circuit voltage of the PV panel. In the present work, an unloaded pilot PV panel, with characteristics similar to those of the main PV panel and installed under similar conditions, is used to measure open circuit voltage. the main PV panel never disconnected from the load, resulting in increased energy output. The simulation results shows that the panel tracks the MPP under changing atmospheric conditions and load.

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