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Boost Converter Control of Photovoltaic System Using Advanced Incremental Conductance MPPT Technique under Different Irradiance Levels

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Abstract—*Photovoltaic (PV) energy resource is the most important available renewable energy resource. It is clean, inexhaustible and pollution free.*

In recent years, many techniques have been proposed for tracking the maximum power point to increase efficiency of PV systems .These techniques are different from each other in many aspects; incremental conductance technique is one of them. This paper implements the MPPT in the boost converter for SPV system by means of a simulink model utilizing 'incremental conductance + integral regulator' technique.

1. INTRODUCTION

Photovoltaic systems require maximum power point tracker because the output power of the PV panel depends on the operating voltage terminal and current. As the intensity of light falling on the panel changes, both voltage and its internal resistance changes. Change in the internal resistance of panel due to change in irradiation results in mismatch between load and source impedance. So as the result of which panel is not able to produce power which it is capable of generating, resulting in less generation of power. This results in lower generation of power then what it is actually proficient of generating [1]. To extract maximum power from the panel the load impedance should be equal to the internal resistance of the panel [2].

For any PV system, the output power can be increased by tracing the maximum power point of the system. To get this maximum power point tracking controller is needed to track the efficient power of the PV system. A DC to DC converter is used between SPV Panel and the load to adjust the load resistance of SPV equal to the internal resistance of the panel by changing the duty cycle using MPPT algorithm. Therefore the maximum power point tracking is of great importance in photovoltaic systems[3].

2. MODELING OF THE PHOTOVOLTAIC ARRAY

A basic photovoltaic cell is a low-power electric generator. To simplify the behavior of a real photovoltaic cell we proposed to use the model of a cell with a single diode, Fig. 1. This model has almost the same accuracy that gives the model with two diodes in parallel.[4, 5]

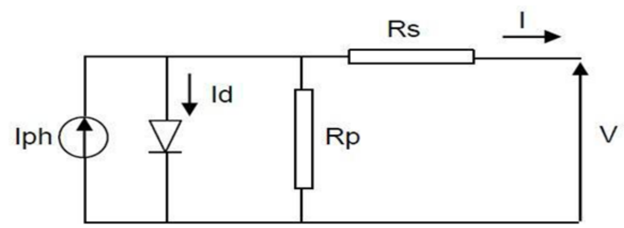

Fig. 1: Equivalent Circuit of a Real Solar Cell[4]

A solar cell can be described by the following equations for the model with the single diode :

$$I = I_{ph} - I_{sat}[exp(\frac{V + R_s I}{aV_t})] - \frac{V + R_s I}{R_p} \qquad (1)$$

Where Isat is the reverse saturation current of the diode, a is non-ideality factor of the p-n junction, Vt = q / KT , Rp and Rs are the intrinsic shunt and series resistance of the solar cell respectively, Iph is the generated current under a given irradiation and I and V are the output current and output voltage of the PV cell.

The single diode model has been simulated using the Matlab/Simulink.

The curve of Fig. 2 shows the current-voltage I(V) of a photovoltaic cell. Indeed, photovoltaic modules are made by series association in order increase the voltage of the PV generator and / or in parallel in order increase the output current of the generator [6, 7]. A module consists of Ns cells in series and in parallel Np cells, the equation

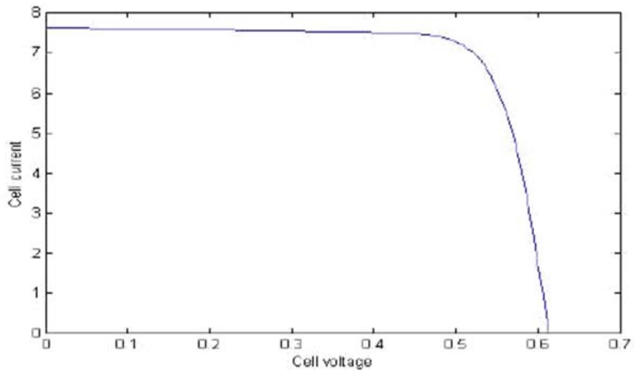

Fig. 2: Current-voltage of a photovoltaic cell.[5]

of photo-generated current Iph in Standard Test Conditions (G = 1000W/m2 and Ta = 25C, AM1.5) is given by :

$$I_{ph} = (I_{ph,n} + K_I \Delta(T)) \frac{G}{G_n} \quad (2)$$

The conduction current of the diode is given by the following equation :

$$I_d = I_{sat}[exp(\frac{V + R_s I}{aV_t}) - 1] \quad (3)$$

The saturation current of the diode is given by the following equation :

$$I_{sat} = \frac{I_{sc,n} + K_I \Delta(T)}{[exp(\frac{V_{oc,n} + K_V \Delta(T)}{aV_t}) - 1]} \quad (4)$$

The current of the module is given by the following equation :

$$I = I_{ph} - I_d - \frac{V + R_s I}{R_p} \quad (5)$$

Where Rs and Rp are respectively the equivalent series and parallel resistors of the module. In fact, to simulate the module, we must find the values of these resistors, since they are not given by the manufacturer in datasheets [8, 9, 10]. The curve of the figures 3 and 4 show the current-voltage I(V) and power-voltage P(V) of the photovoltaic module which has parameters shown in the table 1.

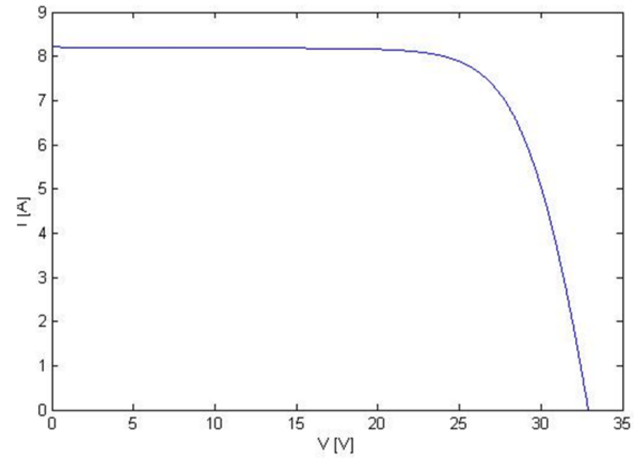

Fig. 3: Current-voltage characteristic of the photovoltaic module.[5]

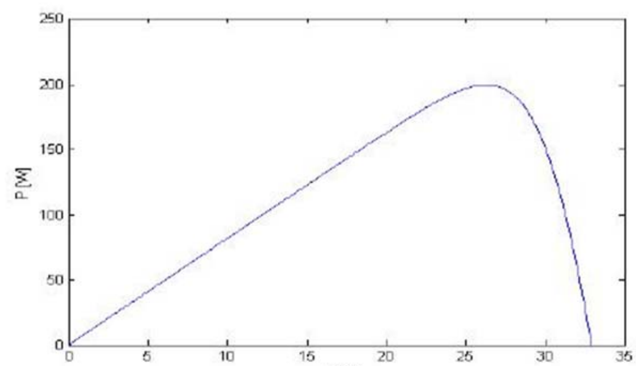

Fig. 4: Power-voltage parameters of the photovoltaic module.[5]

TABLE 1: Parameters of the photovoltaic generator

Imp	5.58A
Vmp	54.7V
Pmax	305.22W
Isc	5.96A
Voc	64.2V
Ns	5
Np	66
Qd	1.3
Rs	0.037998 Ω
Rp	993.51Ω

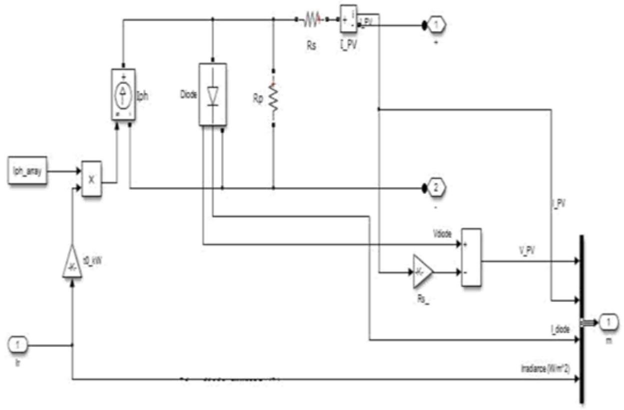

Fig. 5: Simulation Model of PV Array

3. INCREMENTAL CONDUCTANCE ALGORITHM

Incremental conductance (INC) method is a type of MPPT algorithm. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). INC method provides rapid MPP tracking even in rapidly changing irradiation conditions with higher accuracy than the Perturb and observe method. The basic equations of this method are as follows.[11]

$$\frac{dI}{dV} = -\frac{I}{V} \ at\ MPP$$

$$\frac{dI}{dV} > -\frac{I}{V} \ left\ of\ \ MPP$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad right\ of\ \ MPP$$

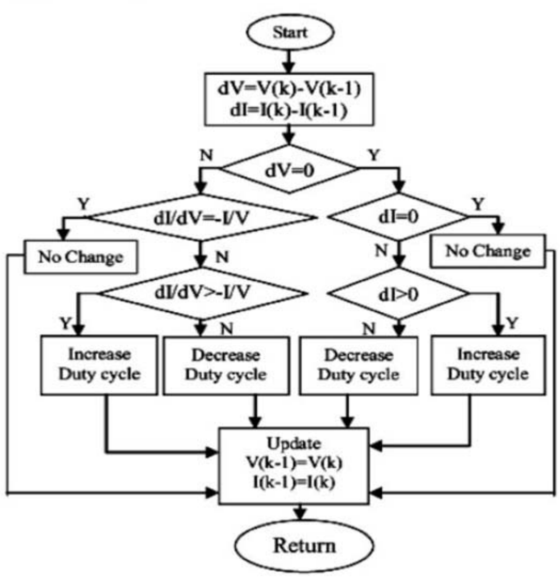

Fig. 6: Flow Chart of Incremental Conductance Algorithm[11]

4. MODELING AND CONTROL OF DC-DC BOOST CONVERTER

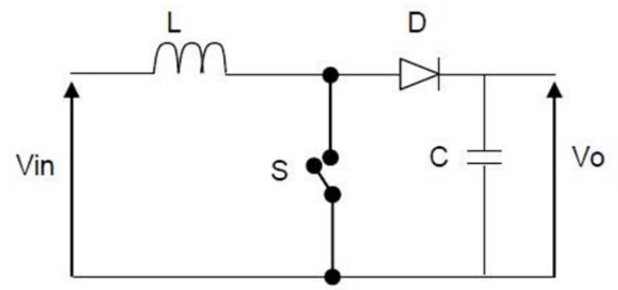

Fig. 7: Equivalent circuit of Boost Converter.[10]

Here we use a DC to DC boost IGBT converter for controlling the generated power which ultimately requires changing the amplitude of the voltage at the ends of the generator without changing the DC bus voltage. The voltage here is controlled by Pulses generated by PWM modulator[12][13][14][15]. The voltage of the converter is given by

$$V_o = \frac{V_{in}}{1 - D} \qquad (6)$$

Where D is the duty cycle of the converter given as the ratio of the turn on time of IGBT to the total time ts.

Here the converter uses incremental conductance MPPT system which automatically changes the duty cycle in order to extract the required voltage to generate maximum power. The output voltage from the boost converter always fluctuates near its reference value to obtain the desired voltage.

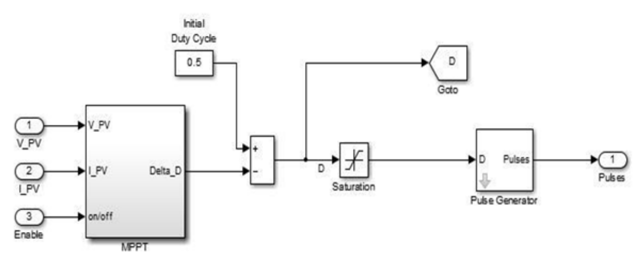

Fig. 8: Simulation Model of Boost Converter Control using MPPT

5. SIMULATION RESULTS

The boost converter enhancing voltage from PV voltage at maximum power to the boost DC voltage. Here switching duty cycle is optimized by incremental conductance plus integral regulator MPPT controller. Following curves shows the behavior of power, voltage output, duty cycle of the boost converter and irradiance changes.

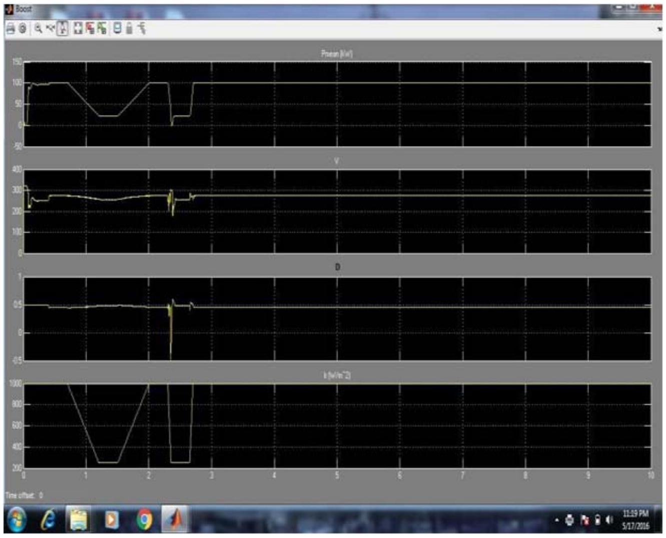

Fig. 9: Power, Voltage, Duty Cycle of Boost Converter and irradiance curves.

6. CONCLUSION

The paper has presented the boost converter control of PV system using incremental conductance plus integral regulator technique. The results shown ant the proposed technique improves the output efficiency of the PV array by changing the duty cycle of the IGBT converter.

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