Modeling of PV Array and Performance Enhancement by MPPT Algorithm

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ABSTRACT

This paper proposes modeling and simulation of photovoltaic model. Taking in to account the temperature and sun's irradiance, the PV array is modeled and its voltage current characteristics and the power and voltage characteristics are simulated. This enables the dynamics of PV system to be easily simulated and optimized. It is noticed that the output characteristics of a PV array are influenced by the environmental factors and the conversion efficiency is low. Therefore a maximum power tracking (MPPT) technique is needed to track the peak power to maximize the produced energy. The maximum power point in the power –voltage graph is identified by an algorithm called perturbation & observation (P&O) method or Hill climbing. This algorithm will identify the suitable duty ratio in which the DC/DC converter should be operated to maximize the power output. The results confirm that the photo voltaic array with proposed MPPT controller can operate in the maximum power point for the whole range of assumed solar data (irradiance and temperature).

Keywords

Maximum power point tracking, photovoltaic, solar, P&O, Buck converter.

1. INTRODUCTION

Solar energy is one of the most important renewable energy sources. Compared to conventional non renewable resources such as gasoline, coal, etc..., solar energy is clean, inexhaustible and free.

In tropical countries like India, as well as other places where solar energy is available in abundance, photovoltaic (PV) has emerged as a major candidate for meeting the energy demand. It offers an option for clean (pollution free) energy source, with almost no running and maintenance cost.

In the recent past years, PV power generation system has attracted more attention due to the energy crisis and environment pollution. Photovoltaic (PV) power generation systems can mitigate effectively environmental issues such as the green house effect and air pollution. PV power generation systems have one big problem that the amount of electric power generated by PV module is always changing with weather conditions, i.e., irradiation. Therefore, a maximum power point tracking (MPPT) control method to achieve maximum power (MP) output at real time becomes indispensable in PV generation systems.

The amount of power generated by a PV depends on the operating voltage of the array. A PV's maximum power point (MPP) varies with solar insulation and temperature. Its V-I and V-P characteristic curves specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV operates at its highest efficiency. Therefore, many methods have

been developed to determine MPPT for a particular insolation value.

The conventional MPPT methods are generally categorized into the following groups:
1) Perturbation and observation (P&O) methods.
2) Incremental conductance methods.
3) Constant current or constant voltage
4) Miscellaneous (e.g., fuzzy control and voltage-based scheme

Among them P & O method has drawn much attention due to its simplicity. But the oscillation problem is unavoidable.

2. SIMULATION MODEL OF PV CELL

The building block of PV array is the solar cell, which is basically an p-n junction semiconductor junction that directly converts light energy into electricity. The physical structure and equivalent circuit are shown below.

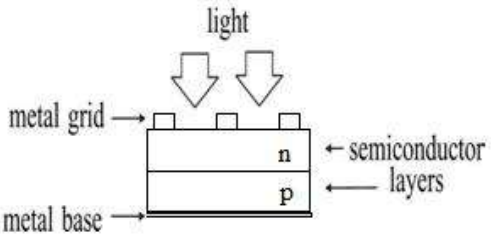


Figure.1 Structure of a PV cell

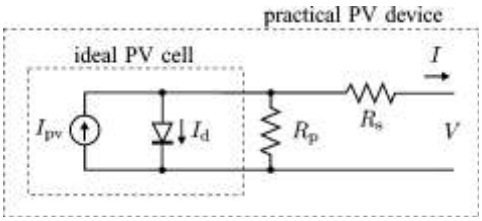
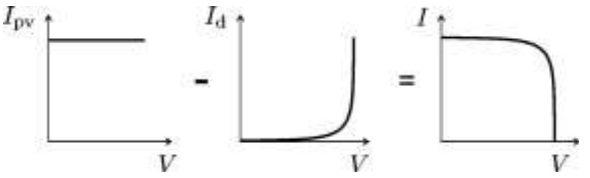


Figure.2 Equivalent circuit of the PV cell

The simplest equivalent circuit of a solar cell is a current source in anti-parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent *Iph*). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current *Id*, called diode (*D*) current or dark current. The diode determines the I-V characteristics of the cell.

$$I = I_{pv} - I_d$$



In an ideal cell *Rs* = *Rsh* = 0, which is a relatively common assumption. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent, *I* and the normal diode current *Id*:

To simulate PV array, a PV mathematical model is used following set of equations.

$$I = I_{pv} - I_o\left(e^{\frac{q(V+IRs)}{nkT}} - 1\right)$$

The model includes the temperature dependence of photocurrent I and saturation current of the diode Io.

$$I_{pv} = I_{pv}(T_1) + K_o(T - T_1)$$

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

$$K_o = \frac{I_{sc}(T_2) - I_{sc}(T_1)}{(T_2 - T_1)}$$

$$I_o = I_o(T_1) \times \left(\frac{T}{T_1}\right)^{\frac{3}{n}} e^{\frac{q\,V_Q(T_1)}{nk\left(\frac{1}{T} - \frac{1}{T_1}\right)}}$$

$$I_0(T_1) = \frac{I_{sc}(T_1)}{\left(e^{\frac{qV_{OC}(T_1)}{nkT_1}} - 1\right)}$$

Table.1 Abbreviations used in the equations

Symbol	Expansion
I	Photon current from Solar Cell
G	Insolation in W/m2
T	Temp for which characteristics have to be found
T_1	Temp for which characteristics is known
I_{SC}	Short Circuit Current
K_o	Increase in Amps / degree increase in temperature
q	Charge of an electron
V_{oc}	Open Circuit Voltage

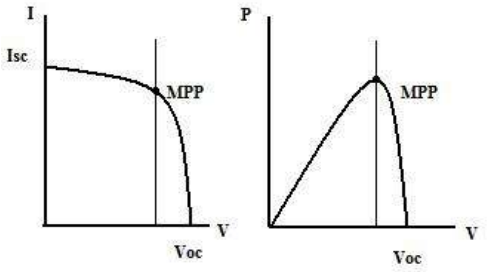


Figure. 3(a) Typical V-I & P-V characteristics of solar array.

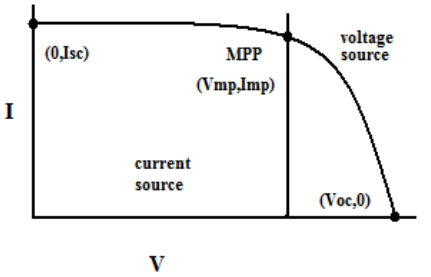


Figure.3 (b)

3. CONTROL ALGORITHM FOR MPPT PERTUBATION & OBSERVATION (P&O) TECHNIQUE:

P&O algorithm is widely used in MPPT because of their simple structure and high reliability. They operate by periodically perturbing & incrementing & decrementing the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing, the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed. This means the array terminal voltage is perturbed for every MPPT cycle. Therefore, when the optimum power is reached, the P&O algorithm will oscillate around it, resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions. The flow chart of the implemented algorithm is shown in Figure.5

The algorithm reads the value of current and voltage from the solar PV module. Power is calculated from the measured voltage and current. The value of voltage and power at kth instant are stored. Then next values at (k+1)th instant are measured again and power is calculated from the measured values. The power and voltage at (k+1)th instant are subtracted with the values from kth instant. In the power voltage curve of the solar pv module, it is inferred that in the right hand side curve where the voltage is almost constant and the slope of power voltage is negative ($dP/dV<0$) where as in the left hand side, the slope is positive.($dP/dV>0$).Therefore the right side of the curve is for the lower duty cycle(nearer to zero) where as the left side curve is for the higher duty cycle(nearer to unity).

Depending on the sign of $dP(P(k+1) - P(k))$ and $dV(V(k+1) - V(k))$ after subtraction the algorithm decides whether to increase the duty cycle or to reduce the duty cycle.

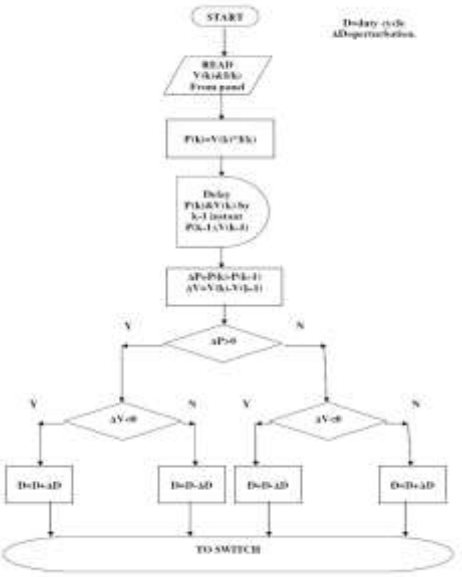


Figure.5 Flow chart for MPPT Algorithm

4. DC/DC CONVERTER USED FOR THE MPPT SYSTEM

A Buck-type dc/dc converter is used to interface the PV output to the battery and to track the maximum power point of the PV array. The converter power switch consists of one or more parallel-connected power MOSFET's. The fly back diode is of a fast switching type. The parameters of the converter are given in table below.

Table.2 Design parameters for Buck converter

PARAMETER	VALUE
Inductance L	1e-2 H
Capacitance C	1e-2 F
Switching frequency	1Khz

5. EXPERIMENTAL SETUP AND SIMULATION RESULTS

MATLAB MODEL OF THE PV MODULE

The model of the PV module was implemented using a Matlab program. The model parameters are evaluated during execution using the equations listed above in this paper. The program calculates the current *I*, using typical electrical parameter of the module (*Isc*, *Voc*). The characteristics for pv module is simulated using the matlab program.

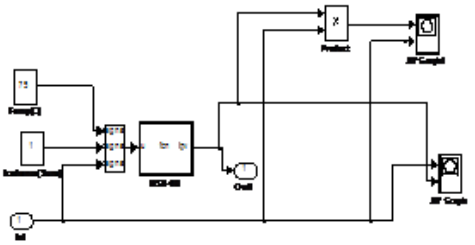


Figure.6 Matlab model PV Array

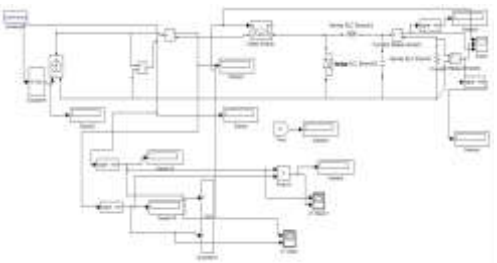


Figure.7.Experimental set up of the whole circuit.

Figure.8. P-V Characteristic curve & operation at MPP

6. CONCLUSION

This paper discussed the modeling and simulation of PV array and also the implementation of an MPPT algorithm. The simulation results (Figure.9) show the voltage and current characteristics and power and voltage characteristics of the modeled PV array. Also from the simulation it is inferred how the maximum power point is tracked using P&O algorithm to maximize the power output of the PV array.

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