Power Control of Stand-Alone Photovoltaic Generation System with MPPT

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ABSTRACT
The reasonable & effective utilization of solar energy is an important path which can deal with the global energy crisis at present. The output power of Photovoltaic (PV) cells keep changing with solar irradiation & ambient temperature because photovoltaic cells exhibit nonlinear voltage-current characteristics. Therefore maximum power point (MPP) of PV cells changing with solar irradiation & ambient temperature. The proposed model is used to determine the voltage current & power at the MPP and quality of voltage at load terminals for different operating conditions. The model consists of PV module, battery bank, MPPT module, controller, PWM inverter and resistive load. The fluctuation in the output of PV module are controlled and held at max. power output by MPPT module. This paper reports modelling & simulation of Stand- Alone PV with MPPT features & inverter controlled technique. The results are compared with system of without MPPT controlled technique by using MATLAB/Simulink software. MPPT Algorithm for PV array is proposed here. This Algorithm detects the MPP of the PV the computed maximum power Pmax is used as reference value of control system. On/OFF power controller is used to control the operation & increases the input power capability of PV module system.

Keywords
Maximum Power Point Tracking (MPPT), Photovoltaic generation, DC/DC Converter, Photovoltaic.

1. INTRODUCTION
Solar energy is a clean, a maintenance-free, and an abundant source of energy. The rapid trend of industrialization of nations and increased interest in environmental issues has recently to consideration of the use of renewable forms such as solar energy and wind energy. Although PV energy has received considerable attention over the last few decades, the high installation cost of PV systems and the low conversion efficiency of PV modules are the major obstacles to using this alternative energy source on a large scale. Photovoltaic (PV) arrays produce electric power directly from sunlight. Photovoltaic system can be divided into two categories: stand-alone and grid connection systems. In conventional stand-alone systems PV array feeds load directly with no connection to the utility system and have the advantages of simple system configuration and control scheme. Particularly, stand-alone system cannot maintain the supply of energy when there is not enough sunlight unless energy storage is used. So to draw maximum power from a PV system and store excess energy, battery banks are used. Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise. Because of the nonlinear relationship between the current and the voltage of the photovoltaic cell, it can be observed that there is a unique maximum power point (MPP) at a particular environment, and this peak power point keeps changing with solar illumination and ambient temperature [1].

An important consideration in achieving high efficiency in PV power generation system is to match the PV source and load impedance properly for any weather conditions, thus obtaining maximum power generation. The technique process of maximum power point is been tracking which is known as maximum power point tracking (MPPT). In recent years, a large number of techniques have been proposed for maximum power point tracking (MPPT), such as the Constant Voltage Tracking (CVT) [2], the Perturb-and-Observe (P&O or Hill-Climbing) method, the Incremental Conductance (INC) method, and so on. At last, these algorithms modify the actual voltage in order to increase the power output. The CVT is very simple and can be easily implemented. But the constant voltage cannot track MPP when solar illumination changes, so the constant voltage method is not often used in the true MPPT strategy. The P&O method is based on the principle of perturbation and observation [3].

Inverter's control is another key aspect in PV generation system. With the development of power electronics, technology of Pulse Width Modulation (PWM) has been widely applied in inverter. The sine PWM technology is applied into many aspects by its simplicity, and easy implementation. In order to improve the efficiency and gains better quality of output power in PV power generation system, a novel standalone PV generation system based on a nonlinear Maximum Power point tracking method algorithm and SPWM control scheme is proposed in this paper.

2. EQUIVALENT CIRCUIT OF PV CELL

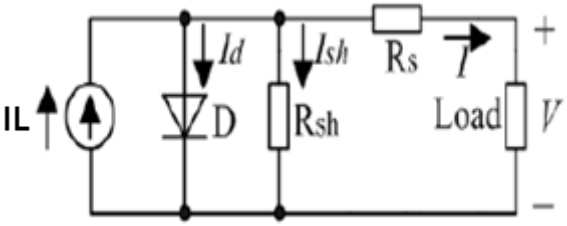

Figure 1 Photovoltaic cell equivalent circuit

Photovoltaic cells consist of a silicon P-N junction that when exposed to light releases electrons around a closed electrical circuit. The circuit equivalent of a PV cell can be modeled through the circuit shown in Fig. 1. This is modeled by the light generated current source (I_L). The intrinsic P-N junction

characteristic is introduced as a diode in the circuit equivalent [4].

Where:

I is the cell current (A).
I_L is the light generated current (A).
Io is the diode saturation current.
q is the charge of electron = 1.6x10-19 (coul).
K is the Boltzman constant (j/K).
T is the cell temperature (K).
Rs, Rsh are cell series and shunt resistance (ohms).
V is the cell output voltage (V).

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn [5]:

- Temperature dependence of the diode saturation current I0.
- Temperature dependence of the photo current IL.
- Series resistance Rs, which gives a more accurate shape between the maximum power point and the open circuit voltage. This represents the internal losses due to the current flow.
- Shunt resistance Rsh, in parallel with the diode, this corresponds to the leakage current to the ground and it is commonly neglected.
- Either allowing the diode quality factor n to become a variable parameter (instead of being fixed at either 1 or 2) or introducing two parallel diodes with independently set saturation currents.

In an ideal cell Rs = Rsh = 0, which is a relatively common assumption [6]. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent, IL and the normal diode current I0:

$$I = IL - I0\left\{e^{\frac{q(V+IRs)}{nKT}} - 1\right\} \quad (1)$$

The model included temperature dependence of the photocurrent IL and the saturation current of the diode I0.

$$IL = IL\,(T1) + K0*(T - T1) \quad (2)$$

$$IL\,(T1) = Isc(T1,nom)\frac{G}{Gnom} \quad (3)$$

$$K0 = \frac{Isc(T2) - Isc(T1)}{(T2 - Ti)} \quad (4)$$

$$I0 = Io(T1) \times \left(\frac{T}{T1}\right)^{3/n} e^{\frac{qVq(T1)}{nk\left(\frac{1}{T}-\frac{1}{T1}\right)}} \quad (5)$$

$$I0(T1) = \frac{Isc(T1)}{\left\{e^{\frac{qVoc(T1)}{nkT1}} - 1\right\}} \quad (6)$$

A series resistance Rs was included; which represents the resistance inside each cell in the connection between cells.

$$Rs = -\frac{dV}{dIvoc} - \frac{1}{Xv} \quad (7)$$

$$Xv = I0\,(T1)\frac{q}{nkT1}e^{\frac{qVoc(T1)}{nkT1}} - \frac{1}{Xv} \quad (8)$$

The shunt resistance Rsh is neglected. A single shunt diode was used with the diode quality factor set to achieve the best curve match.

Solar illumination and ambient temperature will influence the output power of PV module, as shown in Fig.2 The MPP will be changed when peripheral condition is changed. For quick and accurate track of MPP under any weather conditions, a precise MPPT algorithm must be applied in PV system.

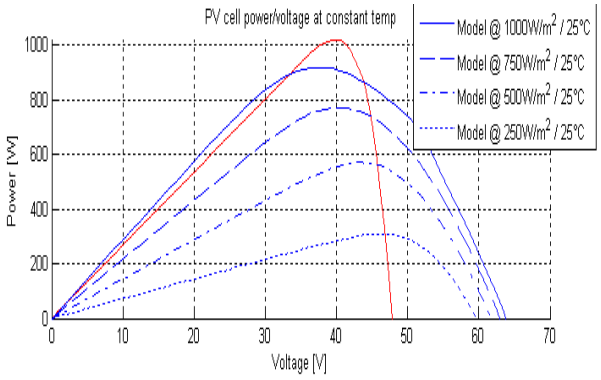

Figure 2 Power-Voltage Characteristics of PV for varying solar irradiation and constant temperature

3. MPPT CONTROL TECHNIQUE

The operating point at maximum power in systems based on PV modules depends on solar radiation level, operating temperature and load current. So that's to develop control algorithms in order to ensure that operating point achieves its maximum value. Main techniques mostly used are:

-MPPT based on Voltage or Current control (VMMPT and CMMPT)

-Hill Climbing (HC)
-Perturbation and Observation (P&O)
-Incremental Conductance method (InC)

Maximum Power Point Tracker (MPPT) has been obtained using a control from nonlinear dynamics theory proposed in [6]. This control strategy has been chose due to the simple implementation with a few common place electronic components and its good tracking effectiveness and dynamic response. Fig.3 shows PV system with nonlinear MPPT algorithm for boost converter. The MPPT inputs are PV voltage and current. From both inputs, the rate of the PV voltage and power will be compared with previous value to determine whether it is lower or greater. Then output will be sent to the control signals to switch for ON/OFF to charging & discharge the capacitor.

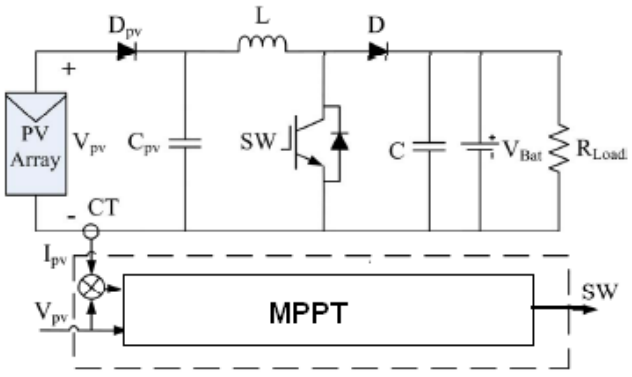

Figure 3 Nonlinear MPPT Algorithm for boost converter

4. MATLAB MODEL OF THE PV MODULE

To confirm the concept, the stand-alone PV system with the MPPT was studied by simulation using the configuration of Fig. 4. The PV system is modeled using power system block set under MATLAB Simulink. By connecting the model blocks together it is easy to see that total plant model has only two input variables, temperature and irradiance, which are situated in the environment model block. These variables are determined the output current, voltage and power of the PV module. The outputs from PV module are then fed into the maximum power point tracking model block where the MPP values of the PV module are calculated. From here the MPP values are fed into the controller model block. The output of controller is connected to the DC/AC inverter. Here the power is converted from DC to AC and then delivered to the load where load studies can be performed. The proposed MPPT algorithm tracks neither the Vmpp nor the Impp. However, it tracks directly the maximum possible power Pmax that can be extracted from the PV. The simulation results of the dynamic performance, which validates the efficient MPPT of PV generation system, have been shown in Fig.5 and Fig.6.

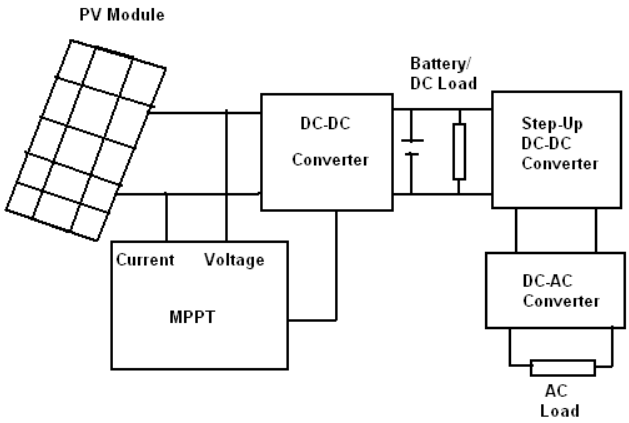

Figure 4 Schematic diagram of the stand-alone PV system

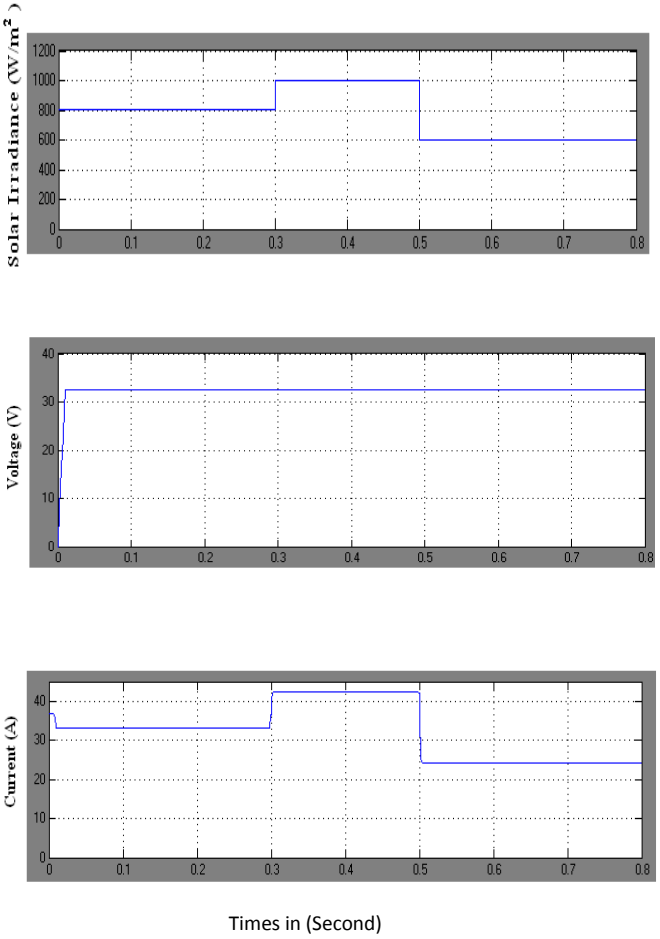

Figure 5 Stepped irradiance and PV output voltage and current waveforms

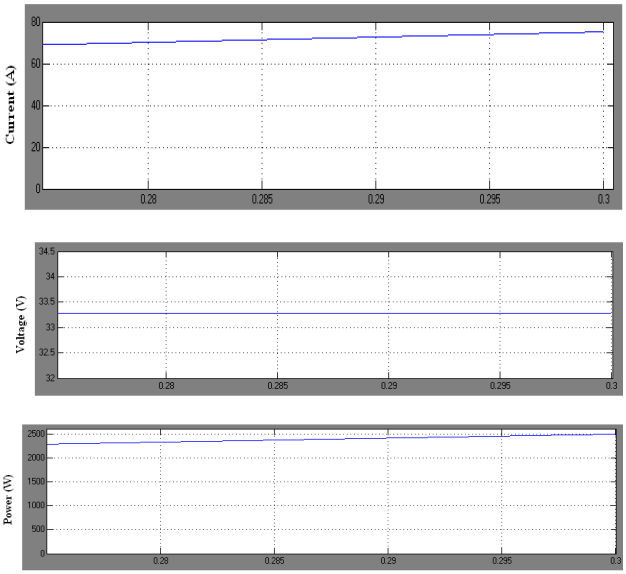

Figure 6 The expanded PV output voltage, current and power waveforms at 1 KW/m^2 irradiance

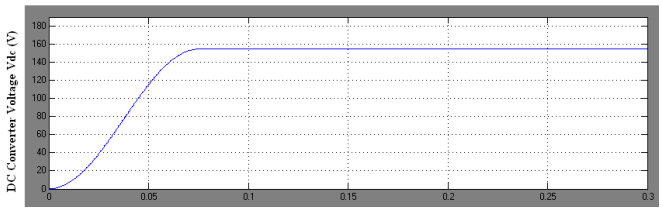

Figure 7 Boost Converter Voltage

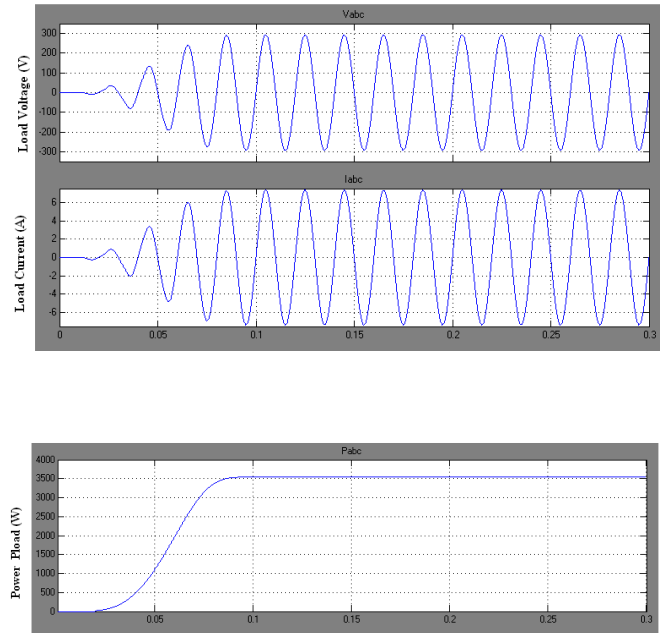

Figure 8 Load voltages, Current & Power waveforms

5. CONCLUSION

In this paper PV generation stand alone system has been considered. The modeling of the system including PV array, Boost Converter, PWM controlled inverter was provided. The simulation conducted to confirm the system good performances for changing of the value of solar irradiance. The PV array characteristics compiled with theoretical characteristics and MPPT technique is successfully track the MPP, boost converter increase the input voltage level and battery provided the charge and discharge voltage. The simulation result is responded fastly and operates the system always to near its MPP for considered irradiance.

6. REFERENCES

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