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MATLAB Simulation Model for PV System with MPPT Function

Chandni Jagga*[1], Ashish Khandelwal[2], Atul Sharma[3]

[*1,3]Lecturer Electrical Engg. Deptt. , Sri Balaji College of Engg. & Tech. Jaipur

[2]H.O.D. Electrical Engg. Deptt. ,Sri Balaji College of Engg. & Tech. Jaipur

chandnijagga@gmail.com

Abstract

As the world's power demand is increases photovoltaic power supply to the utility grid is gaining more and more visibility. The user wants to utilize maximum solar power of an array by operating the photovoltaic array at it's highest energy conversion output. The electrical system PV modules are powered by solar arrays requires special design considerations due to varying nature of the solar power generated resulting from unpredictable and sudden changes in weather conditions which change the solar irradiation level as well as the cell operating temperature.

In this paper, using MATLAB Simulink a mathematical model of a PV cell is developed and presented. In this model there are basic circuit equations of PV solar cells including the effects of solar irradiation and temperature changes. There is also discussion about maximum power point tracking function. A mathematical model of MPPT function is developed and presented using MATLAB Simulink. The main objective is to find the parameters of the non linear current – voltage equation by adjusting the curve at three points-

(1) Open circuit (2) Maximum Power (3) Short Circuit

This method finds the best current voltage equation for the single diode PV model including the effect of the series and parallel resistances.

Keyword:- MPPT Function, PV System, MATLAB Simulation**.**

I. Introduction

Photovoltaic system directly converts the solar energy into electricity which can be easily transported and converted to other forms for the daily life use. In the PV system there are semiconductors which are in form of cells, panels, modules and arrays to collect and convert the sunlight into direct current. The basic device of PV system is cell. These cells may group to form panels and modules. Further panels are grouped to form large PV arrays. The term array is usually employed to describe a PV panel with several cells connected in series and/or parallel or a group of panels. The DC power is further converted into AC by any other device. This paper focuses on modeling of PV modules or panels composed of several basic cells.

The maximum efficiency of utilization of solar panels is obtained at maximum power operating point. This is basically a maximum power point tracking function, which based on the panel physical characteristics and fabrication parameters, solar irradiation and operating temperature. This paper presents analytic model for equivalent circuit parameters of solar panels and arrays, are derived from basic cell modules.

In a system the power delivered from or to a device is optimized where the derivative dI/dV of current voltage curve is equal and opposite the I/V ratio (where dP/dV=0). This is known as maximum power point. Such applications as putting power on the grid, charging batteries, or powering an electric motor benefit from MPPT. In these applications, the load can demand more power than the PV system can deliver.

This is the basic block diagram of photovoltaic system. In this there are PV modules are connected with inverter which are used for the conversion of DC power into AC power. Further this AC power is supplied to fuse box, meter and grid.

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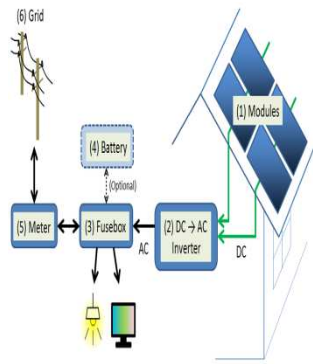

Fig.1 Basic photovoltaic system

II. Photovoltaic Solar System

Sunlight can be directly converted into electricity using photovoltaic (PV) cell. A photovoltaic cell is a device that converts sun light into electric current using the photoelectric effect. This usually requires conversion to certain desired voltages or alternating current (AC), which requires the use of the inverters. Multiple solar cells are connected inside the modules. Modules are wired together to form arrays, then tied to inverter, which produces power with the desired voltage, and frequency/phase (when it's AC). Many residential systems are connected to grid. In these grid connected PV systems, use of energy storage are optional. Sometimes there are batteries or additional power generators are often added as back up's, which form stand alone power systems.

The physical of PV cell is very similar to that of the classical diode with a p-n junction formed by semiconductor material. When the junction absorbs light, the energy of absorbed photon is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field, and circulate as current through an external circuit. The solar cell is the basic building of the PV power system it produces about 1 W of power. To obtain high power, numerous such cell are connected in series and parallel circuits on a panel (module), The solar array or panel is a group of a several modules electrically connected in series parallel combination to generate the required current and voltage. One cell of PV module we used is a low-power solar cell with open voltage Voc=3.25V and normal rated current Irated=100mA. In general, the equivalent models of solar cells have three types:

(1) an ideal model with one current source and diode just.

(2) an extra small resistor to simulate the line loss.

(3) a big internal resistor to realize the solar cell's power loss.

Each solar cell has its own characteristic I-V curve. Of course, I_{PV} and V_{PV} change with sunlight intensity and temperature level, so does output power of PV module, where IPV and VPV are the total current and voltage of PV module, respectively.

Figure shows the equivalent circuit of a PV module:

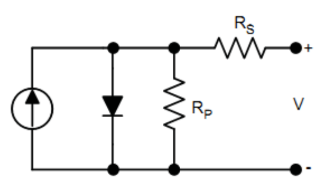

Fig.2 single diode PV model

Its mathematical expression can be written as:

$$I = I_L - I_D[\exp(\frac{qV + qIR_S}{AKT}) - 1] - \frac{V + IR_S}{R_{Sh}}$$

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Where V = the output voltage of the PV module,

I = the current output,
I_D= the diode saturation current,
q = the electron charge,
A= the material factor of the p-n junction,
K= the Boltzmann constant,
T = the absolute temperature,
R_s= the intrinsic series resistance,
R_{sh} = the parallel resistance

The current through diode is:

$$I_o \times (e^{\frac{q \times (V + I \times R_s)}{n \times k \times T}} -1)$$

III. Maximum Power Point Tracking System

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

The problem considered by MPPT methods is to automatically find the voltage VMPP or current IMPP at which a PV array delivers maximum power under a given temperature and irradiance. In this section, commonly used MPPT methods are introduced in an arbitrary order.

These all methods are given below-

1. Constant Voltage
2. Open Circuit Voltage
3. Short Circuit Current
4. Perturb and Observe
5. Incremental Conductance
6. Temperature
7. Temperature Parametric
8. Proposed Method

Among these, the proposed method, which moves the operation point toward the maximum power point by periodically increasing or decreasing the array voltage, is often used in many PV systems The flowchart of proposed method is shown below-

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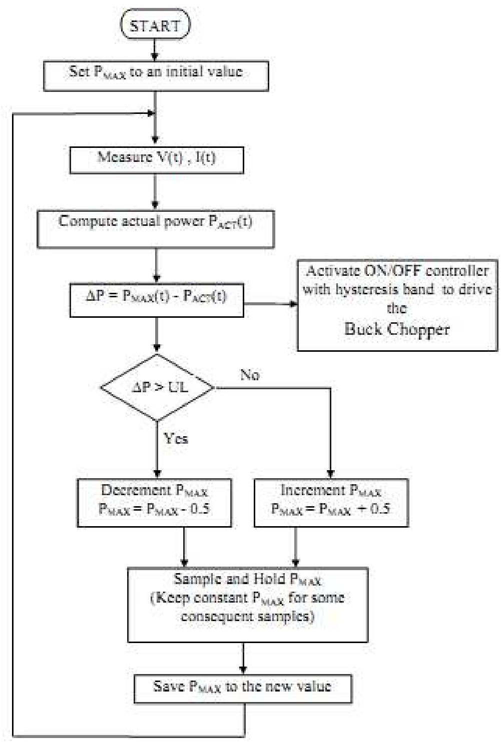

Fig. 3 Flow chart of proposed method

IV. Matlab Model Of System

Figure 4 shows the model of PV system with MPPT function using Matlab simulation. This model shows the internal structure of PV System with MPPT function. In the model of PV cell, the PV panel are connected to maximum power point tracking and a digital clock is also connected to the MPPT. The one terminal of MPPT is connected to scope and the other terminal is connected to the buck-boost converter. The one terminal of buck-boost converter is connected to scope. The resistive load is connected to the buck-boost converter. The scope is used for the output pulses.

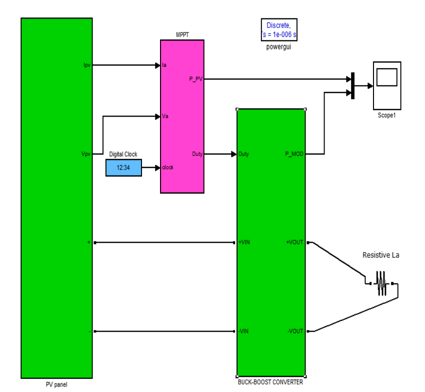

Fig. 4 Model of system

Figure 5 shows the internal structure of PV system which is modeled using MATLAB simulation. In this the PV module is connected is to the controlled current source and PV array. This is further connected to the diode. The PV module is also connected to scope.

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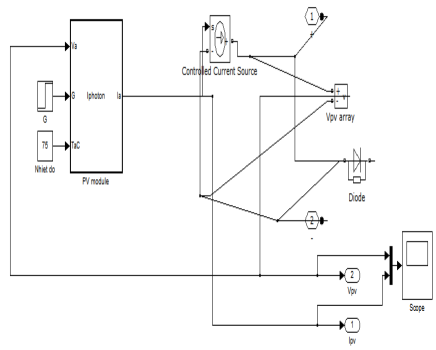

Fig. 5 block diagram of modeled PV System

Figure 6 shows the internal structure of MPPT system which is modeled using MATLAB simulation. This shows the separate blocks of MPPT model and connection with these blocks.

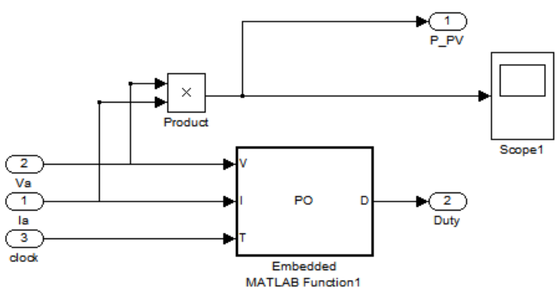

Fig. 6 Block diagram of modeled MPPT system

V. Simulation Results

The simulation results of the individual system components and overall results after integrating the different components are presented below. The electrical characteristics of the PV module are generally represented by the current vs. voltage (I-V) and the current vs. power (P-V) curves. Figs. show the (IV) and (P-V) characteristics of the used photovoltaic module at different solar illumination intensities. Fig.7 and 8 shows the strong non linearity of the I-V and P-V characteristics of the used solar with different isolation levels. The I-V characteristic of the solar PV decreases gradually as the voltage goes up and when the voltage is low the current is almost constant. The power output of the panel is the product of the voltage and current outputs. The PV module must operate electrically at a certain voltage that corresponds to the peak power point under a given operation conditions.

The PV cell temperature is remained constant at 250 degree Celsius and the solar intensity is varied in steps up to the rated value of 10 W-cm^2. It is seen from the fig. that for a constant solar intensity the current remains constant with increasing voltage up to 100V after which it decreases. It is further observed that the current increases with increasing intensity thereby increasing the power output of the solar cell. Marginal variation in current is observed for a temperature variation from 25degree Celsius to 65degree Celsius for a voltage up to 65 volts. Above this voltage the current decreases in a sharp manner for small variation in voltage. It is further seen that the voltage of which the cell current becomes zero increases with decreasing temperature. The voltage and power characteristics are presented-

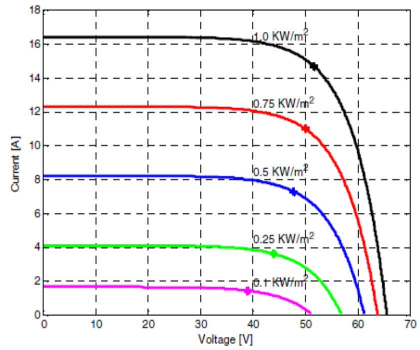

Fig. 7 I-V Characteristics of PV Module

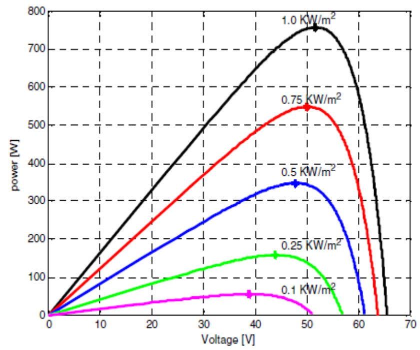

Fig. 8: P-V Characteristics of PV Module

VI. Conclusion

In this paper an accurate PV module electrical model is presented and demonstrated in MATLAB for a solar panel. This paper is first step to develop a complete solar photovoltaic power electronic conversion system in simulation. The final objective is develops a general model to simulate the electrical behavior of the PV system in grid connected application.

In this paper, we presented MATLAB – based setup for simulation of single PV cell and its array. The simulation setup is can be used to study the effect of variation in temperature values. The value of I_{SC} was found to increase with increase in temperature, whereas, the V_{OC} was observed to decrease with increase in temperature. The maximum power as well as the voltage at which the power peaks was seen to increase with increase in temperature.

VII. References

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