

Modelling and Dynamic Analysis of Solar Photovoltaic Generation

Kondalarao Gowdiperi, Grandhi Ramu
Electrical and Electronics Engineering Department,
Chaitanya Institute of Science and Technology,
Kakinada, A.P, India.

ABSTRACT

This paper establishes a dynamic model of grid-connected PV system by Matlab/Simulink to reflect the characteristics of the system accurately. Based on the accurate modelling system, maximum power point tracking (MPPT) control is studied. Grid-connected PV system includes a PV array, a control system, a distribution network and a load. Maximum power point tracking (MPPT) can effectively improve the solar energy conversion efficiency of PV systems.

I. INTRODUCTION

Solar energy has become a very potential new energy. Grid-connected photovoltaic (PV) system does not require bulk and loss battery and reduces transmission losses. As Conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Among its advantages are that it is: 1) abundant; 2) pollution free; 3) distributed throughout the earth; and 4) clean and noise-free source of electricity. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used: 1) increase the efficiency of conversion for the solar array and 2) maximize the output power from the solar array. In recent years, PV system has become one of the main ways to use solar energy. To understand and analyze the performance of a grid connected PV system, simulation software of a grid connected PV system is required. Grid –connected photovoltaic system is shown in fig.1. It includes a PV array, a voltage source inverter (VSI), a control system, a distribution network, a load and a grid. The PV array consists of a number of individual photovoltaic cells that are connected in series and parallel array to convert sunlight to electricity by the use of the photovoltaic effect. The PV array produces the dc power, and hence power electronics and control equipment points are required to convert dc to ac power. power produced by PV array into ac power and this ac power is injected into the utility grid. The control system

consists of current control strategy and voltage control strategy. Current control strategy is used to achieve the dc voltage regulation at dc link and unity power factor at grid and the voltage control strategy is applied to achieve maximum power point tracking. Maximum power point tracking (MPPT) can effectively improve the solar energy conversion efficiency of PV systems. In this paper, Perturb-and-observe (P&O) method is used to achieve this function.

II. Mathematical Modelling of PV Array

The PV receives energy from sun and converts the sun light into DC power. The PV array consists of a number of solar cells, which are connected in series and parallel to achieve the required voltage and current. We can substitute PV cell by equivalent electric circuit where is included a power supply and a diode. If we connect a resistive load R to cell then working point of cell will be on crossing point volt-ampere characteristic of cell and load characteristic. The simplified equivalent circuit model is as shown in figure.2. The PV cell output voltage is a function of mathematical equation of the photocurrent that mainly determined by load

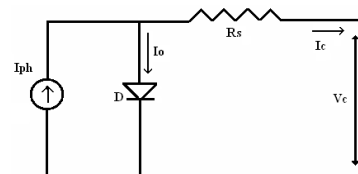


Fig.1. Simplified – equivalent Circuit of Photovoltaic Cell

current depending on the solar irradiation level during the operation. The equation is,

$$V_c = \frac{AKT_c}{e} \ln \left[\frac{I_{ph} + I_o - I_c}{I_o} \right] - R_s I_c \quad (1)$$

Where the symbols are defined as follows:

e: electron charge (1.602×10^{-19} C).
 k: Boltzmann constant (1.38×10^{-23} J⁰K).
 Ic: cell output current, A.
 Iph: photocurrent, function of irradiation level and junction temperature (5 A).
 IO: reverse saturation current of diode (0.0002 A).
 Rs: series resistance of cell (0.001 Ω).
 Tc: reference cell operating temperature (20 °C).
 Vc: cell output voltage, V.

Both k and T_C should have the same temperature unit, either Kelvin or Celsius. The curve fitting factor A is used to adjust the I-V characteristics of the cell obtained from (2) to the actual characteristics obtained by testing. Hence, the effects of the changes in temperature and solar irradiation levels should also be included in the final PV array model. A method to include these effects in the PV array modeling is given by Buresch [1]. According to his method, for a known temperature and a known solar irradiation level, a model is obtained and then this model is modified to handle different cases of temperature and irradiation levels. Let (2) be the benchmark model for the known operating temperature T_C and known solar irradiation level S_c as given in the specification. When the ambient temperature and irradiation levels change, the cell operating temperature also changes, resulting in a new output voltage and a new photocurrent value. The solar cell operating temperature varies as a function of solar irradiation level and ambient temperature. The variable ambient temperature T_a affects the cell output voltage and cell photocurrent. These effects are represented in the model by the temperature coefficients C_{TV} and C_{TI} for cell output voltage and cell photocurrent, respectively, as

$$C_{TV} = 1 + \beta_T (T_a - T_x) \quad (2)$$

$$C_{TI} = 1 + \frac{\gamma_T}{S_c} (T_x - T_a) \quad (3)$$

Where, $\beta_T=0.004$ and $\gamma_T=0.06$ for the cell used and T_a=20°C is the ambient temperature during the cell testing. This is used to obtain the modified model of the cell for another ambient temperature T_x. Even if the ambient temperature does not change significantly during the daytime, the solar irradiation level changes depending on the amount of sunlight and clouds. If the solar irradiation level increases from S_{X1} to S_{X2}, the cell operating temperature and the photocurrent will also increase from T_{X1} to T_{X2} and from I_{ph1} to I_{ph2}, respectively. Thus the change in the operating temperature and in the photocurrent due to variation in the solar

irradiation level can be expressed via two constants, C_{SV} and C_{SI}, which are the correction factors for changes in cell output voltage V_C and photocurrent I_{ph}, respectively,

$$C_{SV} = 1 + \beta_T \alpha_S (S_x - S_c) \quad (4)$$

$$C_{SI} = 1 + \frac{1}{S_c} (S_x - S_c) \quad (5)$$

where S_C is the benchmark reference solar irradiation level during the cell testing to obtain the modified cell model. The temperature change, ΔT_c , occurs due to the change in the solar irradiation level and is obtained using

$$\Delta T_c = \alpha_s (S_x - S_c) \quad (6)$$

The constant α_s represents the slope of the change in the cell operating temperature due to a change in the solar irradiation level [1] and is equal to 0.2 for the solar cells used. Using correction factors C_{TV}, C_{TI}, C_{SV} and C_{SI}, the new values of the cell output voltage V_{CX} and photocurrent I_{PHX} are obtained for the new temperature T_X and solar irradiation S_X as follows,

$$V_{cx} = C_{TV} C_{SV} V_c \quad (7)$$

$$I_{phx} = C_{TI} C_{SI} I_{ph} \quad (8)$$

V_C and I_{PH} are the benchmark reference cell output voltage and reference cell photocurrent, respectively. The resulting I-V and P V curves for various temperature and solar irradiation levels were discussed and shown in [6, 8, 9], therefore they are not going to be given here again. Depending on the load power required, the number of parallel branches can be increased to 2 or more. The effects of the temperature and solar irradiation levels are represented by two variables gains. They can be changed by dragging the slider gain adjustments of these blocks named as variable temperature and variable solar irradiation. The effects of the changing temperature and solar irradiation level are modeled inside the block called Effect of Temperature & Solar Irradiation.

The output power from PV is the result from multiplying PV terminal voltage and PV output current. The power output from PV modules is shown in (2).

$$P_c = V_c [I_{ph} - I_o * e^{(\frac{q}{kT} V_c - I_o)}] \quad (9)$$

$$I_c = I_{ph} - I_o * e^{(\frac{q}{kT} V_c - I_o)} \quad (10)$$

III. Maximum Power Point Tracking

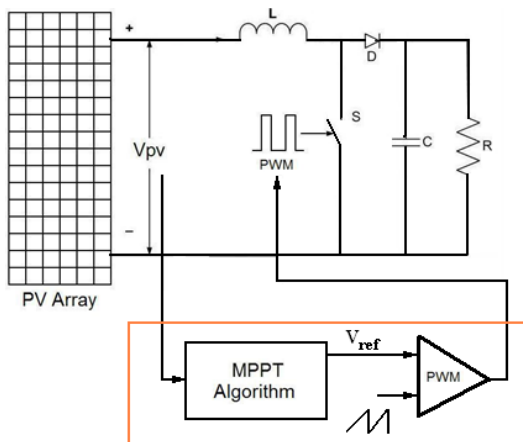


Fig 2. MPPT Control of PV

The open circuit Voltage algorithm is the simplest MPPT control method. This technique is also known as constant voltage method. VOC is the open circuit voltage of the PV panel. VOC depends on the property of the solar cells as shown in figure.3. A commonly used VMPP/Voc value is 76% .This relationship can be described by equation (11)

$$V_{MPP} = k * V_{oc}$$

Here the factor k is always less than unity. It looks very simple but determining best value of k is very difficult and k varies from 0.71 to 0.8. The common value used is 0.76; hence this algorithm is also called as 76% algorithm. The operating point of the PV array is kept near the MPP by regulating the array voltage and matching it to a fixed reference voltage Vref. The Vref value is set equal to the VMPP of the characteristic PV module or to another calculated best open circuit voltage this method assumes that individual insulation and temperature variations on the array are insignificant, and that the constant reference voltage is an adequate approximation of the true MPP. The open circuit voltage method does not require any input. It is important to observe that when the PV panel is in low insulation conditions, the open circuit Voltage technique is more effective. Detailed flowchart of the open circuit voltage algorithm is depicted in Figure.4.

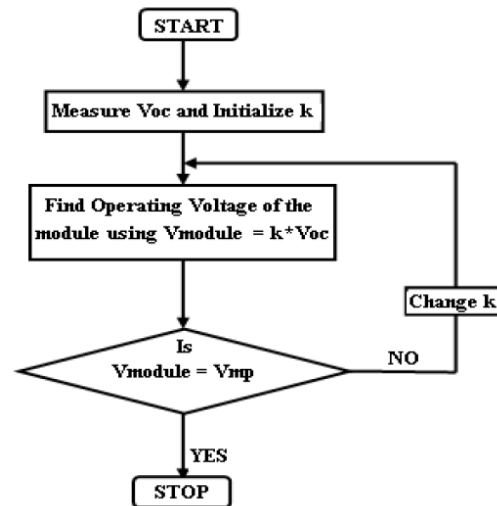


Fig 3. Flow chart of MPPT control

IV. SIMULATION RESULTS

Grid connected PV modules are shown in figure 9. MPPT control is used in the to extract thje maximum possible power from the PV modules. In this paper Current input type PV module is implemented in simulink. The simulation of grid-connected PV system contain various simulation blocks of PV array, voltage source inverter, filter circuit, load, utility grid, current controller, voltage controller, MPPT and phase locked-loop(PLL). In this paper, PV array generates a voltage of 75V dc for a solar irradiance of 400W/m2, it is observed from fig.4. This dc voltage is converted into ac voltage by a voltage source inverter; it is controlled sinusoidal pulse width modulation. This ac voltage is injected into utility grid. The voltage, current and power wave forms at DC to DC Converter and grid are shown in fig.5 to fig.8 respectively.

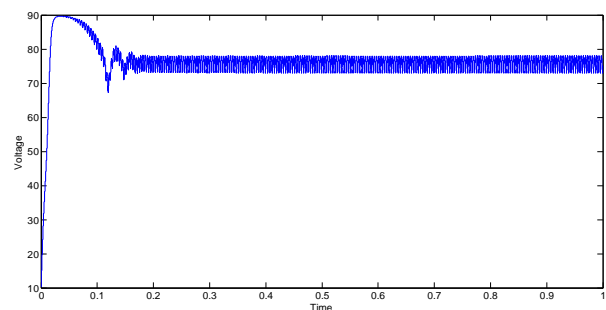


Fig 4. Voltage at the output of DC to DC converter

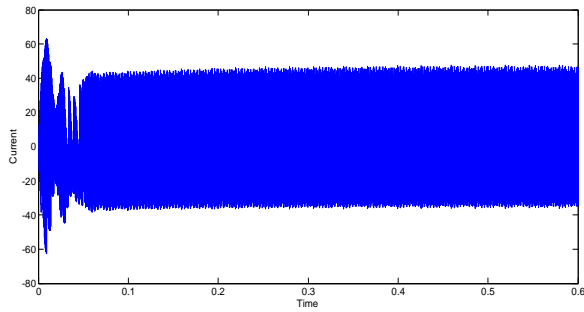


Fig 5. Current at the output of DC to DC converter

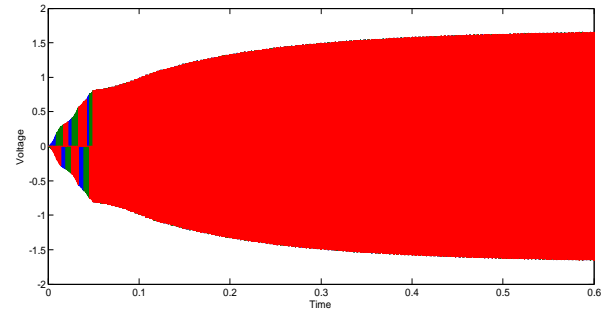


Fig6 . Voltage at the Grid connection point

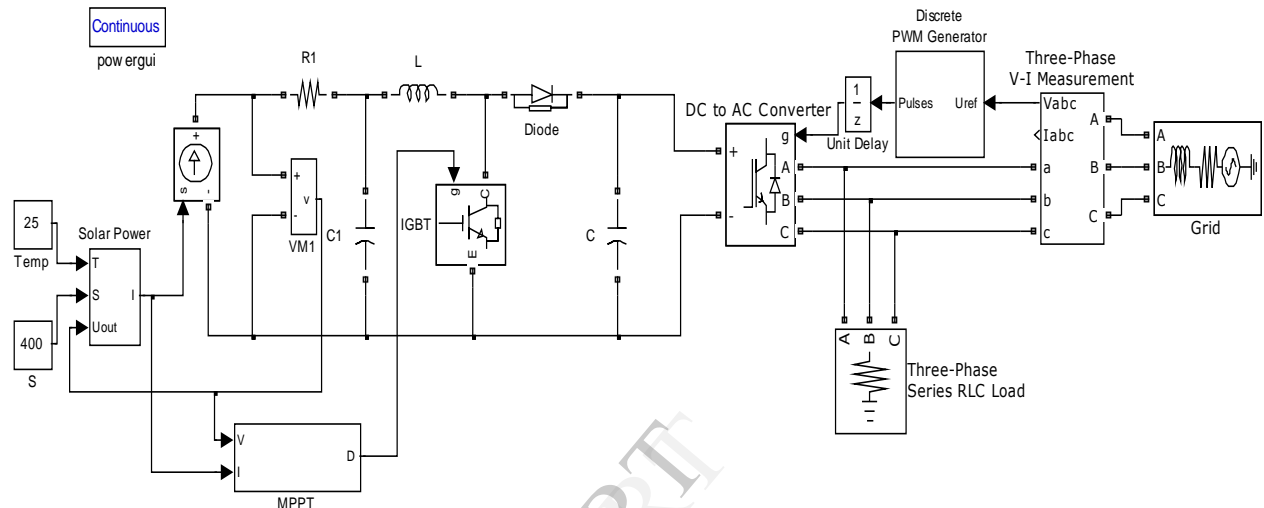


Fig 9. MATLAB/SIMULINK Model of MPPT control of Grid connected PV modules

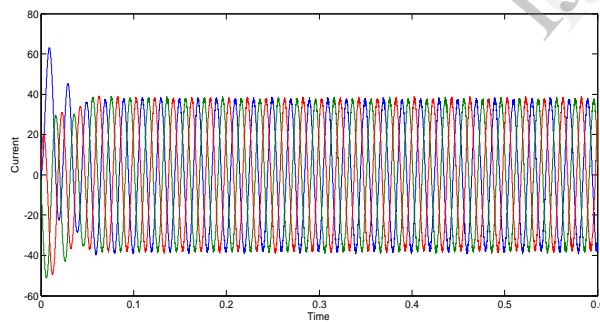


Fig 7. Current at the Grid connection point

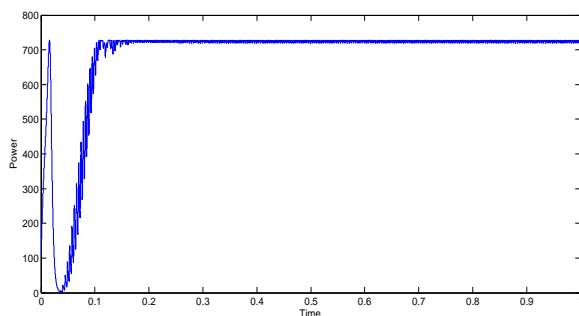


Fig 8. Power of the Solar panels

V. CONCLUSIONS

In this paper, a grid-connected PV system based on MATLAB has been proposed. Based on the accurate modelling system, maximum power point tracking (MPPT) and fault analysis are studied. Voltage control strategy can achieve the maximum power point tracking and maximization of the real power output of the PV system. MATLAB/SIMULINK model of grid connected photovoltaic (PV) system is useful to understand and master the performance of PV systems and also to optimizing the design and lowering costs. It is also useful for shorten development cycles as well as improve system reliability and efficiency.

VI. REFERENCES

1. S. Oh, M. Sunwoo, "Variable structure PWM controller for high efficient PV inverters," IEEE International Conference on Sustainable Energy Technologies, pp. 24-27, Nov. 2008.
2. A. Bellini, S. Bifaretti, V. Iacovone, "Resonant DC-DC converters for photovoltaic energy generation systems," International Symposium on Power

Electronics, Electrical Drives, Automation and Motion, pp. 815-820, Jun. 2008.

3. O.Wasynczuk, N. A. Anwah, "Modeling and dynamic performance of a self-commutated photovoltaic inverter system," IEEE Transaction on Energy Conversion, vol.4, no.3, pp. 322-328, Sep. 1989.

4. A. Yazdani and P.P. Dash, "A Control Methodology and Characterization of Dynamics for a Photovoltaic (PV) System Interfaced With a Distribution Network" IEEE Trans. Power Del., vol. 24, no. 3, pp.1538-1551, Jan. 2009.

5. A.Yazdani and R.Iravani, "An accurate model for the dc-side voltage control of the neutral point diode clamped converter," IEEE Trans.Power Del., vol. 21, no. 1, pp. 185-193, Jan. 2006.

6. Najet R, Belgacem B, Othman H. Modeling and control of photovoltaic energy conversion connected to the grid. *Frontiers in Energy*, 2012, 6(1):35-46

IJERT