Modeling and Control of Photovoltic using P&O MPPT Method

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Abstract— Renewables are the need of the day. In todays world when there in high increase in demand of electric power renewables are the saviors. Distributed Generators (DG) Ie. renewables are the power sources located near load centers which are provided with power electronics converters for grid interfacing. As the energy produced by renewbles vary maximum power point tracking is used to trace maximum power from the renewables. In this paper solar is used in choice of renewables and perturb and observe is used as the MPPT method to trace the maximum power point of solar photovoltic. The system consists of solar photovoltic model with a DC-DC converter in which MPPT method is implemented. A 700KW Grid integrated Photovoltaic system is simulated by MATLAB/SIMULINK software along with the proposed control strategy and the results show the feasibility and performance of the control structure.

Key words: Distributed Generators (DG); Photovoltaic (PV); DC-DC converter; Maximum Power Point (MPP), P&O

I. Introduction

ANY electric drives and applications require advanced power electronics converter to fulfill the high power demands. This requirement resulted in power converter structure as an alternative in high power and medium voltage situations. Global warming has become a major for the world due to increasing use of nonrenewable resources. Nonrenewable resources like coal, nuclear elements, etc. have given rise to many problems. The problem faced by the world includes pollution, uncertain rise in temperature, astonishing weather change and many more to add to this list. Moreover shortage of fossil fuels is the next big problem that the world will be facing in the near future. To overcome these shortcomings a permanent solution is required. The ultimate solution to this problem is to shift our concentration from nonrenewable sources to renewable source of energy. Hence nonrenewable sources of energy like solar, wind and hydro gaining importance over nonrenewable source of energy due to its advantages over nonrenewable sources of energy.

There are different types of renewable energies; the popular of them is photovoltaic (PV) system. Initially PV modules used to be expensive, but with advancement of time their price has reduced to great amount, and the payback period also reduces, as they become increasingly economical due to their use in many applications. The efficiency of PV modules has also increased in recent years about 24 to 30%. Over the last 20 years or so th is a drastic change in the price of PV due to increase in its efficiency and reliability. This augmented to a grid connected photovoltaic system wherein PV system is coupled to mains of the system.

The advantage of PV system is connected to the grid is that it can transmit the extra power to the grid after fulfilling the local demand. In case if the PV system generates less than the requirement in that case it can extract extra power from the grid to meet the load demands. Thus PV solar energy acts as an alternative resource of electricity. The PV system, designed in this work, aims to transfer electrical power from PV panels to the grid. Solar renewables generate energy in form of DC power which is converted into AC power using power electronics devices. First, a dc-dc Converter is used to boost up PV voltage to a level higher than the peak of grid voltage. As the energy generated from renewables are not constant even for a span of a day. They vary as per different atmospheric conditions. As for solar irradiance, atmospheric temperature etc. effect the electrical energy produced by the solar photovoltic. Along with this converter also tracks the maximum power point of PV module. There are many algorithm for tracking maximum power point. In this system perturb and observe method is used. Also Maximum Power Point Tracking (MPPT) is used to track maximum value of voltage and hence power.[1]

MATLAB is one of the more well-known simulation software used by industries and as well as the institutions due to its range of advantages. To smoothen the progress of development of solar PV based power conversion systems, large numbers of simulation models developed in MATLAB are available in the literature.

The system components and power control scheme were deled in terms of dynamic behaviors. The proposed models were simulated in Matlab/Simulink.

II. System Description

A 700KW PV system is designed in this work, which aims to transfer electrical power from PV panels to the grid. First, a dc-dc Converter is designed to boost up PV voltage to a required level. The maximum power point control is also incorporated in the converter to extract maximum power from PV module. There are different algorithms available for tracking maximum power point, here perturb and observe method is used. In this method PV module's voltage and current both are to be sensed for tracking maximum power point.

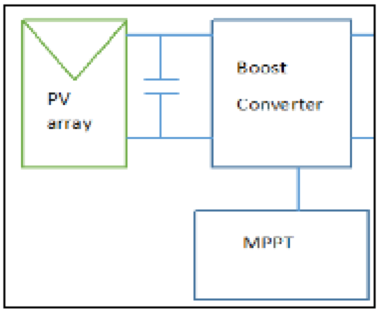

Fig. 1: Block Diagram

A. PV modelling

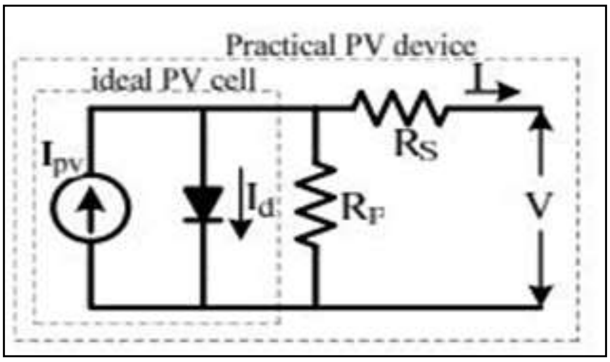

Fig. 2: Equivalent Circuit of Solar Photovoltaic

Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a load by using proper energy conversion devices.[2]

This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. A. Photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light as depicted in fig. 1. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. [8]

The figure above shows the equivalent circuit of PV cell. The current source I_{ph} represents the cell photocurrent. R_{sh} and R_s are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of R_{sh} is very large and that of R_s is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.[1]

The Solar Photovoltaic system simulated in the present paper uses the following equations [1]

$$I = I_L - I_B \quad (1)$$

$$I_D = I_0[\exp(q(V+I*Rs)/(\gamma kTc) - 1] \quad (2)$$

Where I is the photovoltaic current, I D is diode current, I L the Photovoltaic current at different temperature and radiance, k is Boltzman constant(1.384*10^-23),q is charge of electron(1.6*10^ -19),γ is ideality factor (1.3) ,T is temperature,I 0 is saturation current.

Module Photovoltaic current is calculated by

$$I_{ph} = [I + K(T - 298)] * \lambda/1000 \quad (3)$$

Module reverse saturation current

$$Irs = I/[\exp(qv/(NkAT)) - 1] \quad (4)$$

Module saturation current is given by PV module output current is calculated by, where V_{pv} is equal to V_{oc}

$$Io = Irs\,[T/T_r]\exp[q*(E_{go}/(B_k(1/T - 1/T_r))] \quad (5)$$

The current output of PV module is

$$I_{pv} = N_s*I_{ph} - N_p* Io\,[\exp\{q*Vpv+Ipv*RsNsAkT\} - 1] \quad (6)$$

Where V pv =V oc , N s =72, N p =1

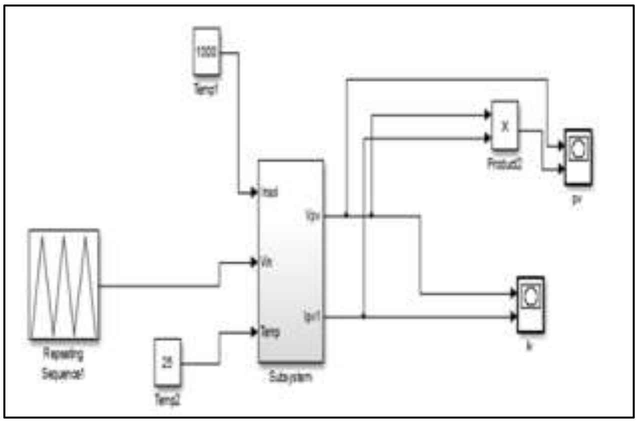

Fig. 3: Matlab Modelling of PV module

1) Technical Details

Short Circuit Current Isc	8.82 A
Open circuit Voltage Voc	45.5V
Voltage at MPP Vmpp	36.8V
Current at MPP Impp	8.32A
Ideality Factor A	1.6
Boltzman Constant	$1.38*10^{-23}$
Temperature Coefficient K_i	0.0017A/C
Temperature in Kelvin T	293K
No of cells in parallel	1
No of cells in series	72
No of strings in parallel	120
No of strings in series	20
Charge of electron q	$1.6*10^{-19}$
Energy band Gap Eg	1.1 eV
Irradiance **λ**	10000 Wb/m^2

Like all other semiconductor devices, solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby effecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. Therefore increasing the temperature reduces the band gap.In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. The impact of increasing temperature is shown in the figures 3 and 4 below.

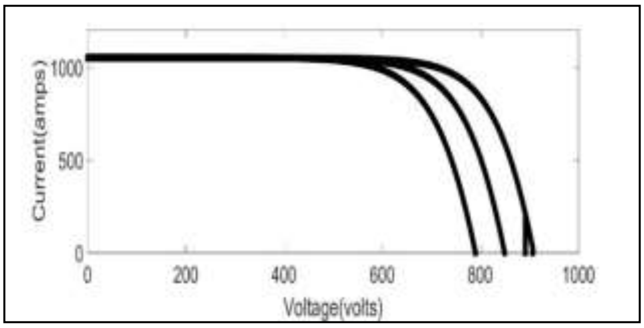

Fig. 4: Current verses Voltage for varying Temperature

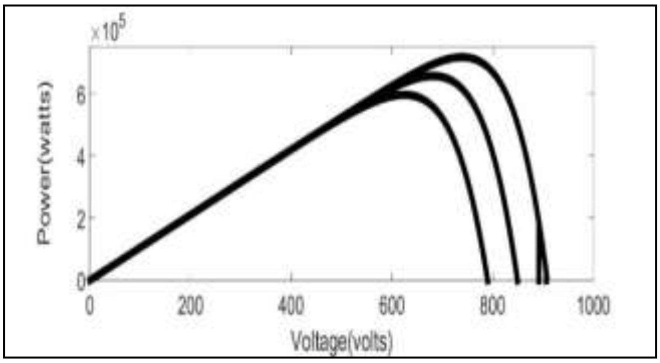

Fig. 5: Power verses Voltage for varying Temperature

Changing the light intensity incident on a solar cell changes all solar cell parameters, including the short-circuit current, the open-circuit voltage, the efficiency and the impact of series and shunt resistances. The light intensity on a solar cell is called the number of suns, where 1 sun corresponds to standard illumination,1 kW/m^2. For example a system with 10 kW/m^2 incident on the solar cell would be operating at 10 suns, or at 10X.The below figure 5 and 6 show the effect of isolation on IV and PV curves of solar photovoltaic

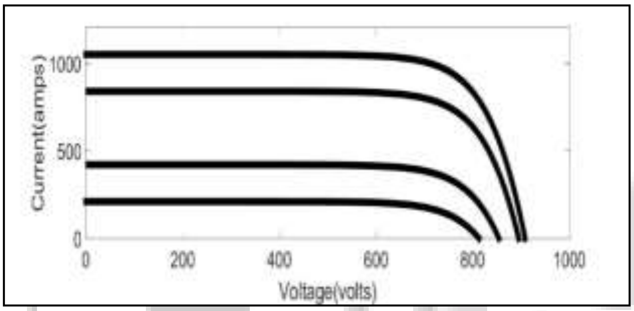

Fig. 6: Current verses Voltage for varying Irradiance

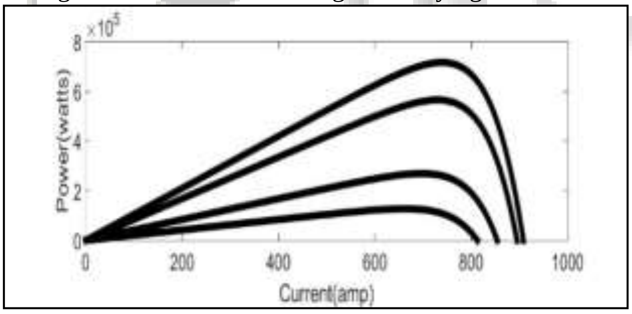

Fig. 7: Power verses Voltage for varying Isolation

B. DC-DC converter

The voltage output of solar photovoltaic is dependent on atmospheric conditions and the irradiance available, so DC-DC converter is used to maintain the constant voltage input to the inverter irrespective of the change of solar photovoltaic voltage output.The DC- DC converter shown in this paper is a boost converter, also termed as step up DC-DC converter.[3,4,5]

The modelling of the presented converter uses following equations

The duty cycle of the boost converter can be obtained from the equation

$$V_o = V_s/1-D \qquad (7)$$

Where V_o is the output voltage required, V_s is the input voltage, D is duty cycle.

Selection of resistor R is ad output voltage is controlled by

$$P_0 = V_0/R = V \text{ o } I \qquad (8)$$

And Now maximum and minimum inductor current can be obtained from

$$I_{Lmax} = I_L + \Delta I_L/2 \qquad (9)$$

$$I_{Lmin} = I_L - \Delta I_L/2 \qquad (10)$$

Where $\nabla I_L = (0.2 \text{ to } 0.4) * I_o * V_o/V_s$

The value of inductor is given by

$$L = Vs{*}D/\Delta I_s f \qquad (11)$$

where L is the inductor value, D is the duty cycle, f is switching frequency.

The value of capacitor is obtained from

$$C = D/R\ (\Delta V_0/V_0)f \qquad (12)$$

where Δ Vo is output voltage ripple.

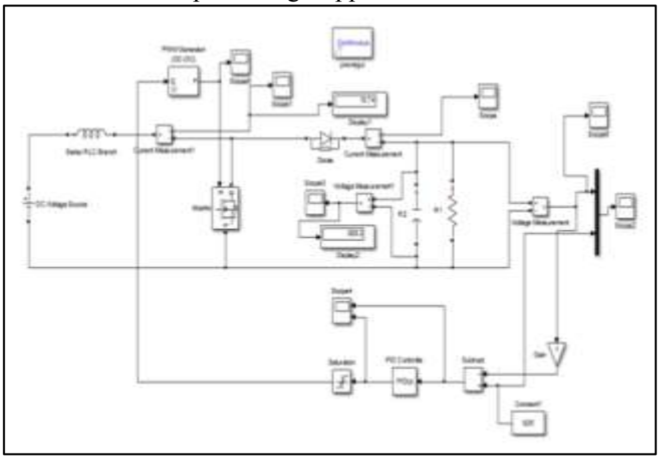

Fig. 8: boost converter in MATLAB

C. Maximum Power Point Tracking

Maximum power point tracking (MPPT) is a technique used with wind turbines and photovoltaic (PV) solar systems to maximize power output. Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

The operating point of solar photovoltaic is decided by the load to which it is connected. As the solar irradiance falling on the solar photovoltaic module varies throughout the day, the operating point of the solar photovoltaic module is bound to change. In order to ensure the operation of PV modules for maximum power transfer, a special method called Maximum Power Point Tracking (MPPT) is employed in PV systems. The maximum power tracking mechanism makes use of the algorithm and an electronic circuitry. The mechanism is based on the principle of impedance matching between load and PV module, which is necessary for maximum power transfer. This impedance matching is done by using a DC-DC converter.

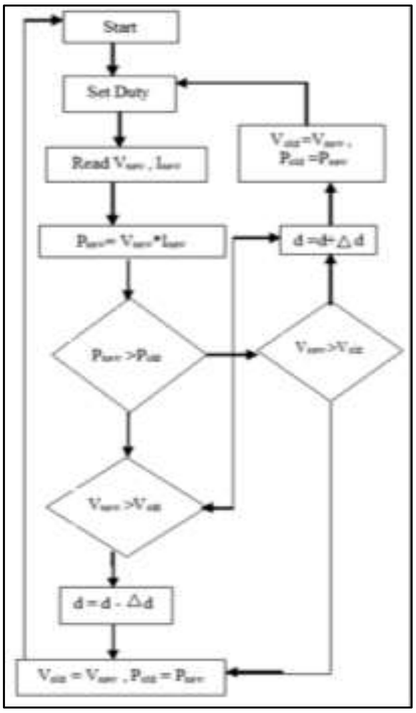

Fig. 8: Flow chart of Perturb and Observe

Due to the simplicity in implementation, the MPPT algorithm used in this paper is Perturb and Observe. In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called Perturb and Observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

As shown in figure 9 in this method the duty cycle D is perturbed at regular intervals and power from PV module is measured at that instants. If the change in d is effecting the direction so that operating point of approaches maximum power point on power voltage characteristic is looked up.

D. Results & Conclusion

The figure given below shows the graphs of voltage and power of solar photovoltic module with and without MPPT

Fig. 9: Power from PV with and without MPPT

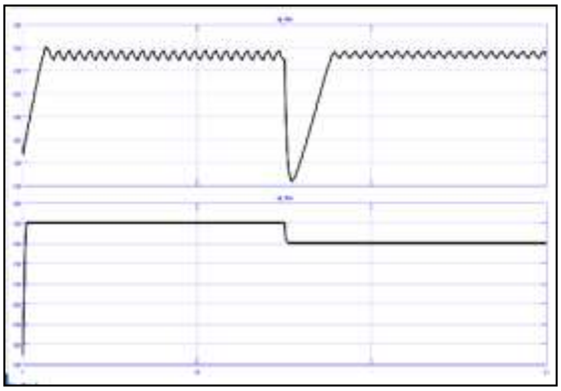

Fig. 10: Voltage with and without MPPT

Above shown both figures explicit the effect of MPPT on voltage and power, as the load is changed after few seconds, without MPPT the solar photovoltaic delivers low voltage and power even through it capable to more voltage and power, while with MPPT as the load changes the voltage and power are traced back to maximum available at that isolation and temperature. This serves the purpose of MPPT.

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