Design of Isolated Solar Photovoltaic Power Generation System

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***Abstract*- Depletion of non-renewable energy sources with the increasing demand in electricity and also to avoid islanding condition an efficient and sustained source of energy becoming mandatory. This paper focuses on mathematical modeling and simulation of PV module with boost converter interconnected with AC Load. MPPT algorithm named Perturb & Observer technique is implemented in boost converter to extract maximum possible power from PV module which in turn depends on solar irradiance and temperature. This work lead to utilize the renewable solar energy at a large scale by interconnecting PV module and AC Load while extracting constant maximum power from module. This paper will review existing approaches on MPPT algorithms. PV module of 5.5 kw is converted into AC and fed to AC Load. P-V and I-V characteristics are obtained by modeling mathematically for data sheet "Sun Power SPR-305-WHT-U Solar panel in MATLAB code. The output waveforms for power output from PV module before and after implementation of MPPT algorithm are analyzed through MATLAB Simulation.**

***Index Terms*- Solar Photovoltaic (PV) system, Maximum Power Point Tracking (MPPT), Perturb & Observation (P&O), Boost Converter.**

I. INTRODUCTION

The energy demand supply gap is increasing due to the increase in the consumption of electrical energy (all over the world) and depletion of fossil fuels. Therefore it is important to look for the alternative sources of energy. In order to find out solution for above problems many researches are carried out to find sustainable energy sources, mainly in renewable energy sources [1]. There are many types of renewable sources available viz. solar energy, wind energy, hydro energy, thermal energy, biomass *etc*. Among the above stated renewable energy sources solar photovoltaic is gaining more importance due to its reliability and ease of availability. PV cells are a silent producer of electricity. Due to absence of mechanical parts it has low maintenance cost, low operating cost, and is eco-friendly [1] [2]. The energy from sun can be collected in many forms but one of the most popular techniques is Photovoltaic (PV) cell in which the energy is directly obtained in electrical form, in which the irradiance from sun (sunlight, including sun ultra violet radiation) is directly converted into electricity by the means of photovoltaic effect. The photovoltaic effect is a process in which light (photons) is converted into electricity (voltage), which uses semi-conductor material such as silicon for the conversion. When the solar radiation is incident on the semi conducting film, it causes an electrical current to flow through it. Photovoltaic cells produce only direct current (DC) electricity.

Electrical energy obtained from PV module is in DC form also it varies with solar irradiance and cell temperature. Maximum Power Point (MPP) tracker is used [3]. PV module is designed part interconnected with Load through boost converter in which MPPT algorithm is Simulated.

II. PHOTOVOLTAIC CELL

When the PV cell is exposed, sunlight energy is produced in the form of a DC voltage. Solar cell is a non-linear current source. The current which is produced by solar cell is depends on the irradiation, cell temperature, characteristic of material.

A. Photovoltaic power system

The irradiance energy convert into electric energy without using mechanical part in photovoltaic phenomenon. System consists three part one of is solar module second one is interface part and last one is electric load. The second part can manage and induced energy.

B. PV Module

The power produced by only one PV is not enough for general use. So many PV cells are connected in series and parallel to get desired power. One module consist approximately 36 or 96 cells.

Solar Cell or Photovoltaic (PV) cell is a device that is made up of semiconductor materials such as silicon, gallium arsenide and cadmium telluride, etc. that converts sunlight directly into electricity. The voltage of a solar cell does not depend strongly on the solar irradiance but depends primarily on the cell temperature [3]. PV modules can be designed to operate at different voltages by connecting solar cells in series. When solar cells absorb sunlight, free electrons and holes are created at positive/negative junctions [4]. If the positive and negative junctions of solar cell are connected to DC electrical equipment, current is delivered to operate the electrical equipment. The equivalent circuit of solar cell is shown in Figure 1.

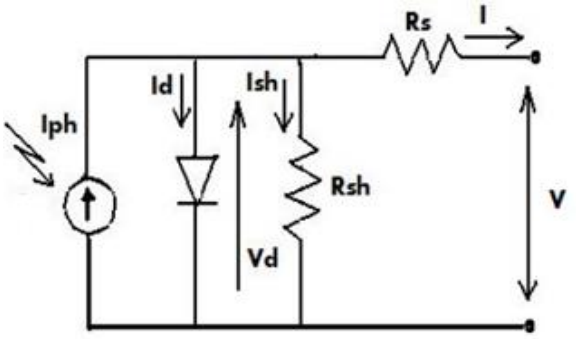

Figure 1. Equivalent circuit of solar panel

The basic mathematical equation of I-V characteristics of ideal PV cell is given below,

$$I = I_{pv} - I_o \left[\exp\left(\frac{q(V+I R_S)}{KTAN_S}\right) - 1\right] \quad (1)$$

The diode current:

$$I_d = I_o \left[\exp\left(\frac{q(V+I R_S)}{KT}\right) - 1\right] \quad (2)$$

Solar output current [3]:

$$I = IL - Id - Ish \quad (3)$$

$$I = I_{pv} - I_o \left[\exp\left(\frac{V+I R_S}{a V_T}\right) - 1\right] - \left[\frac{V+I R_S}{Rsh}\right] \quad (4)$$

PV and IV characteristics obtained from mathematical modeling are Figure 2. Which shows that there is only one point where maximum power is possible to obtain from the array i.e. maximum power point (MPP).

As the P-V characteristic is constantly varying by changing the irradiance and temperature, the MPP must be tracked at the changed moment to maximize the output power from the panel. Therefore, both a tracking speed and accuracy are required.

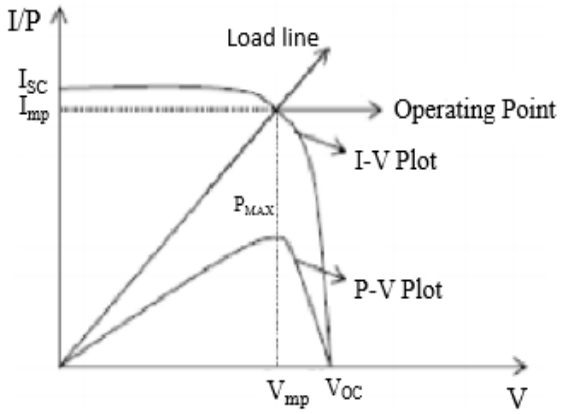

Figure 2: I-V & P-V characteristics of the solar cell

III DC-DC BOOST CONVERTER

In a boost converter the output voltage is greater than the input voltage. A boost converter using a power IGBT shown in Figure 3 [5].

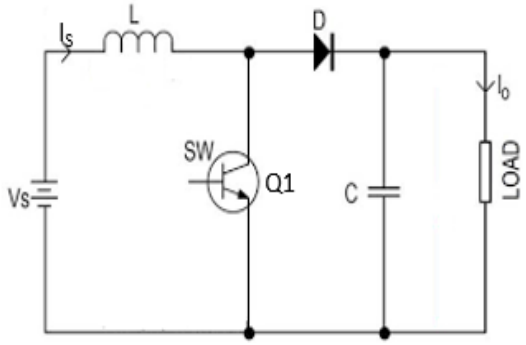

Figure 3: Circuit diagram of Boost Converter

The circuit operation has two modes. In mode 1, power IGBT switched on at t = 0. Input current rises and flow through inductor and switched Q1. Whereas in mode 2 the switched off at t = t1. So, the current flow through inductor, capacitor and diode. The energy stored in the inductor will be transferred to the load.

IV. MAXIMUM POWER POINT TRACKING ALGORITHMS

MPPT is basically an algorithm implemented in the converter to ensure MPP with the variation in irradiance and temperature. It matches the panel output with the load requirements. Significant amount of work has been done to improve solar efficiency [8][9].
One of Most widely used algorithm is Perturb and Observe MPPT.

A. Perturb and Observe MPPT Method:

The P & O algorithms operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage or current and comparing the PV output power with that of the previous perturbation cycle. The rate of PV Array operating voltage is more than zero. In the next perturbation cycle the algorithm continues in the same way. In this technique we generally use only one sensor that is the voltage sensor, to sense the PV module voltage and hence the cost of implementation is less and hence easy to implement without any complexity [7].

Algorithm for P & O technique:

1. Read the value of current and voltage from the solar PV module.
2. Power is calculated from the measured voltage and current.
3. In the next stage we are using the delay. The delay is used to remember the previous cycle value of Voltage and Power (i.e. V(K-1), P(K-1)).
4. Change in Power and voltage from current cycle and previous cycle is calculated by ΔP & ΔV.
5. 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 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. Whereas left of the curve is for the higher duty cycle.
6. Depending on the sign of dP i.e. (P(k-1) – P(k)) and dV i.e. (V(k-1) – V(k)) after subtraction the algorithm decides whether to increases the duty cycle or reduce the duty cycle.

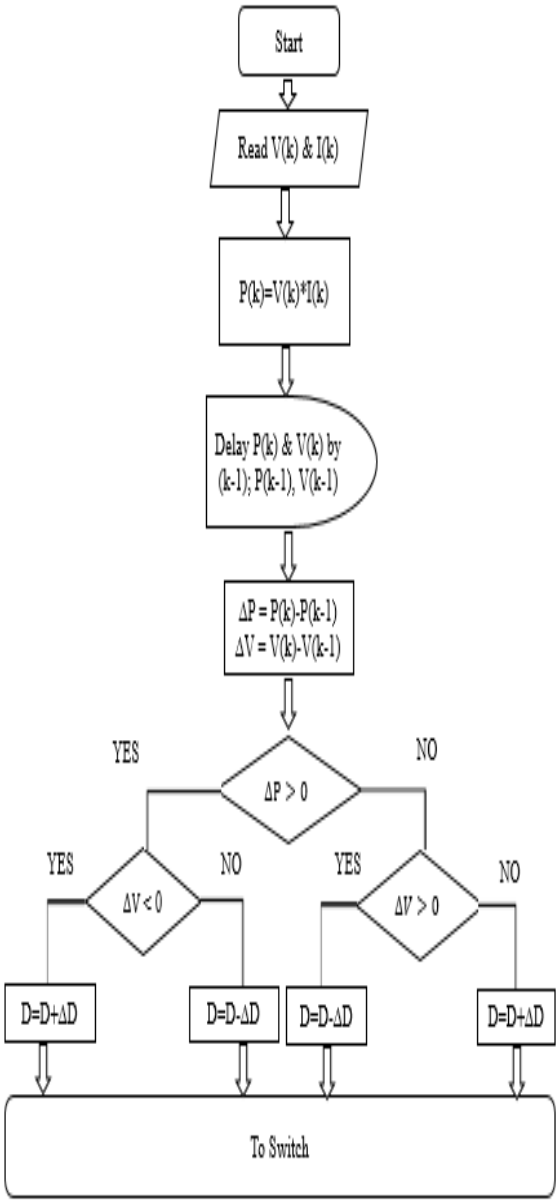

Figure 4: Flow chart of Perturb and Observe MPPT algorithm[7]

V. COMPLETE SIMULATION AND RESULTS

This section discusses the dynamic behavior of the whole PV array and AC Load interconnected system by analyzing simulation results in MATLAB. The complete block diagram of model is as Figure 5. For the modeling data of module "Sun Power SPR-305-WHT-U Solar panel"at STC is considered which is tabulated in Table I.

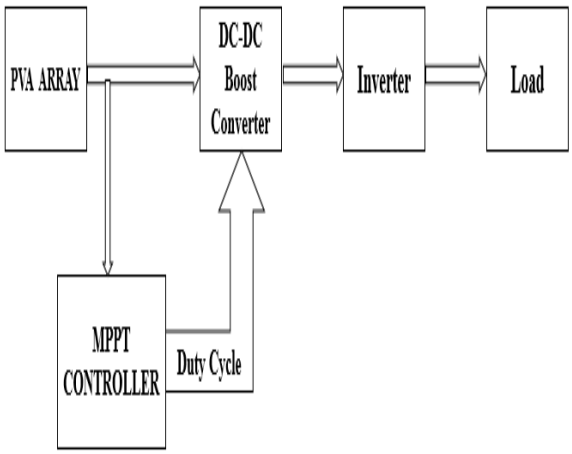

Figure 5. Complete model's block diagram

The estimation of correct parameters is very important for proper modeling of the photovoltaic cell as there is a large number of factors that have strong influence on the performance. The experimental data for model verification was estimated.

TABLE I PV MODULE SPECIFICATIONS

SPR-305-WHT-U at STC	
STC Power Rating	305 W
PTC Power Rating	280.6 W[1]
STC Power Per unit of area	17.4 W/ft^2 (187.0W/m^2)
Number of Cells	96
Imp	5.58 A
Vmp	54.7 V
Isc	5.96 A
Voc	64.2 V
Parallel strings	6
Series connected module per sring	3
Cells per module	96

The proposed PV module with Boost DC-DC Converter is shown in Figure.6. It was modelled in MATLAB-Simulink and its simulation results of I-V and P-V curves are shown in Figure 7. To track the MPP of PV module, P&O MPPT algorithms have been used. Simulation was carried out under particular solar isolation and cell temperature for P&O algorithm. The load was resistive load.

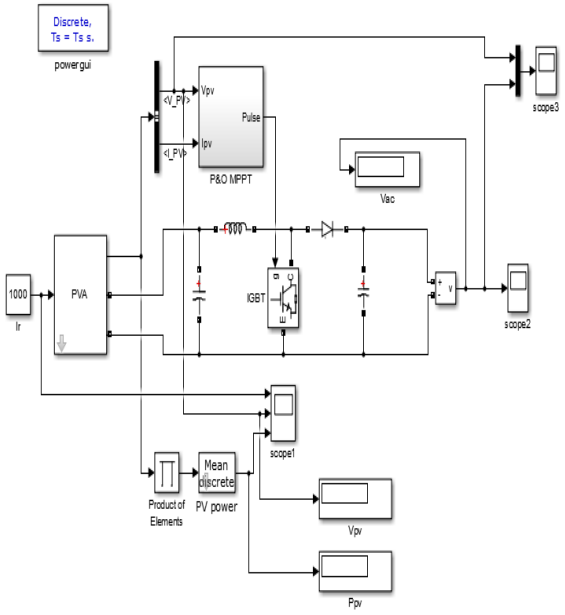

Figure 6: Solar with MPPT algorithm

Simulation of PV array was done under different irradiations and operating temperatures conditions. The I-V & P-V curves plotted through simulation are shown below in Figure 7.

The V-I & P-V characteristics are plotted for different irradiation levels are as follows: 1000, 800, 600 & 400 W/m2 and a constant temperature of 25^o C. The results show that the power increases with the increase in irradiation level and vice-versa. Maximum possible power we can extract from array is 5494 W at STC (25°C and 1000 W/m²) and the maximum voltage is 175 Volts.

Maximum Power = $P_{MAX} \times N_{series} \times N_{parallel}$ (5)

Maximum Voltage = $N_{series} \times V_{OC}$ (6)

Maximum Current = $N_{parallel} \times I_{SC}$ (7)

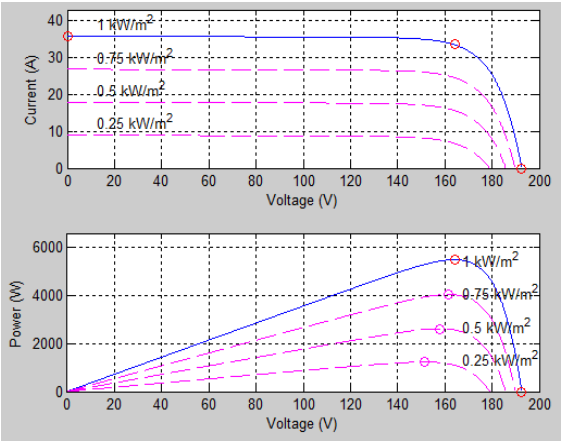

Figure 7: Effect of irradiation on PVA

Figure 8 shows the curve with MPPT and without MPPT which indicates that by using MPPT with Boost Converter we will get Maximum output Voltage.

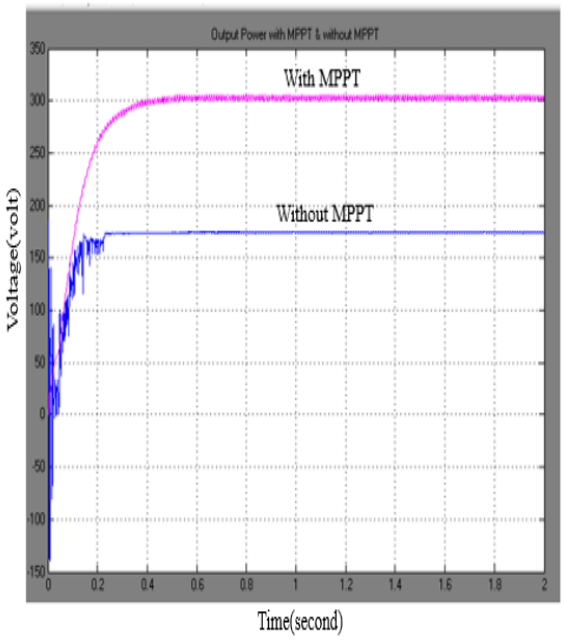

Figure 8: Output Voltage with MPPT & without MPPT(Without MPPT 175 V & With MPPT 304 V)

VI CONCLUSION

This paper presents the mathematical modeling of PVA "Sun Power SPR-305-WHT-U Solar panel" the PV and IV characteristics are verified by simulating the complete model in MATLAB. In this paper, the used. MPPT techniques are of most importance to extract the maximum power available in PV. P & O MPPT algorithm is simulated for a constant irradiation of 1000 W/m2 and temperature of 25^{o} C for which we get 305 Watts of power across the load, simulation of Solar PV without MPPT gives 174 Volts of voltage which shows that the use of MPPT in solar PV can be used for improving the efficacy and maximize the output voltage of solar PV system.

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