Perturb and Observe Algorithm for Maximum Power Point Tracking in Photovoltaic Systems

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Abstract – The demand for renewable energy sources in today's world is increasing because of the acute energy crisis. Even though sunlight experiences the phenomenon of reflection and absorption by the atmosphere, but still the solar energy incident on the surface of the earth is on the order of ten thousand times greater than the world energy consumption [1]. Photovoltaic power generation is gaining importance because of its ease of availability, cleanliness and pollution-free nature [2]. However, there are two major barriers for the use of PV systems, low energy conversion efficiency and high initial cost. The power characteristics of a photovoltaic system vary with the level of solar irradiation and temperature therefore making the extraction of maximum power from the PV panel a complex task. In order to harness maximum power from a photovoltaic system, several techniques called as maximum power point tracking techniques are implemented in such systems. This paper presents a detailed study of one of the important maximum power point tracking techniques called as Perturb and Observe algorithm.

Index Terms – Photovoltaic system, maximum power point tracking (MPPT), solar cell.

1. INTRODUCTION

Environmental problems like air-pollution due to emission from thermal power plants and vehicles, depletion of fossil fuels and greenhouse effect are forcing environmental engineers to switch from conventional energy resources to renewable ones. Among the various renewable energy resources, photovoltaic power generation is one of the most promising energy resources currently. Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP. The PV array is an unregulated dc power source, which has to be properly conditioned in order to interface it to the grid [3]. Tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system. In a conventional PV system, PV cells generate a DC that greatly depends on the solar irradiance, temperature and voltage at the terminals of the PV systems. The interface of the PV array to the grid is realized with a PV inverter which converts the DC power into the AC power. The two typical configurations of a grid-connected PV system are single or two stages. In a two-stage configuration, the first stage (DC-DC Converter) is used to boost the PV array voltage and track the maximum power and the second stage (DC-AC converter or inverter) ensures the conversion of this DC power into high-quality AC voltage [2], [4]. A Maximum Power Point Tracking Technique (MPPT) is used for extracting the maximum power from the solar PV module and transferring that power to the load. The Perturb and Observe (P&O) method is the most common MPPT approach applied in PV systems [1]. This method determines the system control commands according to the difference in the power output between the current system state and previous system state. Thus, determining the perturbation step used to a system is an essential issue.

This paper implements a photovoltaic system with a DC-DC boost converter and a Perturb and Observe maximum power point tracking algorithm to let the PV system operate at maximum power.

2. MATHEMATICAL MODELING OF PV ARRAY

Typically a solar cell can be modeled by a current source and a diode connected in parallel to it. It has its own series and parallel resistance [5]

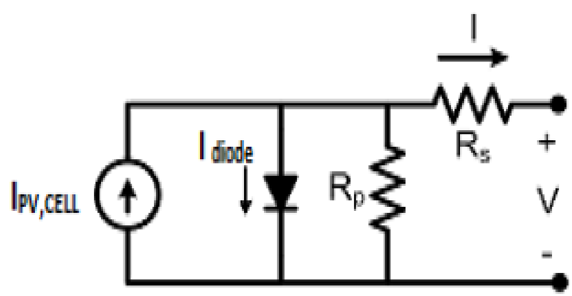

Figure 1. Single Diode model of PV cell

The equation for the output current (I) of a PV cell is given as:

$$I = I_{PV,CELL} - I_{diode} \quad (1)$$

$$I = I_{PV,CELL} - I_{0,CELL}\left[exp\left(\frac{q*V}{\alpha*k*t}\right) - 1\right] \quad (2)$$

Where, $I_{PV,cell}$ is the current generated by the incident light , I_{diode} is the Shockley diode equation, $I_{0,cell}$ [A] is the reverse saturation or leakage current of the diode [A], q is the electron charge [$1.60217646 * 10^{-19}$C], k is the Boltzmann constant [$1.3806503 * 10^{-23}$J/K], T [K] is the temperature of the p-n junction and α is the diode ideality constant which lies between 1 and 2 for mono crystalline silicon.

The basic equation (1) of the elementary PV does not represent the I-V characteristic of practical PV arrays. Practical modules are composed of several connected PV cells requires the inclusion of additional parameters Rs and Rp, with these parameters (1) becomes:

$$I = I_{PV} - I_0 \left[exp\left(\frac{V+R_S*I}{V_t*\alpha}\right) - 1 \right] - \frac{V+I*R_S}{R_P} \qquad (3)$$

The light-generated current of the module depends linearly on solar irradiation and is also influenced by temperature according to the following equation:

$$I_{PV} = \left(I_{PV,n} + K_I \Delta T\right) \frac{G}{G_n} \qquad (4)$$

Where K_I is the Temperature coefficient of I_{SC} , G is the irradiance (W/m²) and G_n is the irradiance at standard operating conditions.

The diode saturation current I_0 dependence on temperature can be expressed as:

$$I_0 = I_{0,n} \left(\frac{T_n}{T}\right)^3 exp\left[\frac{q*E_g}{\alpha*k}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \qquad (5)$$

E_g is the band-gap energy of the semiconductor and $I_{0,n}$ is the nominal saturation current and can be expressed as:

$$I_{0,n} = \frac{I_{SC,n}}{\left[exp\left(\frac{V_{OC,n}}{V_{t,n}*\alpha}\right) - 1\right]} \qquad (6)$$

Where $V_{OC,n}$ is open circuit voltage ,$I_{SC,n}$ is the short circuit current , $V_{t,n}$ is the thermal voltage , T_n is the temperature at standard operating conditions. $V_t = Ns*kT/q$ is the thermal voltage of the module with N_s cells connected in series.

3. PERTURB AND OBSERVE ALGORITHM

Perturb and Observe (P&O) method involves the perturbation in the operating voltage of the PV array. The P&O method (Fig.3) operates by periodically incrementing or decrementing the output terminal voltage of the PV cell and comparing the power obtained in the current cycle with the power of the previous one (performs *dP/dV*). If the voltage varies and the power increases, the control system changes the operating point in that direction; otherwise, it changes the operating point in the opposite direction. Once the direction for the change of voltage is known, the voltage is varied at a constant rate [6]. It is often referred to as hill climbing method, because they depend on the fact that on the left side of the MPP, the curve is rising ($dP/dV > 0$) while on the right side of the MPP the curve is falling ($dP/dV < 0$) this is shown in Fig. 2.

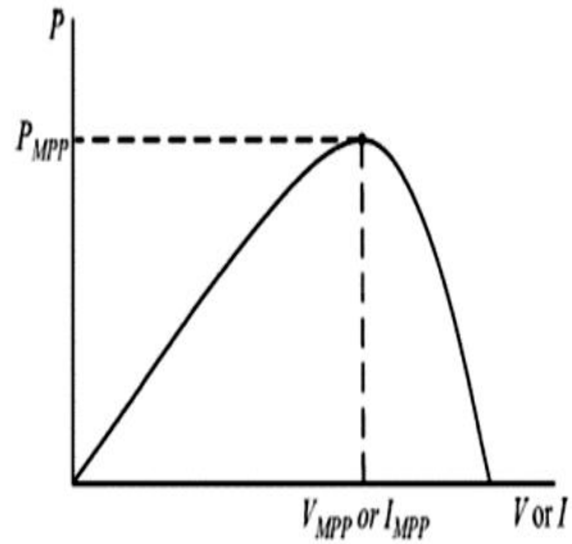

Figure 2. Characteristic PV array power curve

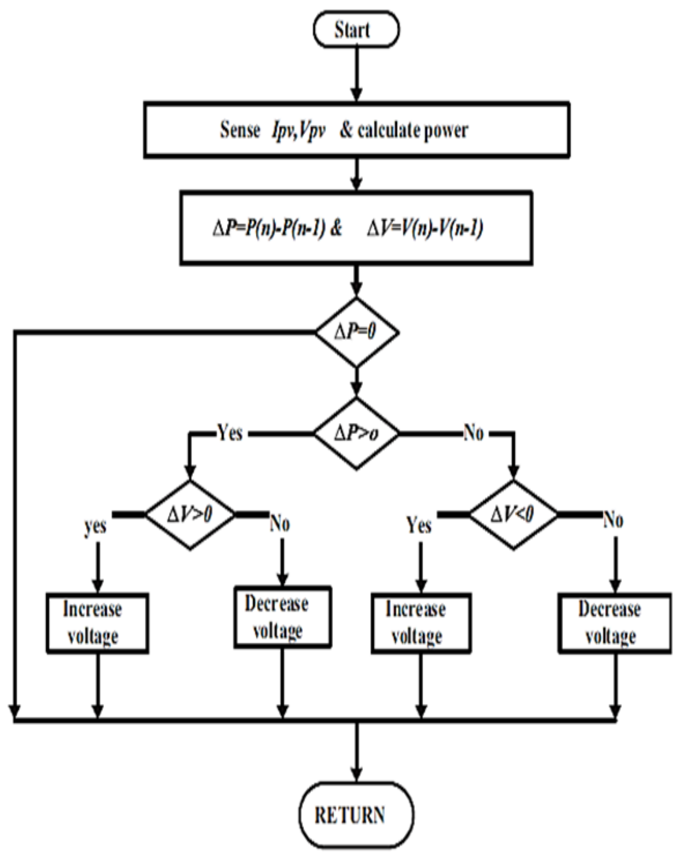

Figure 3. Flowchart of P&O algorithm

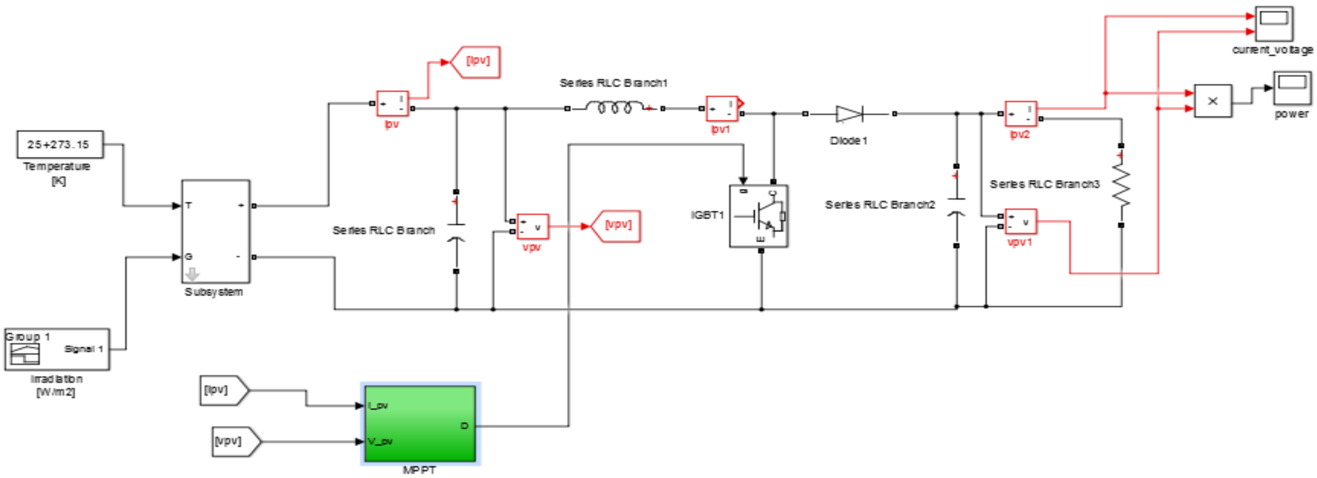

Figure 4. SIMULINK Model of the Photovoltaic System with MPPT Unit

4. RESULTS AND DISCUSSIONS

In this paper, BP MSX-120 photovoltaic model is used for the validation of the performance of P&O MPPT algorithm. The simulation is run for the conditions specified in Table 1. The power output of the PV array is 119.6 W at a load of 100Ω and output power 1s approximately 120W at a load of 20Ω.

Figure 3. Flowchart of P&O algorithm

1000 W/m^2	25^{0}C	100Ω	120 W

Table 1: Simulation Data

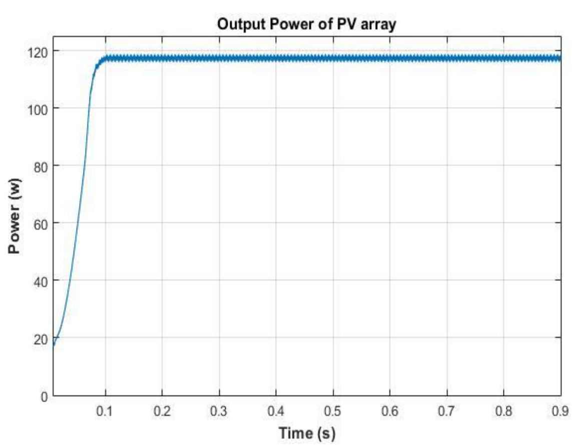

Figure 5. PV array output power at R=100Ω

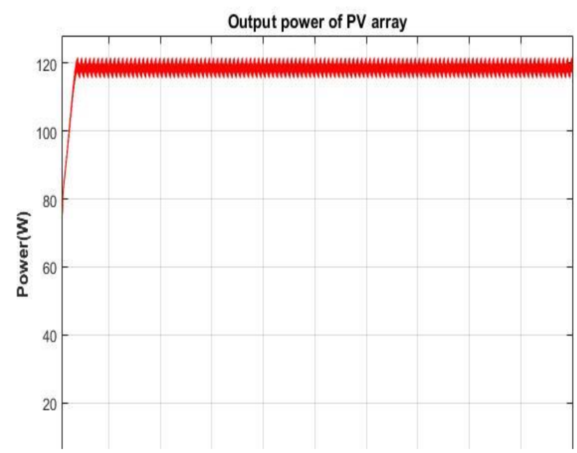

Figure 6. PV array output power at R=20Ω

Time (s)

Load(R)	P_{PV}
100Ω	119.6 W
20Ω	120 W

Table 2: Results from simulation in MATLAB-SIMULINK

5. CONCLUSION

In this paper a complete PV system has been simulated in MATLAB-SIMULINK. The PV system uses an MPPT controller and runs Perturb & Observe algorithm for the purpose of tracking maximum power. BP MX-120 photovoltaic model has been chosen for validating the simulation results. It has been found that the PV array is able to approximately track maximum power of 120W using P&O algorithm even when the load changes from 100Ω to 20Ω.

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