

MPPT Controller for Solar PV Cells using GSAPSO Algorithm

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Abstract

Solar energy is a very general source of renewable energy due to some advantages. In many countries, Photovoltaic power systems have been mostly used. However, there are many urgent issues to tackle in the application of PV power systems. The main problem is how to improve efficiency. Since the PV arrays display a nonlinear Power–Voltage (P–V) characteristic curve which varies with insolation and temperature, how to achieve Maximum Power Point Tracking (MPPT) is a very significant technology. In this work, we have explored the optimization methods for efficient tracking such as PSO and GSA. The essential issue of MPPT control is an optimization problem which can be achieved by using evolutionary algorithms. PSO algorithm owns the characteristics of good robustness, parallel processing and high probability of finding global optimal solution. By combining GSA to PSO, the performance has been improved. The proposed GSAPSO algorithm greatly shortens the searching time, reduces the fluctuation of output waveform and improves the efficiency through particles dormancy and activation control, optimal number of particles algorithm and search sequence selection. It achieves a smooth starting for maximum power and achieves it in less time than the widely used other methods.

Keywords: Solar Cell, GSA, MPPT, PSO, PO

1. Introduction

The direct conversion of light to electric energy is possible through the use of Photo-Voltaic Generator (PVG). Unfortunately, the energy transform process is characterized by poor efficiency. This is caused because of primarily to the physical structure limits of the solar cells that found the PVG source. In addition to the observed poor efficiency, the resultant electric energy got from the PVG might be completely lost if there is no adequate electric load connected across the terminals of the PVG. However, the electric energy can be used by PVG mostly; only possible when proper matching between the PVG and the electric load is measured.

Photo-Voltaic (PV) cell is defined as when solar energy collected by photovoltaic effect, and it is considered as the most suitable renewable resource because of the abundance, sustainability and ubiquity also counted as a strong alternative to avoid reliance on fossil fuel¹. From field experience, the Solar Photo-Voltaic (SPV) system (Series parallel combination of PV cells/arrays use to provide required terminal voltage and current ratings) show low output power then on name plate rating².

The Maximum Power Point Tracking (MPPT) used to remove the maximum power from solar Photo-Voltaic (SPV) system which tracks the maximum power from array input varying with the ratio between current and voltage. One of the key reason produced for low output

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power from Solar Photo-Voltaic (SPV) system is the mismatch between the arrays or cells^{3,4}. To reach the maximum point of power output for SPV, many algorithms have been developed. Several researches are also going on for the further development the MPPT algorithms⁵⁻⁷.

The objective of this paper is to explore the model of different MPPT algorithms for SPV subsystems which simulate by using of MATLAB/SIMULINK software and to present GSAPSO based approach to get MPPT. Perturb and observe method has been observed and MPPT using GSAPSO is compared in this paper

1.1 System Design of PV Module

1.1.1 PV System

System design of PV module or PV System is the combination of solar cells arranged in parallel, series or both is considered as solar PV module. The solar cell is the basic part of a PV module. A PV array is used to convert the light from the sun into DC current and voltage. To increase the terminal voltage of DC converter, it is connected to the PV array and provides the means to implement an MPPT technique by controlling its switching duty cycle. A single phase inverter is then connected to perform the power conversion of the array output power into AC power suitable for injection into the grid. The phase and magnitude of the inverter output voltage are shaped by pulse width modulation control. To decrease the harmonics in the output current a harmonics filter is added after the inverter is the result from the power conversion process. An interfacing transformer, to set up the inverter output (AC voltage) with the grid voltage level is connected after the filter. Protection relays and circuit breakers are used to isolate the PV system is used to isolate the PV system when faults occur to prevent damage to the equipment if their ratings are exceeded².

1.1.2 Modeling PV Module

Below is a description of simulated PV cell is well known as equivalent circuit model which essential to simulate its physical behavior. Double exponential model is one of the famous model for PV cell [8] depicted in Figure 1. The representation of currents escaping due to diffusion and charge recombination mechanisms is done by using the p-n junctions (physics), two diodes in parallel has been modeled by PV cell. The internal PV cell resistance and contact resistance are also including with the model Identify applicable

sponsor/s here. Delete the text by resistances, R_s and R_p respectively, if there are no sponsors.

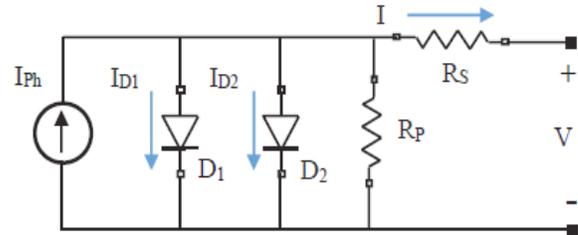


Figure 1. Double exponential PV cell model.

PV cell terminal voltage and output current are ruled by –

$$I = I_{ph} - I_{D1} - I_{D2} \frac{V + IR_s}{R_p} \tag{1}$$

$$I_{D1} = I_{01} \left[\exp\left(\frac{q(v + IR_s)}{akT} - 1\right) \right] \tag{2}$$

$$I_{D2} = I_{02} \left[\exp\left(\frac{q(v + IR_s)}{akT} - 1\right) \right] \tag{3}$$

Where,

I_{ph} - Cells internal generated photocurrent,

I_{D1} and I_{D2} - Currents passing through diodes D1 and D2,

a - Diode ideality factor,

k - Boltzmann constant ($1.3806503 \times 10^{-23}$ J/K),

T - Cell temperature in degrees Kelvin,

q - Electron charge ($1.60217646 \times 10^{-19}$ C),

I_{01} and I_{02} - Reverse saturation currents of each diode respectively.

Assume, due to charge recombination current is too small, so the current passing through the diode D_2 can be neglected. A simplified PV cell model [9] can be reached as shown in Figure 2.

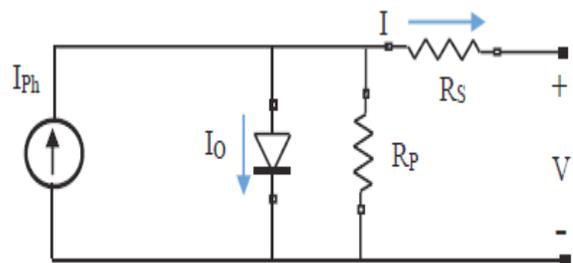


Figure 2. Simplified PV cell model.

This model provides a good cooperation between accuracy and model complexity, the relation simplifies to

$$I = I_{ph} - I_0 \left[\exp\left(\frac{q(v + IR_s)}{akT}\right) - 1 \right] - \frac{v + IR_s}{Rp} \quad (4)$$

The exponential term in equation shows the nonlinear relation between the terminal voltage and output current which clearly specify the existence of the p-n semiconductor junction in PV cell. The outcome of a unique IV characteristic for the cell where the current output is constant ended a wide range of voltages until it reaches a certain point where it begins dropping exponentially. Power output from a PV cell is dictated by the magnitude of the load resistance in case of fixed loads. If the load impedance does not equal the value required to abstract maximum power then it is possible to use a switched mode DC converter to do the matching between the load and the PV cell. The procedure of altering the PV array terminal voltage externally to abstract maximum power for different loads is known as Maximum Power Point Tracking (MPPT). Several techniques are can be used to perform this task as will be explained in a following section of the paper. The PV cell characteristics also be influenced by external factors including solar irradiation and temperature level to incorporate these effects into the model, two additional relations are used.

$$I_0 = I_{0r} \left[\frac{T}{Tr} \right]^3 \exp \left[\frac{qEg0}{Bk} \left(\frac{1}{Tr} - \frac{1}{T} \right) \right] \quad (5)$$

$$I_{ph} = [Iscr + k_i(T - 298)] \frac{S}{1000} \quad (6)$$

In the ideal PV Cell model, I_{ph} , I_0 , Rsh , and Rs are related to cells temperature and radiation intensity, and are not easy to be determined. This makes the engineering application very difficult. Manufacturers of PV arrays provide only a few experimental technical parameters such as open-circuit voltage V_{OC} , short-circuit current I_{SC} , the maximum power point voltage V_m , the maximum power point current I_m , and the maximum power point power P_m . Simplify, to match with the parameters, the ideal PV model provided by industry as below⁹.

From the common parameters like V_{OC} , I_{SC} , V_m , I_m , C_1 and C_2 can be calculated and the PV cell model can be created. The above model is created under temperate 25°C, 1000 W/m². Considering variable ambient temperature and solar radiation, the model can be adjusted as below –

$$T_c = T_a + t_c S \quad (7)$$

$$I = Isc \left\{ 1 - c_1 \left[\exp \left[\frac{v - \Delta v}{C_2 V_{OC}} \right] - 1 \right] \right\} + \Delta I \quad (8)$$

Where,

$$\Delta I = \alpha \frac{S}{S_{ref}} \Delta T + \left(\frac{S}{S_{ref}} - 1 \right) \cdot I_{sc}$$

$$\Delta V = -\beta \Delta T - R_s \Delta I$$

$$\Delta T = T_c - T_{ref}$$

Here, I and V are the output current and voltage of the PV cell, V_{OC} and I_{SC} are the open-circuit voltage and short-circuit current, S_{ref} and T_{ref} are the reference solar radiation and temperature, α and β are the temperature coefficient of the short-circuit current and open-circuit voltage, and R_s is the internal series resistance.

2. Modeling of MPPT Algorithm

2.1 Maximum Power Point Tracking (MPPT)

The Maximum Power Point Tracking (MPPT) controller draws maximum available power by forcing the PV module to operate at close to maximum power operation point. Power output from Solar PV module changes due to modifies in temperature and solar radiation. Maximum Power Point Tracker (MPPT) is used with a dc-dc converter (step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. The duty cycle of dc-dc converter is changed with the load impedance as well as the source is also modified and matched at the maximum point of power. The duty cycle of the converter is changed till the peak power point is achieved.

Consider, V_o is output voltage and V_i is input voltage, for a step down converter – $V_o = D \times V_i$

Where, D is the duty cycle. Solving for the Impedance transfer ratio –

$$R_o = D^2 \times R_i$$

$$R_i = R_o / D^2$$

The input resistance R_i is changes with respect to changes in duty cycle, where output resistance R_o remains

constant. So by changing the duty cycle the peak power point is obtained corresponding by the resistance⁶.

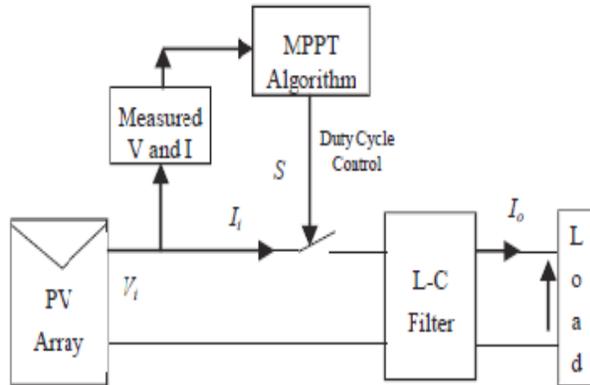


Figure 3. Block diagram of the MPPT algorithm along with the circuit.

2.1.1 Modeling of Perturb and Observe (P&O) Algorithm

We choose the modified Perturb and Observe (P&O) method for its simplicity, relatively accuracy and rapid response. Figure 4 shows the flowchart of P&O method. The new perturbation direction can be determined by comparing (before and after the perturbation) the PV cell output power for each control cycle. PV cell output power can get nearer to the maximum power point by small perturbation and the operating point becomes steady state. By comparing previous and current output power, new perturbation direction can be decided.

If, $\Delta P * \Delta V > 0$, the operating voltage should increase.

While, $\Delta P * \Delta V < 0$, the operating voltage should decrease. At, $\Delta P * \Delta V = 0$, the maximum power point.

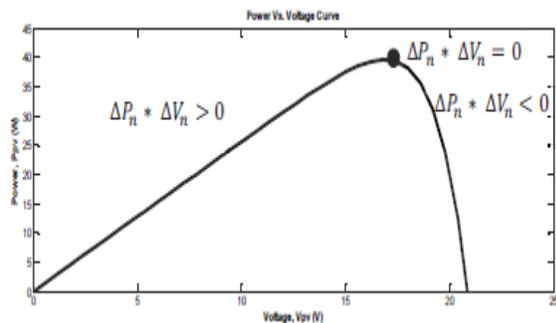


Figure 4. Power vs. voltage curve for perturb and observe method.

The operating voltage alteration has been done by adjusting a step size, ΔD (0.01) to the duty cycle D

of a DC-DC converter. The step size, ΔD and the time between iterations are the two parameters of this model. The smaller the P&O step size, the more accurate is the result and longer is the tracking time. In this paper we used the boost converter for the voltage changing. In our algorithm we reduced the perturbation if $\Delta P * \Delta V > 0$ and we increase the perturbation if $\Delta P * \Delta V < 0$ ¹⁰.

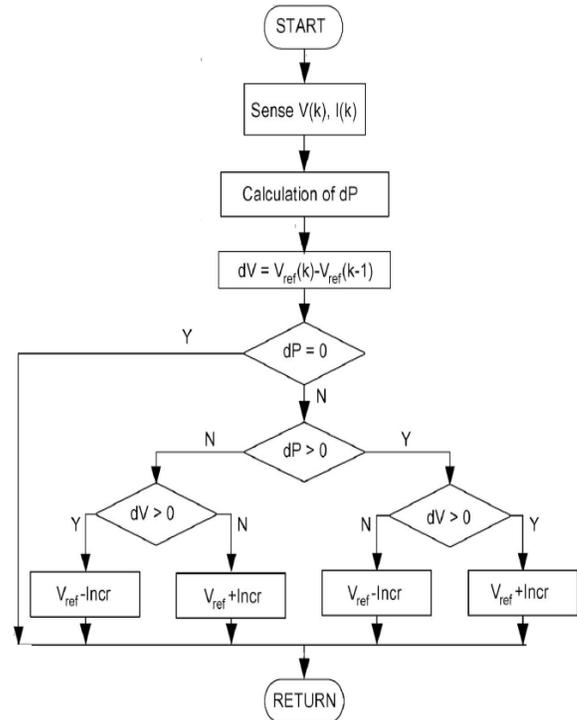


Figure 5. Flow chart for Perturb and Observe (P&O) method.

Below Figure shows the power outcomes by PO method.

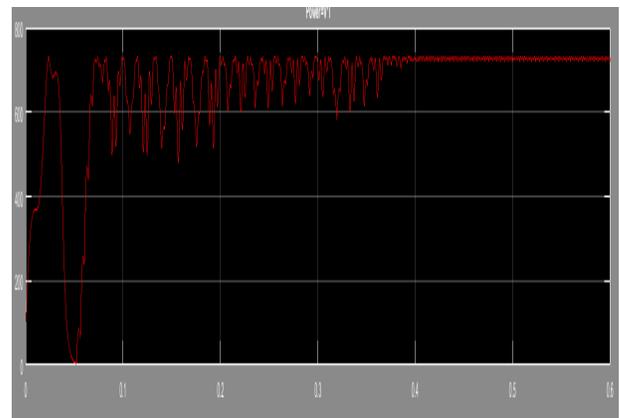


Figure 6. Perturb & Observe method based power observation.

2.2 GSAPSO Method of MPPT

In this method, GSA and PSO has been combined to get the better initial tracking and to achieve faster maximum power point^{11,12}. In this, duty cycle is the output of the algorithm which uses three different duty cycles in which central duty cycle is considered of the previous moment and other two taken as minimum deviated duty cycles in both negative and positive direction.

The objective function uses the ratio of powers to achieve better optimization of the required duty cycle. The change in power and duty cycle can be obtained using

$$d_{new} = d_{old} * Q1 \quad (9)$$

Here d_{old} is the previous duty cycle and Q1 is given by

$$Q1 = \frac{POWER(d_i^k)}{POWER(d_i^{k-1})} \quad (10)$$

The objective function is defined as

$$POWER(d_i^k) > POWER(d_i^{k-1}) \quad (11)$$

Below Figure shows power outcome by GSAPSO method

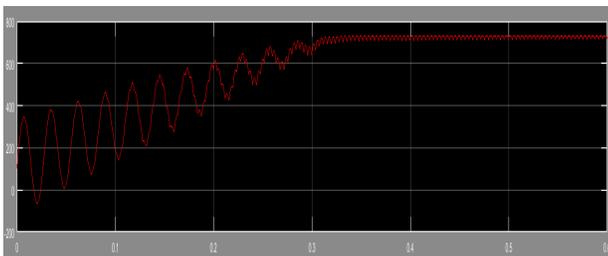


Figure 7. GSAPSO method based power observation.

3. Conclusion

This work proposes an improved Maximum Power Point Tracking (MPPT) method for the Photo-Voltaic (PV) system using a modified particle swarm optimization (PSO) algorithm and Gravitational Search Algorithm (GSA). The main benefit of the method is

the reduction of the steady state oscillation (to practically zero) once the Maximum Power Point (MPP) is located. Furthermore, the proposed method has the ability to track the MPP for the great environmental condition, e.g., large fluctuations of insolation and partial shading condition. The algorithm is simple and can be calculated very rapidly. To calculate the effectiveness of the proposed method, MATLAB simulations are carried out with perturb and observe method and with proposed method separately.

4. References

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