

Overview of Genetic Algorithm Technique for Maximum Power Point Tracking (MPPT) of Solar PV System

Alok Kumar
 M. Tech (Student)
 Solar & Alternative Energy
 Amity University, Haryana

Amit Kumar
 M. Tech (Student)
 Solar & Alternative Energy
 Amity University, Haryana

Ranjana Arora
 Assistant Professor
 Renewable Energy Deptt.
 Amity University, Haryana

ABSTRACT

The power generation capacity of solar photovoltaic systems (SPV) depends on input solar radiation (insolation) and ambient temperature. To improve the design efficiency of the system, maximum power point tracking (MPPT) techniques has to be utilized while installing SPV systems. A comparative analysis of three maximum power point tracking techniques for solar photovoltaic systems has been presented in this paper. Along with this, various advantages of using genetic algorithm (GA) as a MPPT approach for SPV systems has been projected. The proposed methods are taken from the literature from previous research articles to the earliest applied ones and it has been revealed that three distinct methods are implemented with number of variations. The present study can become a bench mark for designing of practical SPV systems with considerable improvement in efficiency.

General Terms

Genetic Algorithm, MPPT, P&O and Incremental Conductance

Keywords

Solar PV System, Open Circuit Voltage, Short Circuit Current.

1. INTRODUCTION

Due to rapidly developing economy, world today requires new sources of energy as conventional fuels are going to get vanished soon. Moreover the degradation and damage caused to the environment cannot be ignored now with the view of disturbed ecological balance. The main drawback of using renewable energy sources is low not upto the mark performance parameters. The attractiveness of using solar photovoltaic systems is increasing rapidly because of its well designed situation for existing distribution systems [1]. The power generated by SPV systems is dominated by operating voltage of module or an array. The performance improvement of SPV systems can be done by tracking the maximum power point for it. A PV maximum power point (MPP) varies with input solar insolation and temperature and P-V curve indicates a distinctive point at which it delivers maximum power with peak efficiency [2]. Consequently, many methods have been developed to determine MPP which varies in the level of effectiveness, cost, hardware realization and their complexity of application [3,4]. In the current study, the methods explained below are chosen for investigation as

-Perturb and Observe (P&O) [5]: In this scheme, for each value of voltage and current measurement of PV array, the voltage value is increased or decreased to move towards the maximum power point. Due to very good results obtained and less complexity involved this method has got much popularity. The problem with this method is time taken for

computation which eventually depends on initial conditions of the system and oscillations around the MPP.

Incremental conductance [6]: In this method the MPP of a SPV can be obtained by comparing incremental and instantaneous conductance ($\frac{I}{V}$ and $\frac{dI}{dV}$).

1. $\frac{dP}{dV} > 0$ or ($\frac{dI}{dV} > -\frac{I}{V}$) to the left of MPP
2. $\frac{dP}{dV} < 0$ or ($\frac{dI}{dV} < -\frac{I}{V}$) to the right of MPP
3. $\frac{dP}{dV} = 0$ or ($\frac{dI}{dV} = -\frac{I}{V}$) at the MPP

This method is very helpful in dealings for actual search in MPP in coherence with changing atmospheric conditions. But during its implementation we come across the basic problem of oscillations present around MPP as we are trying to achieve

$$\frac{dP}{dV} = 0$$

So some unwanted disturbance can move away the MPP. In this method a linear relationship between V_{oc} and maximum voltage point V_{mp} and between I_{sc} and current of maximum power I_{mp} is assumed.

$$V_{mp} = M_v V_{oc} \quad (1)$$

$$I_{mp} = M_c I_{sc} \quad (2)$$

Where M_c is the current factor and M_v is the voltage factor. This is a very simple method but actually the assumptions of linearity in eq.1 and eq.2 are not practically viable because of non-linearity of PV model influenced by input solar insolation and ambient temperature.

2. THE MODEL

The equivalent circuit of a single-diode SPV model is shown in Fig.(1) on which all three proposed MPPT techniques are applied. In Fig.1, where R_s and R_{sh} are respectively the shunt and series resistances of the cell, usually the value of R_{sh} is

very large and R_s is very small, hence they may be neglected. So characteristic equations of solar cell PV model can be written:

$$I = I_{ph} - I_{rs} \left(\exp\left(\frac{qV}{akT}\right) - 1 \right) \quad (3)$$

$$I = \left[\frac{\exp\left(\frac{V}{K_T}\right) - 1}{\exp\left(\frac{V_{oc}}{K_T}\right) - 1} \right] \quad (4)$$

Where, $K_T = \frac{kTa}{q}$ and

- I = Output current (A),
- V = Output voltage (V),
- I_{ph} = Cell photocurrent,
- I_{rs} = Cell reverse saturation current,
- q = The charge of an electron,
- k = Boltzmann's constant,
- a = P-N junction ideality factor,
- T = Cell temperature,
- V_{oc} = open circuit voltage,
- I_{sc} = short circuit current

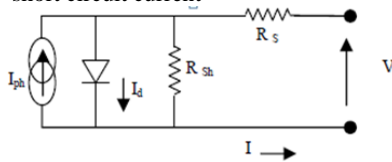


Fig 1: Equivalent circuit of Solar Cell

3. MPPT TECHNIQUES

3.1 Perturb and Observe:

In this method overall, perturbation in duty ratio of the power converter and in the operating voltage of the SPV array is done. As array is joined to a power converter, the role of perturbing a duty ratio changes the PV array current and as a output the PV array voltage. Fig.2, it can be visualized when operating on the left of the MPP, as voltage increases, power also rises and power decreases with the rise in voltage when on the right of the MPP. Therefore, if there is an increment in power, the succeeding perturbation should be kept constant to reach the MPP and if there is fall in power, the perturbation should be regressive. It is also shown that the selection occurs only once in each cycle, so the Algorithm used instantaneous (instead of Average) PV array voltage and current. The process is repeat in a same time until the MPP is reached. The system then revolves around the MPP. These revolutions can be minimized by reducing the perturbation step size. However, a minimal perturbation size slows down the MPPT. A solution to this incompatible situation is to have a changeable perturbation size that gets lesser towards the MPP as shown below.

A two-stage algorithm is proposed here that offers faster tracking in the first stage and finer tracking is done at the second stage. P&O methods can fail under rapidly changing atmospheric conditions. From fig.2, initiating from an operating point A, if atmospheric conditions remains stable, a perturbation ΔV in the PV voltage V will bring the operating point to B and the perturbation will be reversed as power decreases. However, if the irradiance increases and shifts the power curve from P_1 to P_2 within one sampling duration, the start point will move from A to C. This reflects that an increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the MPP and will keep diverging if the irradiance steadily increases. Here two sensors measure the PV array voltage and current, from which power is computed, but depending on the power converter topology, only a voltage sensor might be needed, the PV array current from the PV array voltage is

estimated, eliminating the need for a current sensor. DSP or microcomputer control is more suitable for hill climbing and P&O even though discrete analog and digital circuitry can be used as in programme.

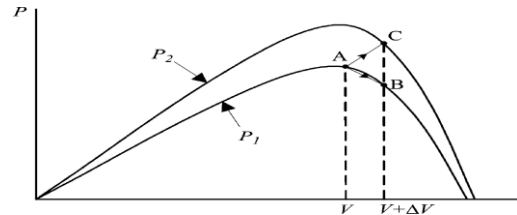


Fig 2: P&O technique for MPP

3.2 Incremental Conductance

The incremental conductance (Inc.Cond) [6], method is based on the fact that the gradient of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by

$$\frac{dP}{dV} > 0 \text{ or } \left(\frac{dI}{dV} > -\frac{I}{V} \right); \text{ left of MPP} \quad (5)$$

$$\frac{dP}{dV} < 0 \text{ or } \left(\frac{dI}{dV} < -\frac{I}{V} \right); \text{ right of MPP} \quad (6)$$

$$\frac{dP}{dV} = 0 \text{ or } \left(\frac{dI}{dV} = -\frac{I}{V} \right); \text{ at the MPP} \quad (7)$$

Since

$$\frac{dP}{dV} = -\frac{d(IV)}{dV} = I + \frac{VdI}{dV} \cong I + \frac{V\Delta I}{\Delta V} \quad (8)$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V}, \text{ to the left of MPP} \quad (9)$$

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V}, \text{ at MPP} \quad (10)$$

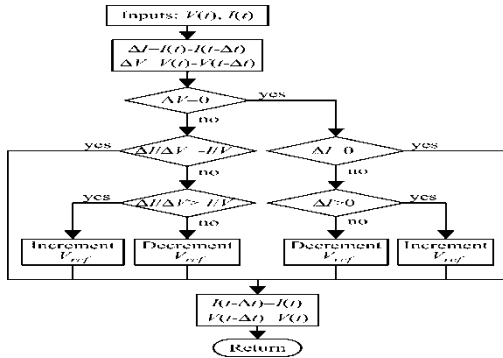
$$\frac{\Delta I}{\Delta V} < -\frac{I}{V}, \text{ to the right of MPP} \quad (11)$$

The comparison of instantaneous conductance (I/V) to the incremental conductance ($\Delta I/\Delta V$) helps in MPP tracking. A value of V_{ref} is taken as PV array where it is forced to work and it is equal to V_{MPP} . In this method once the MPP point is reached, the PV array is maintained at this MPP point until the change in ΔI is achieved. The algorithm increases or decreases the value of V_{ref} to obtain the new MPP. The increment or decrement determines steadily tracking of MPP. With large values of increments assure the fast tracking of system but the system might oscillate around MPP rather to operate near it. Here a method is proposed that brings the operating point of the PV array close to the MPP in a first stage and then uses incremental conductance to exactly track the MPP in a second stage. By appropriate control of the power converter, the initial operating point is set to catch a load resistance comparative to the ratio of the open-circuit voltage (V_{oc}) to the short-circuit current (I_{sc}) of the PV array. This two-stage alternative also ensures that the real MPP is tracked in case of multiple local maxima. A linear function is used to divide the $I-V$ plane into two areas, one containing all the possible MPPs under varying atmospheric conditions.

The operating point is brought into this area and then Inc.Cond is used to reach the MPP. A less obvious but effective way of operating the Inc Cond technique is to use the instantaneous conductance as

$$e = \frac{I}{V} + \frac{dI}{dV} \quad (12)$$

It can be evidently visualized from above equation that e goes to zero at the MPP. A simple proportional integral (PI) control can then be used to drive e to zero. Although two sensors instantaneously measures the instantaneous PV array voltage and current. Inc. cond method lends itself well to DSP and microcontroller control, which can easily keep track of previous values of voltage and current.



Flow chart for the implementation of incremental inductance method

3.3 MPPT of Solar PV system using Genetic Algorithm (GA)

Given below the optimization algorithm based on genetic algorithm [7,8] with various principle advantages:

1. In GA, codes of system parameters are being used for system modeling.
2. For optimization procedure of the system, we don't work with a point but with a population of points.
3. MPPT can be done by function values and we have not to calculate any other value existing in the system as shown in Fig.3

3.3.1 Procedure:

1. Initialization: We need to create a arbitrary population with N binary individuals, with a choice of the length (bits number S, precision). A population is a binary matrix where the number of lines represents the number of individuals and column number represents the length of individuals.
2. Evaluation: it is a very significant step because it gives the chance of an individual to be chosen, the appraisal is given by the value of individuals fitness function (it is a positive function and the individual is optimum for upper limit value of its fitness function), in our case the fitness function is simply the power $P=V*I$. With searching a maximum of a function the perturbation effect around MPP can be removed using this technique. The fitness function is $(f=P^2)$ and convergence of algorithm can be increased by this.
3. Genetic operations: They are the base of GA, they don't exclude probability theories but they give very interesting results, these operations are:
 - Selection: To select, with a rate T_{sel} , a part of population corresponding to the optimum fitness function.
 - Crossover: Cross pairs of individuals, with T_{rcm} probability, to get the novel individuals.
 - Mutation: After crossover, we apply a mutation, with P_m probability, to the new population.

- Insertion: The new population will be integrated to the old population to replace individuals with minimum fitness function.
- Program termination: Executing program creates new best individuals, the program terminates according to the required output of the system.

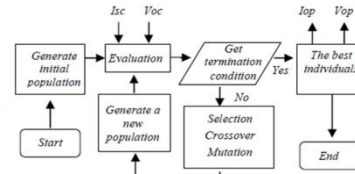


Fig 3: Steps of application of genetic algorithm

3.3.2 Comparison of Results:

The P&O algorithm can depart with rapid change in atmospheric conditions as the value of irradiance change, the position of MPP also get changed. P&O algorithm has got an inability to relate the change in the PV array power with varying temperature and irradiance. With the use of genetic algorithm based MPPT the system take action in a better way to input changes and no oscillations are there around MPP. Moreover here search of maximum fitness function as power is done with a population of points while confirming the stability of system output, which is not the case in Incremental conductance.

4. CONCLUSION:

The PV systems has increased its importance in the vast field of area of green and renewable energy, this paper introduces an efficient identification method for maximum power point function for photovoltaic modules using genetic algorithm. This paper has presented the comparative study of three maximum power point tracking techniques (MPPT) for Solar PV Systems and various benefits of using GA (Genetic Algorithm) over P&O technique and Incremental conductance. The detailed study of abovementioned techniques has been obtained from the literature available in previous research articles to the earliest applied ones. The different application conditions for MPP have been revealed in the current research article with their respective implementation variations. This study could serve as a convenient reference for the future work in SPV power generation with suitable MPP technique for good power output.

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6. REFERENCES

- [1] Femia, N., Spagnuolo, G., and Vitelli, M. 2005. Optimization of perturb and observe maximum power point tracking method, IEEE Trans. Power Electronics, Vol. 20 no. 4, pp. 963-973.
- [2] Hussein, K.H., Muta, I, Oshino, T., and Osakada, M.1995. Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions, IEE Proceedings Generation, Transmission and Distribution, Vol.142 no. 1, pp. 59-64.
- [3] Liu, F., Duan, S. ,Liu, B, and Kang, Y.2008. A variable step size INC MPPT method for PV systems, IEEE Trans. Industrial Electronics, Vol. 55 no. 7, pp. 2622-2628.

- [4] Masoum, M. A. S. and Dehbonei, H.,1998. Optimal power point tracking of photovoltaic System under Operating Conditions, 17th Congress of the World Energy Council, Houston, TX.
- [5] Houssamo, I. , Locment, F., Sechilariu, M.2010. Maximum power tracking for photovoltaic power system :Development and experimental comparison of two algorithms, Renewable Energy, Vol. 35 no. 10, pp 2381-2387.
- [6] Leyva, R.,Alonso, C., Queinnec, I., Lagrange, D. , Martinez-Salamero, L.2006. MPPT of photovoltaic systems using extremum-seeking control, IEEE Trans. Aerospace and Electronic Systems, Vol. 42 no. 1, pp. 249-258.
- [7] Liu, S. and Dougal, R. A.2002. Dynamic multiphysics model for solar array, IEEE Trans. Energy Conversion, Vol.17 no. 2, pp. 285-294.
- [8] Goldberg, D.1992. Genetic algorithm in Search, optimization and machine learning” , Addison-Wesley.