



Modeling of Maximum Solar Power Tracking by Genetic Algorithm Method

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Abstract

This paper, firstly presents a model of solar cell is built using MATLAB SIMULINK and P-V, I-V & P-I characteristics are studied for various values of irradiance & a constant temperature, And then used of Genetic Algorithm (GA) for maximum power point tracking (MPPT) of Photovoltaic (PV) system using the direct control method. The main objective of this paper is to find out that optimal angle, which is used for positional control of solar module for optimal power tracking and also the main contribution of the proposed scheme is the elimination of PI control loop which normally exists to manipulate the duty cycle. Simulation results indicate that proposed controller outperforms the others method for all type of environmental conditions. For efficient utilization of solar energy, the solar PV system must be able to track MPP and extract available maximum power in real-time. Thus, it becomes necessary to properly interface the PV module with a fixed load.

Keywords: Solar Cell, Maximum Power Point Tracking (MPPT), Genetic Algorithm Method (GA), Photovoltaic, MATLAB SIMULINK

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1. Introduction

The necessity of energy is heightening gradually. Now-a-days we mostly use the conventional energy sources like coal, natural gases, gasoline, fossil fuels, oil, nuclear energy etc. to meet this increasing demand. But these non-renewable resources are diminishing rapidly day after day. The rising energy demand and also the alarming depletion rate of the principal energy resources occasion increase the price of natural combustible energy resources. Moreover, the uninterrupted use of fossil fuels has affected drastically the environment diminishing the ecosphere and cumulatively summing to global warming. Hence we had to think about the renewable energy sources like Water, Sunlight, Wind, Tide, Biomass, Geothermal Heat etc. These sources are limitless, sustainable, regenerative and very clean. Out of different kind of renewable energy sources, we concentrate our discussion on solar energy in this paper. It is the most readily available and prominent source of energy with its huge consistency around the world. Solar energy is clean, non-polluting, incurring no fuel costs, needing fiddling maintenance, noiseless and sustainable source of

energy with an enhanced service life and eminent reliability. Our focus falls on solar PV systems in this paper. The purpose of this paper is to increase the efficiency of the PV systems through using Maximum Power Point Tracking (MPPT), by which the solar module can generate maximum amount of power at any time.

To obtain the maximum power, PV system is normally equipped with maximum power point (MPP) tracker in conjunction with the power converter. Many MPP tracking techniques have been proposed in recent years. Among these methods, hill climbing (HC) [1] and Perturbation and Observation (P&O) [2] are the most extensively used algorithms due to the simplicity and ease of implementation. HC is the perturbation in the duty cycle of the power converter, were as P&O method is the perturbation in the operating voltage of the PV array. A major drawback of P&O is that the system oscillates consistently around the MPP, which wastes a considerable amount of power from the PV source [3].

Another popular approach is the Incremental Conductance method. This works based on

incrementally comparing the ratio of derivative of conductance with the instantaneous conductance [3]. The increment size determines how fast the MPP is tracked. Fast tracking can be achieved with larger increments at the cost of accuracy. Furthermore oscillation around the MPP may still occur.

2. Modeling of Solar Cell

To model a single solar cell, we need a current, a diode and two resistors. As we use only one diode here, the model is known as a single diode model. This cell can generally be modeled by connecting the inverted diode in parallel with the current source. The diode has its own shunt and series resistance. Here the part of the cell including current source and the diode is assumed to be ideal. When the cell is subjected to sunlight, direct current is generated and it varies linearly with incoming solar radiation [1-7].

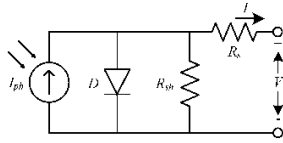


Fig. 1. Single Diode Model of a Solar Cell

A) Equations of Solar Cell

From the above circuit, the characteristics equation of single diode model of solar cell can be written as:

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Now, we know the DC current source as well as the photon generated current is actually the short circuit current but the solar irradiance has an effect on this. Thus it can be written in terms of irradiance, nominal irradiance and the short circuit current of the cell. So we can write:

$$I_{ph} = I_r \left(\frac{I_{sh}}{I_{ro}} \right) \quad (2)$$

Where, I_r is the actual Irradiation in Watts per square Meter and I_{ro} is the nominal Irradiation in Watts per square Meter and I_{sc} is the short Circuit Current in Amperes. Next we concentrate on the diode current. The diode equation is a non-linear mathematical equation which depends on many important factors. The equation can be written as:

$$I_d = I_s \left(e^{\frac{V_d}{a.k.T}} - 1 \right) \quad (3)$$

Where, I_s is diode reverse saturation current in Amperes, q is charge of an electron, k is Boltzmann's constant and T is cell temperature in kelvin. Now the voltage across the diode can be written in terms of output voltage & current, series resistance and the ideality factor of the diode. The equation is as follow:

$$IV_d = V + IR_{se} \quad (4)$$

Here a is the Diode Ideality Factor which is generally assumed as 1.2. This time, the value of the reverse saturation current is we can find out with the help of the a few important factors. The expression is as follows:

$$I_s = I_{sc} / \left(e^{\frac{V_{oc}}{a.k.T}} - 1 \right) \quad (5)$$

Here V_{oc} is the Open Circuit Voltage of the cell. Thereafter we focus on the current through the shunt resistance. The expression of this current is very simple and can be written in terms of output voltage & current of the solar cell and the shunt & series resistance. The expression is:

$$I_{sh} = (V + IR_{se}) / R_{sh} \quad (6)$$

So, we can now write the full expression of the output current of the cell using all the sub-equations as following:

$$I = \left[I_r \left(\frac{I_{sc}}{I_{ro}} \right) \right] - \left\{ \frac{I_{sc}}{e^{\frac{V_{oc}}{a.k.T}} - 1} \right\} \cdot \left\{ \left(e^{\frac{V+IR_{se}}{a.k.T}} - 1 \right) \right\} - \left[\frac{V+I.R_{se}}{R_{sh}} \right] \quad (7)$$

Here if we put the constant values of k , q & a as mentioned earlier, the expression can be rewritten as:

$$I = \left[I_r \left(\frac{I_{sc}}{I_{ro}} \right) \right] - \left\{ \left(\frac{I_{sc}}{e^{1.034 \cdot 10^{-4} T} - 1} \right) \cdot \left\{ \left(e^{\frac{V+I.R_{se}}{1.034 \cdot 10^{-4} T}} - 1 \right) \right\} \right\} - \left[\frac{V+I.R_{se}}{R_{sh}} \right] \quad (8)$$

We now express the above equation using MATLAB SIMULINK blocks. All the simulation work in this paper be done using MATLAB SIMULINK 7.10 with their toolboxes.

To study the P-V, V-I & P-I characteristics at variable irradiance through our model, we take the KD 240GH P series module, in which 60 cells are connected in series. The table 1 shown below [8] gives the datasheet parameters for the module KD 240GH P series at irradiance 1000W/m² & Temperature 25°C. A repeating sequence is taken as a voltage source, temperature is kept constant at 25°C and irradiance is varied between 100 watts per square meter to 1000 watts per square meters by 10 steps. Simulink model of solar cell is shown in fig 2.

We see the effects of varying solar irradiation in the P-V, I-V & P-I curves shown in figure 3 to 5. In each case we study that with increase of the irradiation, the parameters of y-axis of all the curves increase. The maximum power point also increases with the increase in solar irradiation. As the irradiation increases, more sunlight incidents into

the solar cell and the electrons are supplied with more excitation energy and the mobility of electrons is increased. That causes more amount of power generation for a same value of voltage. we can see that initially the value of y-axis parameter increases, but after a certain point, it decreases. On that certain point, the value of power, voltage or current is maximum and that point is called the maximum power point. The Maximum Power Point Tracking (MPPT) algorithms are designed to increase the efficiency of the PV systems. The main function of MPPT is to sample the output of the cells and apply the proper load to obtain the maximum power for any given location, time, season and environmental conditions. The MPPT not only enables an increment in the power delivered from the PV module to the load, but also enhances the operating lifetime of the PV systems. Various popular MPPT algorithms are available but in this paper we utilize the Genetic Algorithm method. In order to we can compare result of our purpose method with result of other methods [9,10], in simulation we used of the MSX-60 PV MODULE at 25° C,A.M1.5, 1000 w/m². Table 2 shows the parameter of the PV module.

Table.1.

Datasheet parameters for kd 240ghp series module

Data sheet parameter for KD240GH		
Irradiance	(W/m ²)	1000
Maximum Power	(W)	240
Maximum Power Voltage (V _{mpp})	(V)	29.8
Maximum Power Current (I _{mpp})	(A)	8.06A
Open Circuit Voltage (V _{OC})	(V)	36.9V
Short Circuit Current (I _{sc})	(A)	8.59A
Temperature Coefficient of V _{OC}	(%/K)	-0.36
Temperature Coefficient of I _{sc}	(%/K)	0.06
No of cell in series (N _s)		60

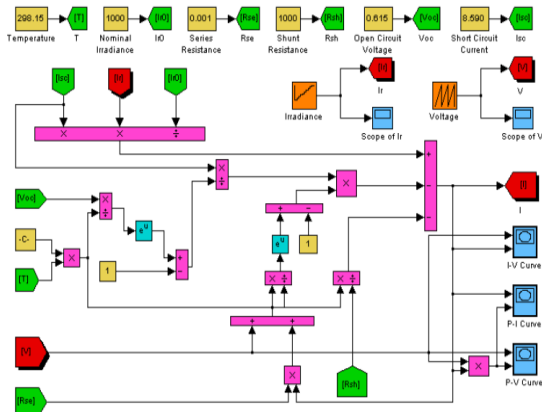


Fig. 2. SIMULNK Model of Solar Cell

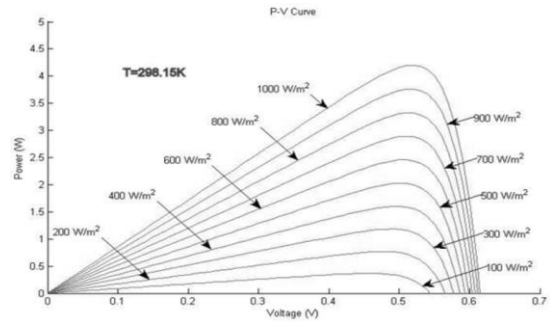


Fig. 3. P-V Curve

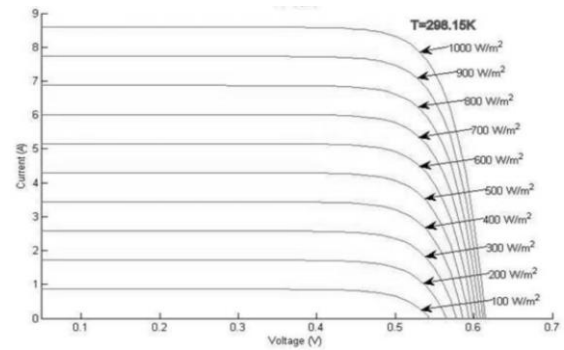


Fig. 4. I-V Curve

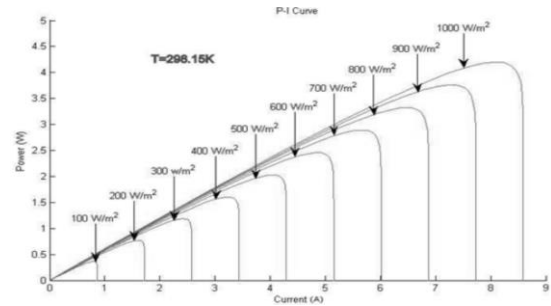


Fig. 5. P-I Curve

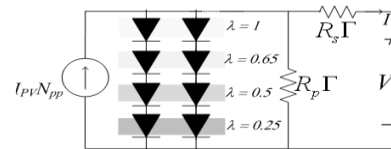


Fig. 6. A PV array illustration for the partial shading condition

Table.2.

Parameters of the msx-60 pv module

Peak Power(W), P _{mpp}	60
Peak power voltage(V), V _{mpp}	17.1
Peak power current(A), I _{mpp}	3.5
Open circuit voltage(V), V _{OC}	21.1
Short circuit current(A), I _{sc}	3.8
Temperature coefficient of current (mA/°C), K _i	0.003
Temperature coefficient of voltage (mV/°C), K _V	-0.08
Number of series cells, N _s	36

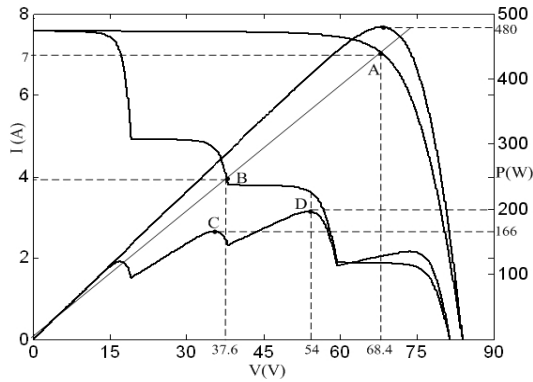


Fig. 7. I-V and P-V curves for the shading pattern of Fig. 6

It is clearly shown, in shadowing condition that described in before, if modules have not MPPT system, power level decries from 480w to 100w. But if we used a good method of MPPT, we can receive 200w from array (Global maximum of power, point D in curves). But if we used conventional MPPT method, perhaps it finds a local maximum of power (point C in curves), that has power 166w. In this paper we used Genetic Algorithm to MPPT.

3. Overview Of Genetic Algorithm (Ga)

GA has been used for optimizing the parameters of the control system that are complex and difficult to solve by conventional optimization methods. GA maintains a set of candidate solutions called population and repeatedly modifies them. At each step, the GA selects individuals from the current population to be parents and uses them to produce the children for the next generation. Candidate solutions are usually represented as strings of fixed length, called chromosomes. A fitness or objective function is used to reflect the goodness of each member of the population. Given a random initial population, GA operates in cycles called generations, as follows:

Each member of the population is evaluated using a fitness function. The population undergoes reproduction in a number of iterations. One or more parents are chosen stochastically, but strings with higher fitness values have higher probability of contributing an offspring. Genetic operators, such as

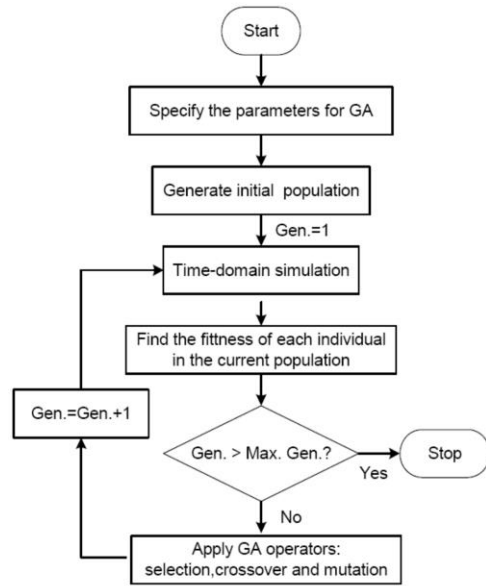


Fig. 8. Flowchart of the genetic algorithm

crossover and mutation, are applied to parents to produce offspring. The offspring are inserted into the population and the process is repeated. The computational flow chart of the GA optimization approach followed in the present paper is shown in Fig. 8.

4. Application of Ga Optimization Technique

In this paper, in order to receive maximum power of PV panels, firstly we used GA to find the MPP (find operating point) and then to find optimal angle of panels in during day, proportional with position of sun in sky. The MATLAB/SIMULINK model of the example solar cell shown in Fig. 2 is developed using equations (1)–(8). The developed MATLAB/SIMULINK model of a PV array with MPPT controller and buck-boost converter is shown in Fig. 9.

Fig. 9 shows the PV system used in this work, in which the simulation of a PV system involving a buck-boost DC-DC converter (with a MPPT controller). The PV modules are MSX60 configured in a 4x2 array. The buck-boost converter is selected due to the availability of wide input window. Moreover, it satisfactorily follows the PV array’s MPP at all times, regardless of the cell temperature, the solar insolation, and the connected load [11].

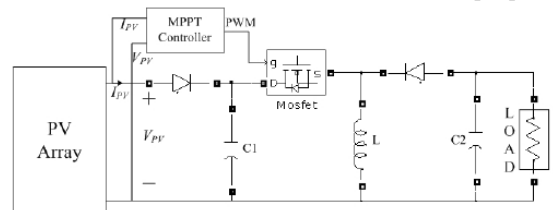


Fig. 9. PV system with buck-boost converter

The converter is design in continuous current mode with the following specifications: $C_1 = 470 \mu\text{F}$, $C_2 = 220 \mu\text{F}$, $L = 1.5 \text{ mH}$, and 20-kHz switching frequency.

Three types of environmental conditions are conducted. In the first condition, the PV array receives the uniform insolation of $\beta=1$ (Fig. 6) before it is changes to partially shaded condition. After, a step change of uniform insolation ($\beta=1$) is applied to PV array. In the second condition start shadow, the I-V and P-V curves change the shape as the environment changes from uniform insolation to partially shaded condition. Consequently, the operating point shifts from A to B, as shown in Fig. 7. In other words, Program started with initial population (initial solution). These solutions consist of purpose amount for variables d and α . d is variable that control operating rat of converter, Thereupon control the operating point. And α is the angle of panel from east toward west. In order to find optimal angle before run the program, we should set the o'clock in input data. In next step should initial solution evaluation to given the fitness of candidate solution. The objective function is evaluated for each individual by simulating the system dynamic model considering purpose mount for α and d .

The objective function is the output power of module. The range of d is between 0.01-0.99 and α is between 0-180o. Then apply other step of GA operators, consist of selection, crossover and mutation. In order to preservation best member, Mutation not operate on this member.

Good solutions are selected, and by means of the GA operators, new and better solutions are achieved. This procedure continues until a desired termination criterion is achieved. Although the chances of GA giving a local optimal solution are very few, sometimes getting a suboptimal solution is also possible. While applying GA, a number of parameters are required to be specified. An appropriate choice of these parameters affects the speed of convergence of the algorithm. For different problems, it is possible that the same parameters for GA do not give the best solution, and so these can be changed according to the situation. For the very first execution of the program, a wider solution space can be given and after getting the solution one can shorten the solution space nearer to the values obtained in the previous iteration. Optimization is terminated by the pre specified number of generations. The best individual of the final generation is the solution. For the third environmental condition, similar to condition 1, the PV array receives the uniform insolation.

5. Simulation Results

In order to show the effectiveness of the proposed model of PV system with MPPT simultaneous tuning the controller parameters in the way presented in this paper. To evaluate the performance of the proposed simultaneous design approach the response with the proposed d are compared with the response without MPPT. The response without the MPPT (no control) is shown with solid line with legend N.MPPT (Fig 10), The responses with MPPT (with GA) is shown with legend W.MPPT with dotted line(Fig 11). It is clear, That the power of panel with MPPT increase.

6. Conclusion

In this paper, a Genetic Algorithm (GA) with the capability of control direct duty cycle is used to track the maximum power point of PV system. Also this algorithm used to find best angle of modules to receive maximum power. A PV system, designed in MATLAB Simulink was used for the validation, in which a dc-dc buck-boost converter was used as a MPP tracker. The performance of proposed controller is compared with conventional HC method. Results reveal that proposed method totally outperforms that HC method in terms of tracking speed and steady state oscillations.

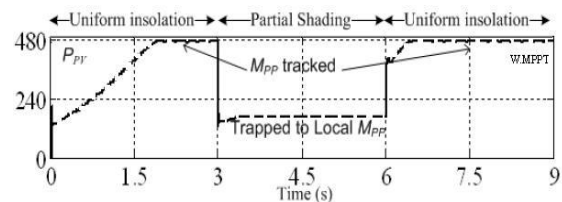


Fig. 10. Tracking power point with HC method

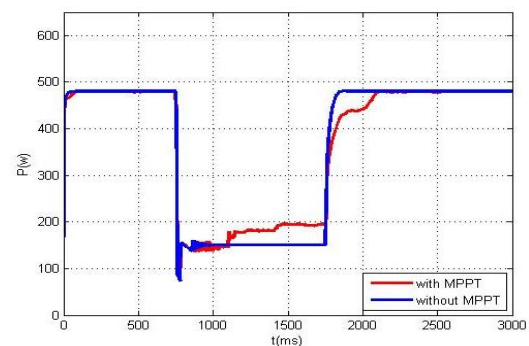


Fig. 11. Tracking power point with proposed algorithm.

References

- [1]. M. G. Villalva, J. R. Gazoli and E. Ruppert F, "Comprehensive approach to modeling and simulation of photovoltaic arrays", IEEE Transactions on Power Electronics, 2009, vol. 25, no. 5, pp. 1198--1208, ISSN 0885-8993.
- [2]. M. G. Villalva, J. R. Gazoli and E. Ruppert F, "Modeling and circuit-based simulation of photovoltaic arrays",

- Brazilian Journal of Power Electronics, 2009, vol. 14, no. 1, pp. 35–45, ISSN 1414-8862.
- [3]. R. Sridhar, Dr. Jeevananathan, N. Thamizh Selvan and Saikat Banerjee, "Modeling of PV array and performance enhancement by MPPT algorithm", *International Journal of Computer Applications*, September 2010, vol. 7, no. 5, pp. 975–8887.
- [4]. Huan-Liang Tsai, Ci-Siang Tu, and Yi-Jie Su, "Development of generalized photovoltaic model using MATLAB/SIMULINK", *Proceedings of the World Congress on Engineering and Computer Science (WCECS)*, October 22-24, 2008, San Francisco, USA.
- [5]. P. S. Revankar, W. Z. Gandhare and A. G. Thosar, "Maximum power point tracking for PV systems using MATLAB/SIMULINK", *Government College of Engineering, Aurangabad, Second International Conference on Machine Learning and Computing*, 2010.
- [6]. Ramos Hernanz, J. A., Campayo Martín, J. J. Zamora Belver, I. Larrañaga Lesaka, J. Zulueta Guerrero, E. Puelles Pérez, "Modeling of photovoltaic module", *International Conference on Renewable Energies and Power Quality (ICREPQ)*, March 23-25, 2010, Granada, Spain.
- [7]. I. H. Altas and A.M. Sharaf, "A photovoltaic array simulation model for MATLAB/SIMULINK GUI Environment", *International Conference on Clean Electrical Power (ICCEP)*, 2007, pp. 341–345.
- [8]. Ayan Kumar Tudu, Prof. Dr. Subrata Paul and Dr. Sunita Halder, "Study of MPPT algorithms for PV systems", *Department of Electrical Engineering, Jadavpur University*, unpublished.
- [9]. K. H. Hussein, I. Muta, T. Hoshino and M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions", *IEEE Proceedings of the Generation Transmission Distribution*, 1995, vol. 142, no. 1, pp. 59–64.
- [10]. A. Brambilla, M. Gambarara, A. Garutti and F. Ronchi, "New approach to photovoltaic arrays maximum power point tracking", *30th Annual IEEE Power Electronic Special Conference*, 1999, pp. 632–637.
- [11]. D. P. Hohm and M. E. Ropp, "Comparative study of maximum power point tracking algorithms; progress in photovoltaic: research and applications", 2003, pp. 47–62.