



Modeling of Maximum Solar Power Tracking by Genetic Algorithm Method

M. Jamiati*

Department of Physics, Naragh Branch, Islamic Azad University, Naragh, Iran

PAPER INFO

Paper history:

Received 26 February 2021

Accepted in revised form 27 March 2021

Keywords:

Genetic algorithm method

MATLAB SIMULINK

Maximum power point tracking

Photovoltaic

Solar cell

ABSTRACT

This paper presents a model of solar cell by using MATLAB SIMULINK. P-V, I-V and P-I characteristics were studied for various values of irradiance at constant temperature. Genetic Algorithm (GA) was used 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 the optimal angle, which is used for the positional control of solar module and optimal power tracking. The principle of GAs is searching for the maximum of fitness function and not for the minimum of power derivation; this gives more stability and minimize oscillation of output power around the maximum power point (MPP). 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 the proposed controller outperforms the others method for all type of environmental conditions.

doi: 10.5829/ijee.2021.12.02.03

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 rapidly diminishing 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 ecosystem 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, the sun is an endless source of energy that can easily be converted into other types of energy such as thermal, electrical and chemical [1].

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. Photovoltaic technology is the science of converting sunlight into electricity [2]. Therefore, this is conditional in many countries putting in place stimulating schemes to help solar energy in the next decades so that investment costs to be reduced [3].

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) [4] and Perturbation and Observation (P&O) [5] 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, whereas 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

*Corresponding Author Email: drmjamiati@gmail.com (M. Jamiati)

MPP, which wastes a considerable amount of power from the PV source. Another popular approach is the Incremental Conductance method. This works based on incrementally comparing the ratio of derivative of conductance with the instantaneous conductance. 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 [4–7].

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. Figure 1 shows an electrical circuit for the single diode model of a solar cell [4, 5].

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

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

where, I is Output current of the PV Cell. I_{ph} is Current of the DC Current Source i.e. the Photon generated current. I_d is Diode Current. I_{sh} is Current through the Shunt Resistance.

We know the DC current source as well as the photon generated current is actually the short circuit current but the solar irradiation 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:

$$I_{ph} = I_r (I_{sc} / I_{r0}) \tag{2}$$

where, I_r is Actual Irradiation in Watts per square Meter, I_{r0} is Nominal Irradiation in Watts per square Meter and I_{sc} is 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 Equation (3).

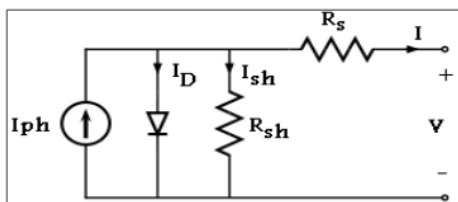


Figure 1. Single-diode model of the theoretical photovoltaic cell [5]

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

where, I_s is the reverse saturation or leakage current of the diode, q is the electron charge [$1.60217646 \times 10^{-19}$ C], k is the Boltzmann constant [$1.3806503 \times 10^{-23}$ J/K], T [K] is the temperature of the p-n junction, and a is the diode ideality constant which is generally assumed as 1.2.

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 stated as follows:

$$V_d = V + I R_{se} \tag{4}$$

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:

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

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 and current of the solar cell and the shunt and series resistance. The expression is:

$$I_{sh} = (V + I R_{se}) / R_{sh} \tag{6}$$

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

$$I = \left[I_r \left(\frac{I_{sc}}{I_{r0}} \right) - \left[\frac{I_{sc}}{e^{\frac{q(V + I R_{se})}{a.k.T}} - 1} \right] \cdot \left\{ \left(e^{\frac{V + I R_{se}}{a.k.T}} - 1 \right) \right\} \right] - \left[\frac{V + I R_{se}}{R_{sh}} \right] \tag{7}$$

Here if we put the constant values of k , q and a as mentioned earlier, the expression can be re-written as:

$$I = \left[I_r \left(\frac{I_{sc}}{I_{r0}} \right) - \left[\frac{I_{sc}}{\left\{ e^{1.034 \cdot 10^{-4} T} - 1 \right\}} \right] \cdot \left\{ \left(e^{\frac{V + I R_{se}}{1.034 \cdot 10^{-4} T}} - 1 \right) \right\} \right] - \left[\frac{V + I R_{se}}{R_{sh}} \right] \tag{8}$$

We now express the above equation using MATLAB SIMULINK blocks. All the simulation work in this paper was performed using MATLAB SIMULINK 7.10 with their toolboxes. To study the P-V, V-I and 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. Table 1 summarized which gives the datasheet parameters for the module KD 240GH P series at irradiance 1000 W/m^2 & Temperature at 25°C [8]. A repeating sequence is taken as a voltage source, temperature and is kept constant at 25°C and irradiance is varied between $100 \text{ Watts per square meter}$ to $1000 \text{ Watts per square meters}$ by 10 steps.

Table 1. Datasheet parameters for KD 240GHP series module [8]

Data Sheet Parameter for KD240GH	
Irradiance	1000
Maximum Power (w)	240
Maximum Power Voltage (V_{mpp}) (V)	29.8
Maximum Power Current (I_{mpp}) (A)	8.06
Open Circuit Voltage (V_{oc}) (V)	36.9
Short Circuit Current (I_{sc}) (A)	8.59
Temperature Coefficient of V_{oc} (%K)	-0.36
Temperature Coefficient of I_{sc} (%K)	0.06
No of Cell in Series (N_s)	60

SIMULINK MODEL OF SOLAR CELL

The MATLAB SIMULINK model of a single solar cell is shown in Figure 2.

CHARACTERISTIC CURVES

We see the effects of varying solar irradiation in the P-V, I-V and P-I curves shown below. In each case we study that with an increase in the irradiation, the parameters of y-axis of all the curves increased. The maximum power point also increases with an increase in solar irradiation. As the irradiation increases, more sunlight incidents into the solar cell and the electrons are supplied with more

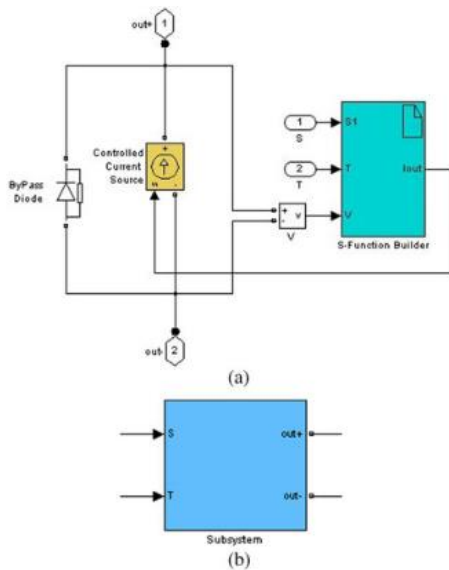


Figure 2. PV module model in MATLAB-Simulink. (a) Block diagram of the PV module model. (b) PV module model in a subsystem [9]

excitation energy and the mobility of electrons is increased. That causes additional amount of power generation for the same value of voltage. Figure 3 illustrates the power generation with respect to voltage and power flux (W/m^2) for the PV panel. There are maximum power generation at certain value of the voltage while increasing the power flux. Figure 4 depicts power with respect to voltage while Figure 5 shows power generation with respect to electrical current.

MAXIMUM POWER POINT

Tracking

In all the curves shown above we see that initially the value of y-axis parameter increases, but after a certain

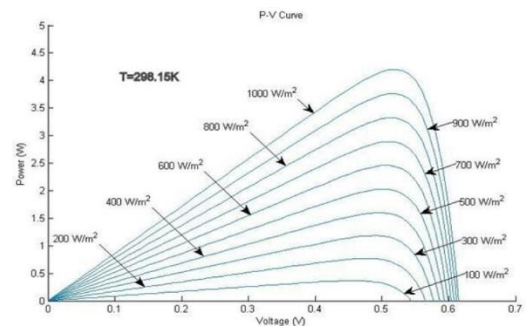


Figure 3. Simulation and measurement P-V curves

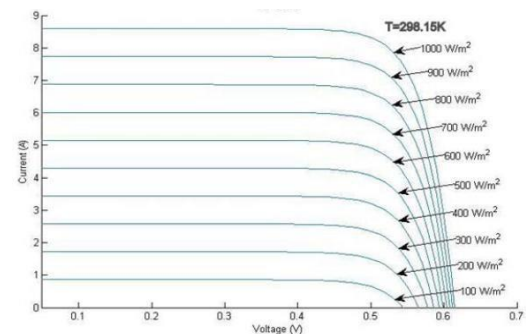


Figure 4. Simulation and measurement I-V curves

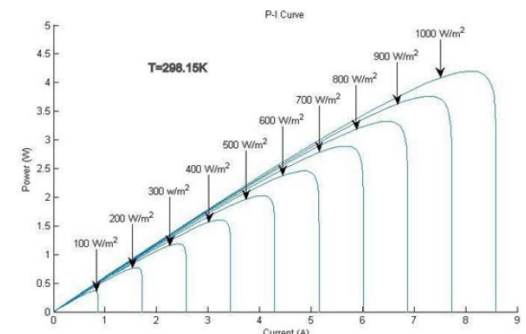


Figure 5. Simulation and measurement P-I curves

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 [10, 11], in simulation we used of the MSX-60 PV MODULE at 25°C, A.M1.5, 1000 w/m². Table 2 summarized the parameter of the PV module.

We know that, partial shading condition significantly changes the characteristics of a PV array. Figure 6 shows a typical partial shading condition. In this example, three shading patterns, i.e. $\lambda=1$, $\lambda=0.65$, $\lambda=0.5$ and $\lambda=0.25$ are applied to the PV array. Figure 7 shows the resulting I V and P V curves for the shading pattern demonstrated in Figure 6 for constant $\lambda=1$.

It is clearly shown that in shading condition that described in before, if modules have not MPPT system,

Table 2. Parameters of the msx-60 pv module at 25 °C, a.m1.5, 1000 w/m²

Data Sheet Parameter for KD240GH	
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

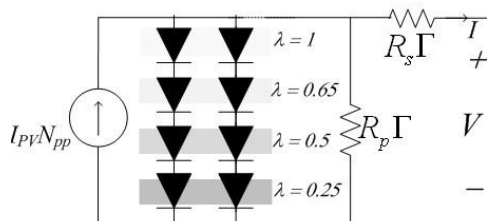


Figure 6. A PV array illustration for the partial shading condition

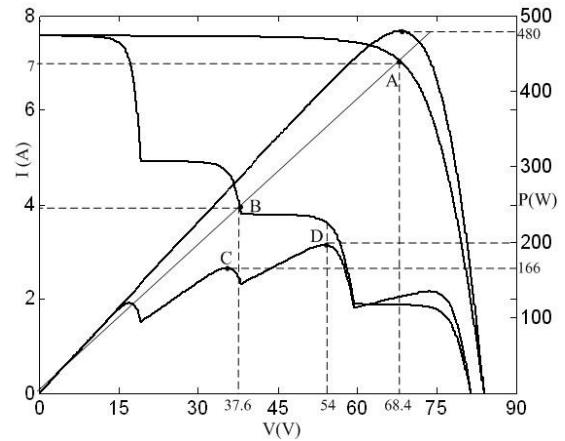


Figure 7. I-V and P-V curves for the shading pattern of Figure 6 and $\lambda=1$

power level decreases 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.

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 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 Figure 8.

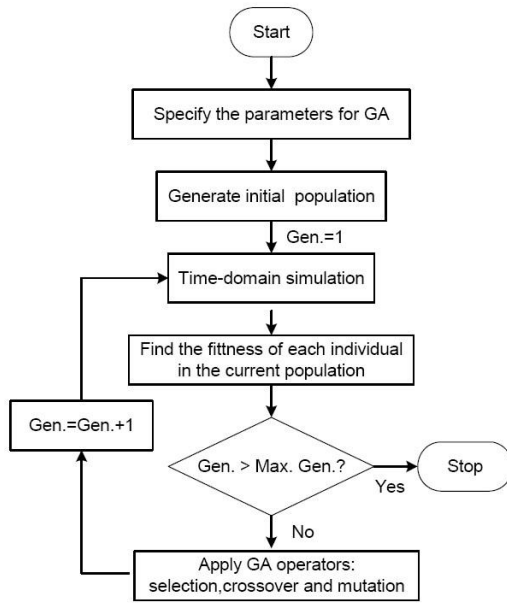


Figure 8. Flowchart of the genetic algorithm

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 Figure 2 is developed using Equations (1) to (8). The developed MATLAB/SIMULINK model of a PV array with MPPT controller and buck-boost converter is shown in Figure 9.

Figure 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 4×2 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 [12]. The converter is design in continuous current mode with the following specifications: $C1 = 470 \mu\text{F}$, $C2 = 220 \mu\text{F}$, $L = 1.5 \text{ mH}$, and 20-kHz switching frequency.

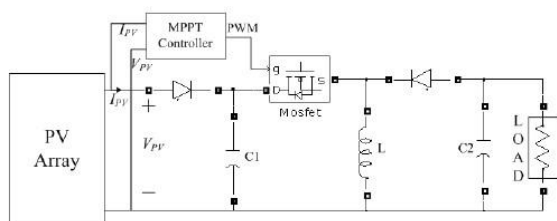


Figure 9. PV system with buck-boost converter

Three types of environmental conditions are conducted. In the first condition, the PV array receives the uniform insolation of $\lambda=1$ (Figure 6) before it is changes to partially shaded condition. After, a step change of uniform insolation ($\lambda=1$) is applied to PV array.

In the second condition starts 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 Figure 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 0-180°. 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 ($\lambda=1$).

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 compared with the response without MPPT. The response without the MPPT (no control) is shown with solid line with legend N. MPPT (Figure 10), The responses with MPPT (with GA) is shown with legend W. MPPT with dotted line (Figure 11). It is clear, that the power of panel with MPPT increased.

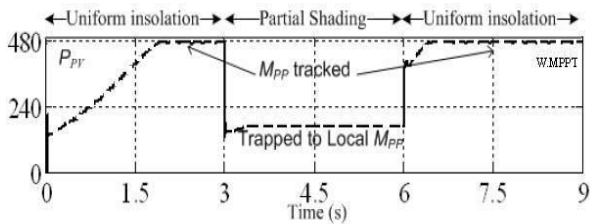


Figure 10. Tracking power point with HC method

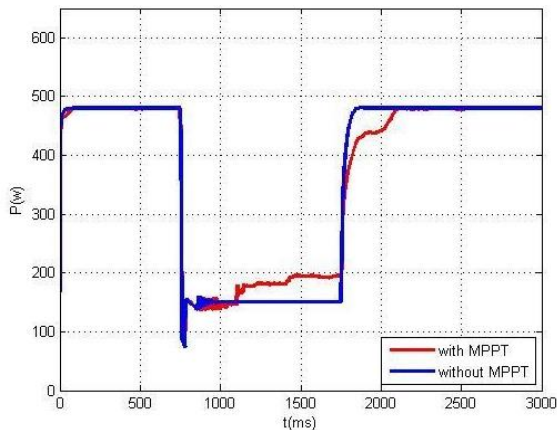


Figure 11. Tracking power point with proposed algorithm

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 the proposed method totally outperforms that HC method in terms of tracking speed and steady state oscillations.

REFERENCES

1. Mirzaei Darian, M. M., Ghorreshi, A. M., and Hajatzadeh, M. J. 2020. "Evaluation of Photovoltaic System Performance: A Case Study in East Azerbaijan, Iran." *Iranian (Iranica) Journal of Energy and Environment*, 11(1), pp.75–78. <https://doi.org/10.5829/IJEE.2020.11.01.12>
2. Firoozzadeh, M., Shiravi, A., and Shafiee, M. 2020. "Evaluation of Photovoltaic System Performance: A Case Study in East Azerbaijan, Iran." *Iranian (Iranica) Journal of Energy and Environment*, 11(1), pp.80–84. <https://doi.org/10.5829/IJEE.2020.11.01.12>
3. Masoudi Nejad, R. 2015. "A survey on performance of photovoltaic systems in Iran." *Iranian (Iranica) Journal of Energy and Environment*, 6(2), pp.77–85. <https://doi.org/10.5829/IJEE.2015.06.02.01>
4. Villalva, M. G., Gazoli, J. R., and Filho, E. R. 2009. "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays." *IEEE Transactions on Power Electronics*, 24(5), pp.1198–1208. <https://doi.org/10.1109/TPEL.2009.2013862>
5. Villalva, M. G., Espindola, M. F., Siqueira, T. G. de, and Ruppert, E. 2011. "Modeling and control of a three-phase isolated grid-connected converter for photovoltaic applications." *Sba: Controle & Automação Sociedade Brasileira de Automatica*, 22(3), pp.215–228. <https://doi.org/10.1590/S0103-17592011000300001>
6. Arora, S., and Sharma, P. 2014. "Modelling & Simulation of Photovoltaic System to Optimize the Power Output Using DC-DC Converter." *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 3(7), pp.10860–10867. <https://doi.org/10.15662/ijareeie.2014.0307036>
7. Al-Shadidi, Z. A. A. 2020. "The Effect of Environmental Factors (Temperatures & Humidity) on the Solar Cell Performance / Matlab Model." *International Journal of Applied Mathematics and Theoretical Physics*, 6(4), pp.61–67. <https://doi.org/10.11648/j.ijamtp.20200604.12>
8. Saha, N., Manna, B., and Palit, D. 2014. "Modeling of Maximum Solar Power Tracking using servomotor by incremental conductance method." In 2014 Annual IEEE India Conference (INDICON), IEEE, pp. 1–6. <https://doi.org/10.1109/INDICON.2014.7030565>
9. Ding, K., Bian, X., Liu, H., and Peng, T. 2012. "A MATLAB-Simulink-Based PV Module Model and Its Application Under Conditions of Nonuniform Irradiance." *IEEE Transactions on Energy Conversion*, 27(4), pp.864–872. <https://doi.org/10.1109/TEC.2012.2216529>
10. Farhat, S., Alaoui, R., Kahaji, A., Bouhouch, L., and Ihlal, A. 2015. "P&O and Incremental Conductance MPPT Implementation." *International Review of Electrical Engineering (IREE)*, 10(1), pp.116. <https://doi.org/10.15866/iree.v10i1.4865>
11. Brambilla, A., Gambarara, M., Garutti, A., and Ronchi, F. 1999. "New approach to photovoltaic arrays maximum power point tracking." In 30th Annual IEEE Power Electronics Specialists Conference, (Vol. 2) IEEE, pp. 632–637. <https://doi.org/10.1109/PESC.1999.785575>
12. Hohm, D. P., and Ropp, M. E. 2003. "Comparative study of maximum power point tracking algorithms." *Progress in Photovoltaics: Research and Applications*, 11(1), pp.47–62. <https://doi.org/10.1002/pp.459>

COPYRIGHTS

©2021 The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers.



Persian Abstract

چکیده

در این مقاله یک سلول خورشیدی در محیط سیمولینک برنامه متلب مدل سازی شده است. مشخصه‌های I-V، P-V و P-I برای مقادیر مختلف تابش در دمای ثابت مورد بررسی قرار گرفت. جهت ردیابی نقطه توان ماکزیمم (MPPT) در سیستم فتوولتایی (PV) از الگوریتم ژنتیک (GA) با استفاده از روش کنترل مستقیم استفاده شده است. هدف اصلی این مقاله، یافتن زاویه بهینه‌ای است که برای کنترل موقعیت ماژول خورشیدی جهت ردیابی نقطه توان ماکزیمم مورد استفاده قرار می‌گیرد. اساس الگوریتم‌های ژنتیک، جستجو برای حداکثر عملکرد تابع تناسب است نه حداقل توان خروجی، این باعث پایداری بیشتر و به حداقل رساندن نوسانات توان خروجی در اطراف نقطه توان ماکزیمم (MPP) می‌شود. مزیت اصلی روش پیشنهادی حذف حلقه کنترلی PI است که به طور معمول برای کنترل چرخه کار مورد استفاده است. نتایج شبیه‌سازی نشان می‌دهد که روش کنترلی پیشنهادی برای شرایط محیطی مختلف نسبت به سایر روش‌ها بهتر عمل می‌کند.
