Journal of Robotics and Control (JRC)
Volume 2, Issue 1, January 2021
ISSN: 2715-5072 DOI: 10.18196/jrc.2149

Modeling and Optimization Maximum power point tracking using GA for PV system

Reza Alayi[1*], Hossein Harasii[2], Hamed Pourderogar[2],
[1]Department of mechanics, Germi branch, Islamic Azad university, Germi, Iran
[2]Young Researchers Club, Germi Branch, Islamic Azad University, Germi, Iran
Email: [1] reza.alayi@yahoo.com, [2] hossein_harasii@yahoo.com, [3] pourderogarhameh@yahoo.com

***Abstract*— In recent years, because of the limitations of fossil fuels and emissions resulting from the use of photovoltaic cells increase. Due to the changing state of the sun, solar cells must follow the sun's radiation to receive more energy. But, in this research, the modeling and analysis of the solar tracking system were carried out to obtain the optimal angle in photovoltaic systems for generating maximum power using genetic algorithm (GA). In this paper, the control system is proposed by the GA genetic algorithm that optimizes the output energy of the PV system by adjusting the spatial angles of the solar panel in both vertical and horizontal axes. In this method, without the need for additional hardware, the optimal panel position angles are calculated by using the Matlab software to capture the most sun and maximize output energy. The main advantage is that the system operates discretely during operation and losses are reduced, as well as in the clouds, solar radiation is received and the output energy rises. The important results of this study can be the system is optimized, the output power of the photovoltaic system in a fixed array mode increases by 15.85%.**

Keywords*— Genetic Algorithm, Solar Panel positioning, Optimization, MPPT.

Abbreviations

GA Genetic Algorithm

PV Photovoltaic

PVs photovoltaic systems

MPPT maximum power point tracker

Symptoms

γ Optimal Azimuth angles

β Tilt angle

E Energy

Ƞ Efficiency

Ic solar radiation

I current

A Area

t time interval

G solar radiation

V voltage

T temperature

q electron

k constant Boltzmann

Subtitle

C consumption

pv Photovoltaic

pf power fixed tilt

s sunlight

d diode

o reverse saturation

sc short circuit

oc open circuit

I. Introduction

In recent years, the use of PVs has replaced the energy from fossil fuels in order to provide energy for justified growth. but the low efficiency of solar systems is an obstacle to the comprehensive development of the use of this clean and inexhaustible source. [1-2-3-4-5] Hence, the energy gain from PVs is very important. PVs are used in two types of fixed panels and solar tracking systems. However, because of the simplicity of installation, the fixed panels are used more. But solar tracking panels have more efficiency and many systems have been developed for tracking the sun. [6-7-8] I addition to the type of this system, the quality, temperature of solar cells, inverters, converters, and increasing the amount of solar radiation is very important for increasing the PVs efficiency. [9-10-11] The sun's radiation on the surface of the PV modules is the highest when the panel's surface is directly exposed to the sun's rays, which is achieved by using the solar tracking system and the proper control method [12].

In the field of economic optimization, the use of photovoltaic cells has been the subject of much research such as Alayi [13-14-15], Kalbasi [16], most of this research has led to the selection of the optimal size of the photovoltaic cell.

Fathabadi, H [17] presented at The Novel high accurate Sensorless dual-axis solar tracking system controlled by maximum power point tracking unit of photovoltaic systems. Eldin, S. S., et al., [18] presented a Feasibility of solar tracking systems for PV panels in hot and cold regions. Sidek, M. H. M., et al [19] presented an Automated positioning dual-axis solar tracking system with precision elevation and azimuth angle control. Sumathi, V., et al., [20] Solar tracking methods to maximize PV system output–A review of the methods adopted in recent decades. Obara, S. Y., et al [21] a presented Development of a solar tracking system of a nonelectric power source by using a metal hydride actuator. Carballo, J. A., et al [22] a presented New low-cost solar tracking system based on open source hardware for educational purposes. Su, Y., et al [23] a presented Experimental study of using phase change material cooling in a solar tracking concentrated photovoltaic-thermal system. Safan, Y. M., et al [24] a presented Performance evaluation of a multi-degree of freedom hybrid controlled dual axis solar tracking system. Omran, A. H., et al [25] a presented Maximizing the power of solar cells by using an intelligent solar tracking system based on FPGA. Hua, C. C., et al [26] some presented Improved solar system with maximum power point tracking. Hafez, A. Z., et al [27] a presented Solar tracking systems: Technologies and trackers drive types–A review. Peng, L., et al [28] a presented A novel tangent error maximum power point tracking algorithm for photovoltaic system under fast multi-changing solar irradiances. Hong, Y. Y., et al [29] a presented A robust design of maximum power point tracking using Taguchi method for stand-alone PV system. Dali, A., et al [30] a presented Maximum Power Tracking and Current Control for Solar Photovoltaic System Applications, Hybrid Dynamical System Approach.

Other research that has been done with different algorithms can be Farzaneh, J., et al [31], Deshpande, A.s., [32]. A very common method is using sensors as feedback to adjust the direction of the panel to track the sun, but the main problem is that due to permanent changes in the location, more energy is consumed in the system and is not good in cloudy conditions.

Therefore, with solar location and predetermined programs, systems can be designed with high precision and high efficiency. Therefore, accurate calculation of the solar location has played a major role in solar equipment. So far, there are various ways to optimal positioning of solar systems.

Up to now, there have been many studies, articles and work on this subject and good results have been achieved. One of the most important issues in this regard is the design and use of a solar tracking system. Solar tracking systems actually calculate or track the motion of sunlight using various methods, and adjust the solar panel by using different mechanisms to maximize captured irradiation from the sun. In this paper, we propose a method for determining the position of the tracking system for maximum energy by the Genetic Algorithm (GA), which can receive the most energy from the PVs at any given time interval.

II. MATRIAL AND METHOD

A. *Area of study*

The present study uses Asalouyeh city data as the study area to bring the results closer to the real world. In Fig. 1 and table 1 can be see the geographical location.

Fig. 1. Geographical location for Asalouyeh city

TABLE I. GEOGRAPHICAL CHARAERISTICS OF STUDY AREA

City	Longitude	Latitude
Asalouyeh	27.49^0	52.59^0

B. *Optimum angles by GA*

It is calculated for the maximum radiation received on the surface of the panel in a specified time period. Considering that the aim of the study is to determine the optimal Azimuth angles (γ) and the Tilt angle (β) of the panel within the set time, in order to apply the proposed algorithm, in order to apply the proposed algorithm, the objective function is expressed as (1). [4]

$$J = h(\beta, \gamma) = E_{net} = E_{pv} - E_c \tag{1}$$

E_{net} is the final output energy which is function of γ and β. E_{pv} is the energy received from the PV panel. E_c is the energy of tracking system which is considered as power losses of the system and as permanent parameters in this paper. The energy produced by the PV system is expressed as: [4]

$$E_{pv} = \eta_{pv} \times A_{pv} \times \int_{t1}^{t2} I_c\,(t) d\tau \tag{2}$$

η_{pv} is the net efficiency of PV system (PV panel, inverter, MPPT, …). A_{pv} is active modules areas and IC is Total radiation dependent on time, in the time interval [t1, t2].

The efficiency of the solar system is determined by the relation (3). [6-9]

$$\eta = \frac{(E_{pv} - E_c)}{E_{PF}} \times 100\% \tag{3}$$

E_{PV} is system energy, without energy consumption. EC is the energy consumption of tracking system and EPF is the energy generated by the solar system is in horizontal angle and fixed tilt angles.

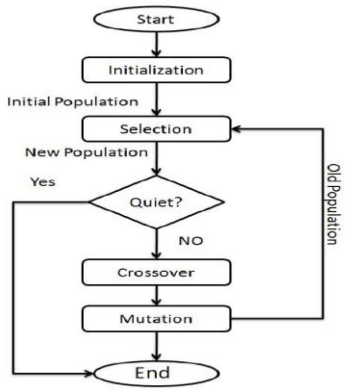

Fig. 2. Genetic Algorithm Flowchart

C. Ideal solar cell modeling

To maximize output power extracted from a PV power plant with the help of MPPT control, understanding and modeling the PV cell is required. An ideal equivalent circuit is a solar cell that is a current source that coincides with a diode. The configuration of an ideal solar cell simulated with a diode is shown in Fig. 3.

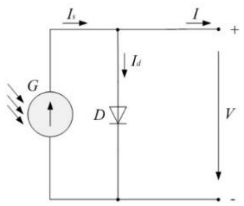

Fig. 3. Ideal solar cell with a diode.

In Fig. 3, G is the solar radiation, I_s is the current generated by the irradiation of sunlight, Id is diode current, I is output current, and V is terminal voltage.

Characteristics of single diode PV cell: [6]

$$I = I_s - I_o\left(e^{\frac{qV}{mkT}} - 1\right) \quad (4)$$

Where I_0 is the reverse saturation or leakage current of the diode, q is the electron charge (1.60217646×10-19 C), k is the Boltzmann constant (1.3806503×10-23 J/K), T (in Kelvin) is the temperature of the p-n junction, and m is the diode ideality constant.

A solar cell can be identified at least by short circuit current (I_{SC}), open circuit voltage (V_{OC}) and diode ideality constant. Therefore, the heat transfers and the conditions of the p-n connection temperature, the short circuit current, is the largest amount of flow generated by the cell.

Short circuit current (I_{SC}): [9]

$$I_{sc} = I = I_s \text{ for } V=0 \quad (5)$$

$$V = V_{oc} = \frac{mkT}{q} ln\left(1 + \frac{I_{sc}}{I_0}\right) \text{ for I=0} \quad (6)$$

Output power is calculated by this equation:

$$P = V\left[I_{sc} - I_0\left(e^{\frac{qv}{mkT}} - 1\right)\right] \quad (7)$$

D. Optimization of Solar Photovoltaic System Function

In this section, in order to improve the performance of the photovoltaic solar system to increase output power, the optimization of the system will be done using the genetic algorithm. First, the desired optimization algorithm is introduced and then the objective function is defined by the required constraints. Finally, with the implementation of the optimization algorithm in MATLAB software, the optimum points are found.

Definition of objective functions: To optimize the performance of the photovoltaic solar system in this study, two of the following objective functions can be defined:

$$\text{objective function1:} \quad \text{Max}\left(G_1(Z, \emptyset_C)\right)$$

$$\text{Subject to:} \begin{cases} Z_{min} < Z < Z_{max} \\ \emptyset_{C,min} < \emptyset_C < \emptyset_{C,max} \end{cases}$$

In which Z_{min} is lower limits and Z_{max} is the upper limit and are equal to 00 and 900 respectively. Ø_(C,$_{min}$)is lower limits and Ø_(C,$_{max}$) is the upper limit and in this study are equal to 00 and 3600 respectively.

III. RESULTS

To determine the performance of the photovoltaic system, we first determine the total solar radiation. To do this, we calculate the total solar radiation for two states with fixed arrays and arrays with a single-axis tracker. We have done the calculation for two days of the year, which were June 10th. And January 10th. The results of these calculations are respectively observed for the Designated days in Figures (4) and (5).

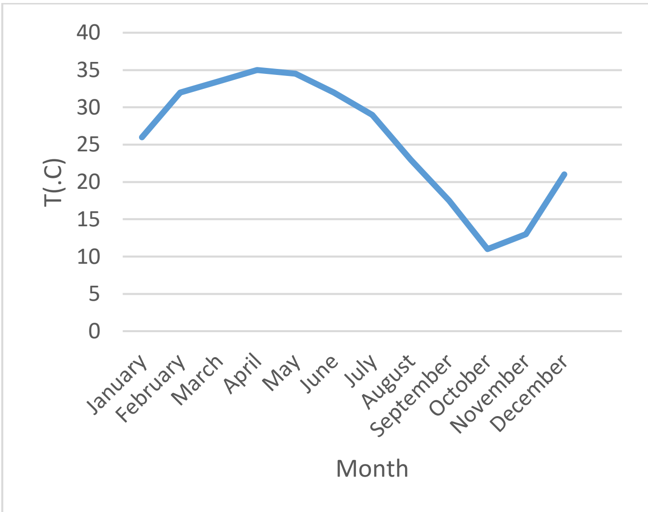

Fig. 4. Mean temperature of Asalouyeh city in different months of the year (Bushehr meteorology)

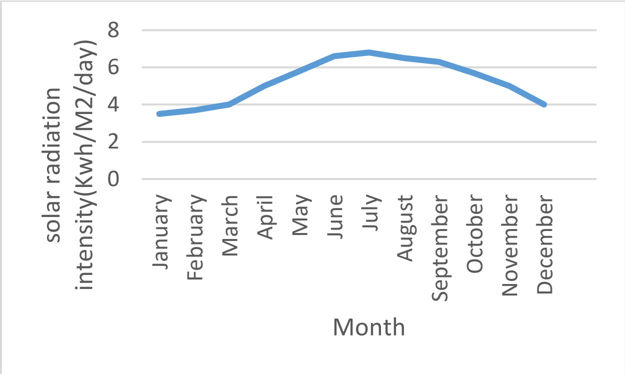

Fig. 5. The annual solar radiation intensity of Asalouyeh

In the next step, to study the performance of the photovoltaic system, we use the sensitivity analysis to determine the current-voltage and power-voltage curves of the solar system in two states with fixed arrays and arrays with a single-axis tracker. Figures (6) and (7) show the I-V and P-V curves on June 10th at 11 o'clock. These curves are presented in Figures (8) and (9), on January 10th (at 11 noon).

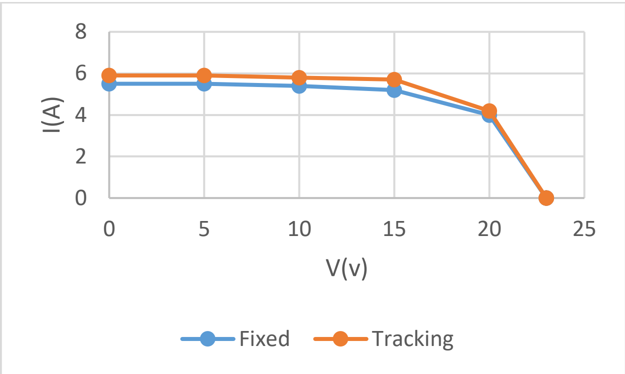

Fig. 6. I-V curve on June 10th at 11 o'clock for Asalouyeh city (for two modes: fixed arrays and single-axis tracker)

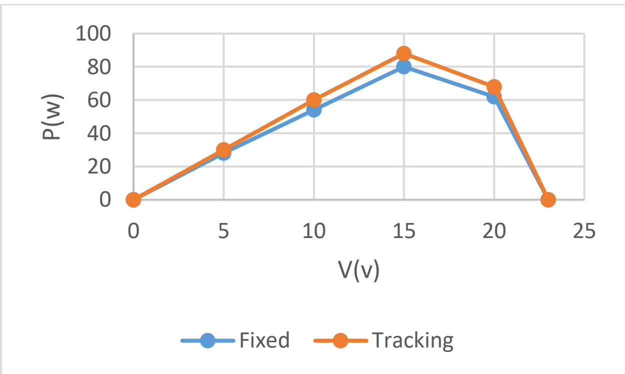

Fig. 7. P-V curve on June 10th at 11 o'clock for Asalouyeh city (for two modes: fixed arrays and single-axis tracker)

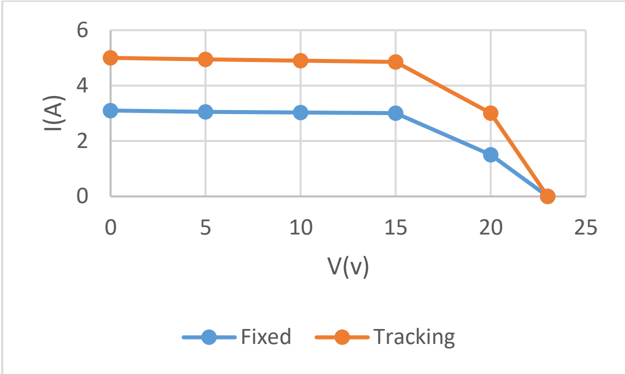

Fig. 8. I-V curve on January 10th at 11 o'clock for Asalouyeh city (for two modes: fixed arrays and single-axis tracker)

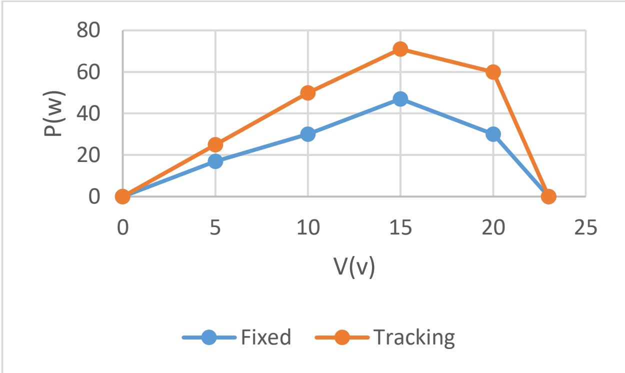

Fig. 9. P-V curve on January 10th at 11 o'clock for Asalouyeh city (for two modes: fixed arrays and single-axis tracker)

By examining the above curves, it can be said that if a photovoltaic system is used with a single-axis tracker, the output current of the PV system increases, which results in higher output power. By reviewing and applying the sensitivity analysis, it is determined that for the 20th of June, the output power of the photovoltaic system with a fixed array is equal to W 87 and with an array with a single axis tracker of W 93. It means that, when using an array with a single-axis tracker, the output power of the photovoltaic system increases to 35% comparing to the fixed array. The amount of this increase for the 20th of January is about 8 times. Because on this day, the maximum output power of a photovoltaic system with a fixed array and array with a single-axis tracker are 50 W and 78 W respectively.

Results of photovoltaic solar system optimization

By defining the objective functions and restrictions and executing the optimization algorithm in the MATLAB software, the optimal angles are obtained. By inserting these optimal angles into solar photovoltaic modeling equations, new results for radiation curves as well as annual energy obtained from the photovoltaic solar system are obtained. According to the results obtained from the optimization algorithm, it was determined that the optimum angle of the slope of the panel and the angle of rotation of the array in array with a single axis tracker is 37.52 and 85.76 respectively. Figure 10 shows the convergence of the genetic algorithm. Figures (11) to (13) also show IV and PV curves for June 10th and January 10th, 11 o'clock in both photovoltaic systems with fixed arrays and single-axis tracker before and after optimization. Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

According to the figures, it can be said that, by optimizing the angles of the photovoltaic system, the output power of the system increases for both fixed arrays and the array with a single axis tracker. Further investigation and analysis of sensitivity showed that the maximum output power of the photovoltaic system for fixed array mode before and after optimization on the 20th of June is 211/41 W and 221/01 W respectively, it means that, if the system is optimized, the output power of the photovoltaic system in a fixed array mode increases by 4.5%. Also, for arrays with single-axis tracker the maximum output power of the photovoltaic system before and after optimization on the 20th of June is 285/36 W and 296/07 W respectively, it means that, if the system is optimized, the output power of the photovoltaic system in a fixed array mode increases by 3.7%.

The maximum output power of the photovoltaic system for fixed array mode before and after optimization on the 20th of January is 12/96 W and 15/54 W respectively, it means that, if the system is optimized, the output power of the photovoltaic system in a fixed array mode increases by 19.91%. Also, for arrays with single-axis tracker the maximum output power of the photovoltaic system before and after optimization on the 20th of January is 108/037/36 W and 125/17 W respectively, it means that, if the system is optimized, the output power of the photovoltaic system in a fixed array mode increases by 15.85%.

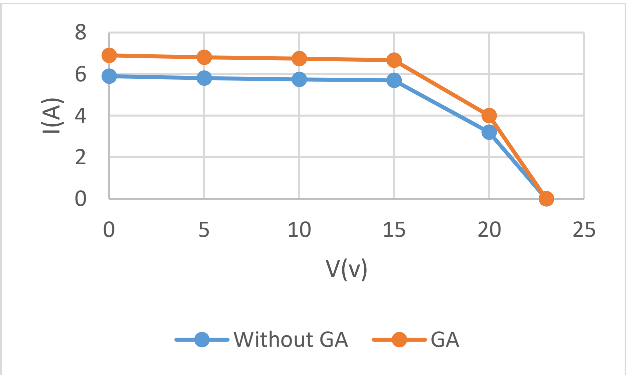

Fig. 10. I-V curve on June 10th at 11 o'clock for Asalouyeh city (fixed array mode before and after optimization)

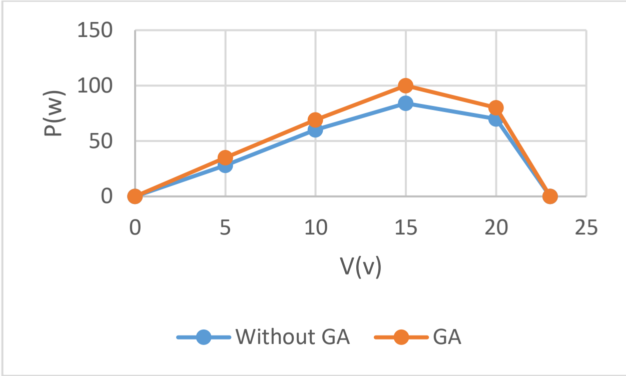

Fig11. P-V curve on June 10th at 11 o'clock for Asalouyeh city (fixed array mode before and after optimization)

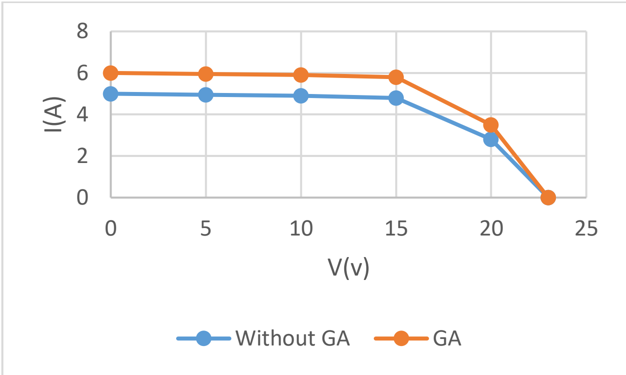

Fig. 12. I-V curve on January 10th at 11 o'clock for Asalouyeh city (fixed array mode before and after optimization)

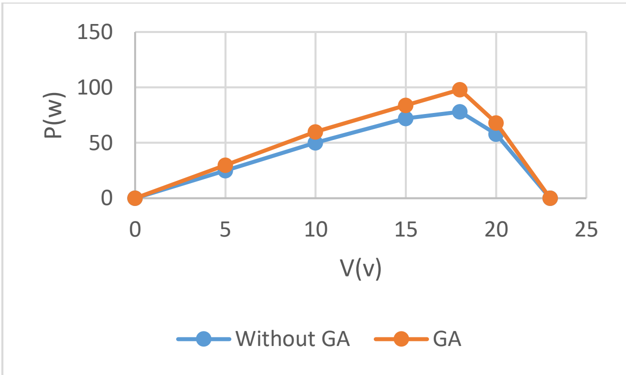

Fig. 13. P-V curve on January 10th at 11 o'clock for Asalouyeh city (fixed array mode before and after optimization)

IV. *Conclusion*

In this research, the analysis of photovoltaic solar systems for the production of electrical energy was investigated and because of the low efficiency of these systems, solar-tracking systems were used to increase their output. The analysis of the photovoltaic system was carried out for the weather in Asalouyeh. The genetic algorithm was also used to optimize the angle of the panels.

By analyzing the photovoltaic system, it was determined that if the photovoltaic system is used with a single-axis tracker, the output current of the PV system increases, which results in higher output power of the system. For June 10th, when using an array with a single-axis tracker, the output power of the photovoltaic system increases to 35% relative to the fixed array. The amount of this increase for the January 10th is about 8 times. Also, considering 24 modules with total area of the module equal to 40 m2, it was found that annual energy production in tracking mode is increased by26%.

In the next step, with the definition of objective functions and constraints and the implementation of the optimization algorithm in the MATLAB software environment, it was found that the optimal angle of the panel and the angle of rotation of the array of single-axis tracker mode was 26.80 and 85.40 respectively. Also, the annual energy produced by a photovoltaic system with a fixed array after optimizing the slope and azimuth angles of the panel increases by as much as 0.17%, And the annual energy produced by the photovoltaic system with a single axis tracking array after optimization is increased to 0.92%.

As a general conclusion, it can be said that the photovoltaic system with a tracker has a higher cost than a photovoltaic system in a steady state, but has a much higher efficiency. Therefore, it can be of more interest to the experts.

According to the potential of the city of Asalouyeh, due to more solar radiation, based on parameters such as temperature, humidity and radiation intensity, the area of Asalouyeh was identified as the most potent area for the installation of solar panels.

REFERENCES

[1] Alayi, Reza, Alibakhsh Kasaeian, and Farideh Atabi. "Optical modeling and optimization of parabolic trough concentration photovoltaic/thermal system." Environmental Progress & Sustainable Energy 39.2, 2020, e13303.

[2] Alayi, Reza, et al. "Optimization and evaluation of a wind, solar and fuel cell hybrid system in supplying electricity to a remote district in national grid." International Journal of Energy Sector Management 14(2), 2019, pp. 408-418.

[3] Ebrahimi, Saeedeh, et al. "Optimal planning of on-grid hybrid microgrid for remote Island Using HOMER software, Kish in Iran." International Journal of Energy, 3.2, 2019,pp. 13-21.

[4] Saravanan, S., and N. Ramesh Babu. "Maximum power point tracking algorithms for photovoltaic system–A review." Renewable and Sustainable Energy Reviews 57, 2016,pp. 192-204.

[5] Zadeh, Mahdi Jedari Zare, and Seyed Hamid Fathi. "A new approach for photovoltaic arrays modeling and maximum power point estimation in real operating conditions." IEEE Transactions on Industrial Electronics, 64.12 ,2017, pp.9334-9343.

[6] Apriani, Yosi, et al. "Analysis of the local energy potential connection with power plants based on archimedes turbine 10 kW." Journal of Robotics and Control (JRC), 1.5 ,2020, pp. 162-166.

[7] Belhachat, Faiza, and Cherif Larbes. "Comprehensive review on global maximum power point tracking techniques for PV systems subjected to partial shading conditions." Solar Energy, 183,2019, pp. 476-500.

[8] Alayi, Reza, Alibakhsh Kasaeian, and Farideh Atabi. "Thermal analysis of parabolic trough concentration photovoltaic/thermal system for using in buildings." Environmental Progress & Sustainable Energy 38.6, 2019, 13220.

[9] Sangwongwanich, Ariya, and Frede Blaabjerg. "Mitigation of interharmonics in PV systems with maximum power point tracking modification." IEEE Transactions on Power Electronics, 34.9,2019, pp. 8279-8282.

[10] Khanjari, Yasamin, et al. "Perormance evaluation of liquid-cooled photovoltaic system using numerical method." Advances in Science and Technology Research Journal, 10.32 ,2016, pp. 184-192.

[11] Choi, Jongmin, et al. "Stabilizing Surface Passivation Enables Stable Operation of Colloidal Quantum Dot Photovoltaic Devices at Maximum Power Point in an Air Ambient." Advanced Materials ,2020, 1906497.

[12] Hashemzadeh, Seyed Majid. "A new model-based technique for fast and accurate tracking of global maximum power point in photovoltaic arrays under partial shading conditions." Renewable energy, 139 ,2019, pp. 1061-1076.

[13] Kasaeian, Alibakhsh, Ali Shamel, and Reza Alayi. "Simulation and economic optimization of wind turbines and photovoltaic hybrid system with storage battery and hydrogen tank (case study the city of Yazd)." Journal of Current Research in Science 3.5,2015, 105.

[14] H. Pourderogar; H. Harasii; R. Alayi; Seyed H. Delbari; M. Sadeghzadeh; A.R. Javaherbakhsh. "Modeling and Technical Analysis of Solar Tracking System to Find Optimal Angle for Maximum Power Generation using MOPSO Algorithm". Renewable Energy Research and Application, 1, 2, 2020, 211-222. doi: 10.22044/rera.2020.9497.1027.

[15] Khalili, Hossiean, Ardeshir Arash, and Reza Alayi. "Simulation and economical optimization hybrid system PV and grid in Ardabil city." Journal of Current Research in Science, 3.5 ,2015, 83.

[16] Kalbasi, Rasool, et al. "Optimal Design and Parametric Assessment of Grid-Connected Solar Power Plants in Iran, a Review." Journal of Solar Energy Research, 4.2 ,2019, pp. 142-162.

[17] Fathabadi, Hassan. "Novel high accurate sensorless dual-axis solar tracking system controlled by maximum power point tracking unit of photovoltaic systems." Applied Energy, 173,2016, pp. 448-459.

[18] Eldin, SA Sharaf, M. S. Abd-Elhady, and H. A. Kandil. "Feasibility of solar tracking systems for PV panels in hot and cold regions." Renewable Energy, 85 ,2016, pp. 228-233.

[19] Sidek, M. H. M., et al. "Automated positioning dual-axis solar tracking system with precision elevation and azimuth angle control." Energy, 124,2017, pp. 160-170.

[20] Sumathi, Vijayan, et al. "Solar tracking methods to maximize PV system output–A review of the methods adopted in recent decade." Renewable and Sustainable Energy Reviews, 74 ,2017, pp. 130-138.

[21] Obara, Shin'ya, et al. "Development of a solar tracking system of a nonelectric power source by using a metal hydride actuator." Solar Energy, 158 ,2017, pp. 1016-1025.

[22] Carballo, Jose A., et al. "New low-cost solar tracking system based on open source hardware for educational purposes." Solar Energy, 174 ,2018, pp. 826-836.

[23] Su, Yan, Yizhong Zhang, and Lianjie Shu. "Experimental study of using phase change material cooling in a solar tracking concentrated photovoltaic-thermal system." Solar Energy, 159 ,2018, pp. 777-785.

[24] Safan, Yasser M., S. Shaaban, and Mohamed I. Abu El-Sebah. "Performance evaluation of a multi-degree of freedom hybrid controlled dual axis solar tracking system." Solar Energy, 170,2018, pp. 576-585.

[25] Omran, Alaa Hamza, et al. "Maximizing the power of solar cells by using intelligent solar tracking system based on FPGA." 2018 Advances in Science and Engineering Technology International Conferences (ASET). IEEE, 2018.

[26] Hua, Chih-Chiang, Yi-Hsiung Fang, and Cyuan-Jyun Wong. "Improved solar system with maximum power point tracking." IET Renewable Power Generation, 12.7 ,2018, pp. 806-814.

[27] Hafez, A. Z., A. M. Yousef, and N. M. Harag. "Solar tracking systems: Technologies and trackers drive types–A review." Renewable and Sustainable Energy Reviews, 91 ,2018, pp. 754-782.

[28] Peng, Lele, et al. "A novel tangent error maximum power point tracking algorithm for photovoltaic system under fast multi-changing solar irradiances." Applied energy, 210 ,2018, pp. 303-316.

[29] Hong, Ying-Yi, Angelo A. Beltran Jr, and Arnold C. Paglinawan. "A robust design of maximum power point tracking using Taguchi method for stand-alone PV system." Applied energy, 211 ,2018, pp. 50-63.

[30] Dali, Ali, Said Diaf, and Mohamed Tadjine. "Maximum Power Tracking and Current Control for Solar Photovoltaic System Applications, Hybrid Dynamical System Approach." Journal of Dynamic Systems, Measurement, and Control, 141.9 ,2019.

[31] Farzaneh, Javad, Reza Keypour, and Ali Karsaz. "A novel fast maximum power point tracking for a PV system using hybrid PSO-ANFIS algorithm under partial shading conditions." International Journal of Industrial Electronics, Control and Optimization, 2.1 ,2019, pp.47-58.

[32] Deshpande, Amruta S., and Sanjaykumar L. Patil. "Maximum Power Point Tracking Using a Hybrid Fuzzy Logic Control." Advances in Data and Information Sciences. Springer, Singapore, 2020. 217-226.