MPPT for Photovoltaic System Located in Latakia Province - Syria by Using Genetic Algorithm

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Abstract

The use of renewable resources for energizing the modern power systems has recently increased due to its sustainability and low operating costs. Photovoltaic (PV) system appears to be a good solution due to the fact that it can be established and operated locally. However, maximum output power of these systems is usually achieved by using the maximum sun and power point (MPP) tracking techniques. This paper suggests a novel genetic algorithm (GA)-based technique to obtain the maximum output power of practical PV system located in Latakia province of Syria. Based on this technique, azimuth and elevation angles of solar panels located in Latakia are first determined to track maximum radiation of the sun for every day of the whole year. After that, a GA-based technique is developed to track the maximum power point corresponding to maximum radiation during the year. Simulation results in MATLB environment demonstrate the validation and effectiveness of the proposed GA-based technique to obtain the maximum generated power of PV system. The results of this research can be easily adopted as a database reference to design the PV control system.

Introduction

Renewable energy is not only an alternative clean and environmentally friendly source of energy, but rather it is a real need especially during large scale crisis due to the possibility of its local control and operation.

Photovoltaic (PV) systems, among other renewable and new energy sources, can be considered as the most available renewable source in Syria. However, maximum harvested energy due to the nonlinearity in PV module characteristics of PV system is not fixed, but rather it varies depending on several factors, such as incident of solar radiation (static placement of solar panels limits their area of exposure to the sun), temperature, load condition, DC/DC converter output voltage, and weather condition.[1] Therefore, in order to maximize the energy extraction of photovoltaic systems under different operating conditions, tracking systems are needed to track both solar radiation (solar tracking) and maximum energy point (MPPT) tracking in relation to solar radiation.[2]

Thorough review of the literature reveals that several methods (techniques) for sun tracking, MPPT tracking, and combination of both have been developed over the past few decades.

Tracking Techniques

A microprocessor-based automatic sun-tracking system is proposed in reference[3] to control the movement of a solar panel to track the motion of the sun. Determining the maximum angle for the panel in both positions (east and west) is done using two limited switches linked to it. The status, reaching the maximum angular positions in either directions has been reached, is analyzed by microprocessor and deiced that panel shouldn't change its positions furthermore. As result, maximum thermal energy is achieved, by keeping the position of the panel at normal direction of the sun. a new micro-controller based solar-tracking system is proposed in reference.[4] The presented system organizes to check the position of the sun and control the related movement of the panels to have a best radiation from the sun on the surface of the solar panel. In addition, it can work independently to set up the geographical location. A tracking system based on computer controller that drives a DC motor with permanent magnets is done to maximize the out power of PV panel by moving it in two axes in.[5] To achieve optimal position for the panel, solar tracker with low cost feature was designed and tested it's capacities on an experimental prototype in reference.[6] This tracker was based on a PC fuzzy logic control algorithm and error signal. In addition, different kind of control strategies were applied such as the traditional ones

"PID" and the upgraded ones "Fuzzy logic control". a tracking self-cleaning system was designed and applied by a stepper motor and gear box which controlled by 8051 microcontrollers is presented in reference.[7] For sun tracking, this technique has no requests for any sensor or synchronization. A novel two axis tracking system with external light sensors to direct the panel to the maximum position of the sun is proposed in reference.[8] The proposed system increases the efficiency by using the solar panel as the sensors. In ref.,[9] a genetic algorithm (GA) is suggested in order to enhancing the performance of PV panels. The parameters of GA were calculated to optimize a solar tracking system. Comparing different axis for sun tracking were done in.[10]

An automatic sun-tracking system was upgraded by introducing a new control technology depends on stepper active tracker.[11] This technology applied by a microprocessor. The designed system has many advanced characteristics for protection and reliable anti- disturbance functions.

A closed loop technique to control a tracking system for PV panel has been done in Reference.[12] This system is a dual axis hybrid type, and acts like a sensor so it can follow the sun continuously. an additional feed-forward control loop was added to the closed one to improve the tracking efficiency of solar panel. The trajectory of the sun is used to manage the rotation angle of PV for the feed-forward tracking objective.[13]

For multiple dual-axis (PV) panels, solar tracking control method is used.[14] The photoelectric sensor is used to detect the signal in this paper and different models of tracking system with two degrees of freedom. The distributed adaptive dynamic surface (DCS) control method is used. a light intensity as a foundation for tracking system and a comparison with a fuzzy logic intelligent method is used in reference.[15] The main controller in this paper was Arduino UNO microcontroller and a four Light Dependent Resistor (LDR) sensors were added for sensing the maximum incident intensity of solar irradiance. a real electronic device for controlling and driving a bi-axial solar tracker system for PV panel is presented in reference,[16] this model is managed by a PC software application with a user-friendly graphical interface, and it has the ability to calculate the sun circadian

orbit so, the panel's surface always perpendicular to solar rays. This process will improve the efficiency of energy extracted.

Reference[3] conjugates the simple Perturb-and-Observe (P&O) MPPT technique with Sun tracker provided with light sensors. This proposed tracker gives a freedom movement in two axes by adding a two-degree mechanical mainframe that supports the PV. Reference[9] presents a fuzzy active controller to track the maximum power point for solar panel dual-axis Sun. this controller will help the panel to orient the solar panel toward the Sun. as a result this will enhance the efficiency of the PV generation system. To improve the performance of the photovoltaic cell, a system using the two-axis solar tracking was introduced next to the maximum MPPPT target in.[10] It also offers a step-by-step incremental, variable-speed conductive algorithm to meet dynamic response and stability requirements. The MPPT algorithm is designed to maintain a PV system that works in MPPT, while solar tracking technology is designed to track the sun both the azimuth angle and the elevation angle in order to enable solar panel perpendicular to sunlight.

In conclusion, the use of the traditional Sensor method for the photovoltaic plant won't provide an ideal tracking to the Sun's place and position when intensity illumination is low. Also, problem of malfunction of tracking system by a the very fast changing climate would rise.

Maximum Output Power of PV-System Methodology
To harvest maximum output power of PV systems, Sun tracking mechanism and maximum power point
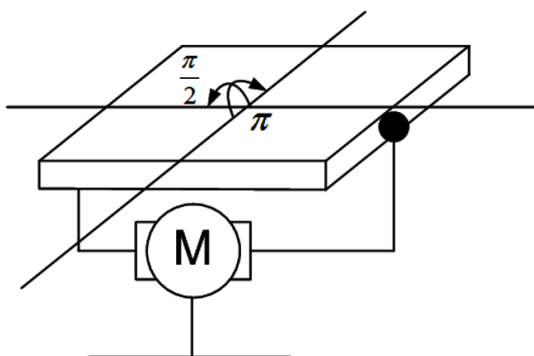
tracker (MPPT) algorithm must be developed and utilized. Sun tracking mechanism guarantees that the solar panel keeps tracking the Sun in such a way that the solar irradiation is always normal to the panel surface. While the MPPT algorithm insures that the harvested power corresponding with each irradiation level is maximized. Therefore, the altitude and azimuth angles of the Sun (the position of the sun), as shown in Fig.1 for any given time and date in the year must be determined Based on these angles and other parameters, the solar irradiation can be calculated easily.

Sun Tracking Technique and Solar Irradiation Calculation
Sun Tracking Technique
Solar tracking means always keeping solar panels (at any time and date) oriented to the sun so that solar radiation is always vertically on the surface of the plate to collect the maximum solar radiation. Keeping solar panels always oriented towards the sun means that we must calculate the angles of the sun's rise and its name (the position of the sun) for any particular time and date of the year. Therefore, for achieving continuous Sun tracking which yields to maximum solar irradiation, we proposed the follow algorithm:

1.   The 365 days of the year are numbered from n=1 through n=365 starting from January 1st.
2.   For any specified day, of the year, and specified time of that day, we have to choose the number of the day (as a number between 1 and 365) and the specified time (0-23).
3.   Based on the day number, the declination angle can be calculated from the following equation.

$$\delta = 23.45\sin\left(360\frac{284+n}{365}\right) \qquad ...(1)$$

Where: $23.45° < \delta < 23.45°$
n : is the number of the day

3.   Determine the solar time using the following equation (The day time is not constant throughout the year (increased or decreased with certain number of minutes):

Fig. 1: The geometry of the PV panel

$$L_{St} = L_t - \frac{60}{15}(L_S - L) + E_t - D_t \qquad ...(2)$$

Where:

where L_{st} is the solar time, L_t is the local time, L_s is the reference Longitude line, L is the local Longitude line, and E_t is the time equation.

$$E_t = 9.87 \sin 2\beta - 7.53 \cos \beta - 1.5 \sin \beta \text{ (in minutes)} \qquad ...(3)$$

$$\beta = (360/365) \times (n - 18) \qquad ...(4)$$

D_t : is the summer or winter time change (increase or decrease by 1 hour).

After calculating the solar time in hours and minutes we convert it into degrees.

Day time changes in minutes as shown in Fig.2.

4. Determine the hour angle using the following equation:

$$\omega = 15 (L_{st} - 12) \qquad ...(5)$$

5. Determine the altitude angle using the following equation:

$$\sin \gamma = \sin \phi \cdot \sin \delta + \cos \phi \cdot \cos \delta \cdot \cos \omega \qquad ...(6)$$

where ϕ : is the longitude line angle in degrees.

6. Determine the zenith angle using the following equation:

$$Z = 90 - \gamma \qquad ...(7)$$

7. Determine the azimuth angle using the following equation:

$$\cos \psi = \frac{\sin \phi \cdot \sin \gamma - \sin \delta}{\cos \phi \cos \gamma} \qquad ...(8)$$

8. Determine the Sun rising angle using the following equation:

$$\omega_s = \cos^{-1} (-\tan \phi \tan \delta) \qquad ...(9)$$

9. Determine the day time hour's number using the following equation:

$$D_H = \frac{48}{360} \times \omega_S \qquad ...(10)$$

Applying the above mentioned algorithm allows us to determine the position of the Sun at any given time and date in the year. Therefore, we can orient our solar panels towards the Sun at that time and date in order to collect the maximum solar irradiation.

After determining the Sun position, we can calculate the solar irradiation applying the following algorithm:

Solar Irradiation Calculation
Solar irradiation consists of three components:
a. Direct radiation on the inclined surface
b. Diffused radiation scattered by the atmosphere
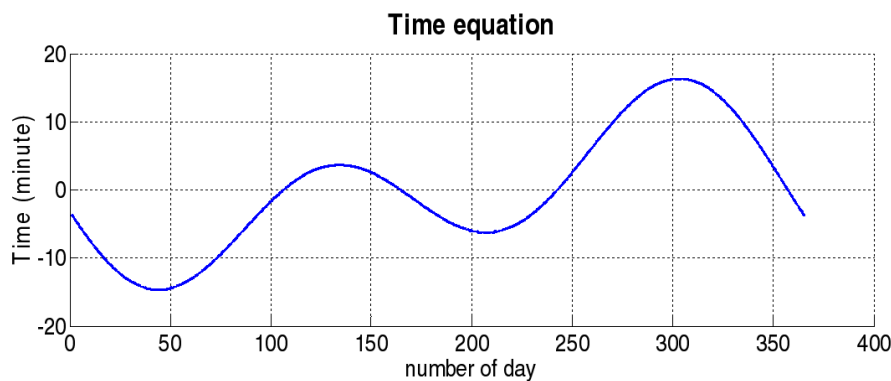c. Reflected radiation due to terrestrial surface

Fig. 2: The circuit diagram of the PV model

1. The direct solar radiation incident on the surface of the Earth is calculated according to the American Association of Heating, Cooling and Air Conditioning Engineers (ASHRAE) using the following equation:

$$H_{Bt} = H_{Bn} \cos \theta i \qquad ...(11)$$

$$H_{Bn} = Ae^{-B/\sin \gamma} \qquad ...(12)$$

Where:

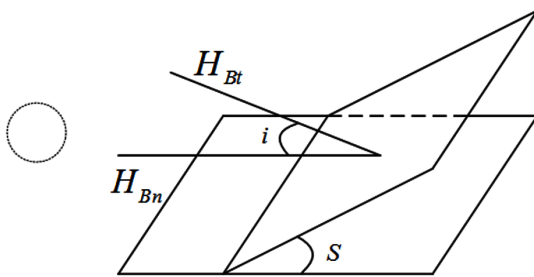θ_i : Is the angle between the sun's radiation and the vertical line on the surface of the board. Since the surface of the board is always oriented towards the sun, then $\theta_i = 0$ and $\cos \theta_i = 1$

H_{Bn} : is the solar radiation $[W/m^2]$
A : is theoretical solar radiation with air density of zero
B : Atmospheric mitigation factor
γ : Altitude angle of the Sun

Changes in A and B values depend on the annular change of the distance between the Sun and the earth and the seasonal change of atmospheric humidity and other components. A and B and the can be determined from ASHRAE' tables for any specified month. Also they can be calculated for any given day in the year using the following equations:

$$A = 1185 \times \left[1 + 0.066 \times \cos \left(360 \frac{n}{370} \right) \right] \qquad ...(13)$$

B = 0.175 x [1-0.2 x cos (0.93*n*)] - 0.0045 x [1-cos (1.86*n*)] ...(14)

2. The diffused radiation scattered by the atmosphere is calculated using the following equation:
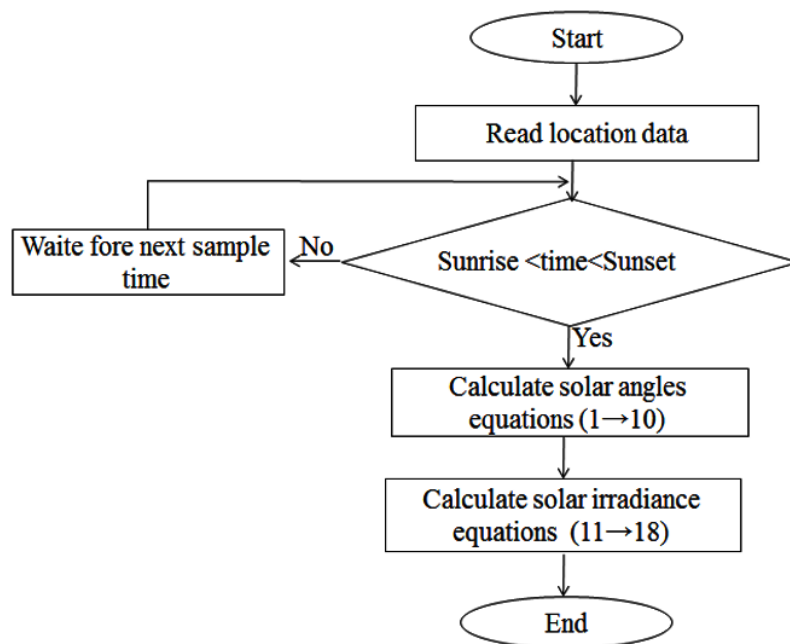

Fig. 3: The circuit diagram of the PV model

Fig. 4: flow chart to calculate sun angles and solar radiation

$$H_{dt} = C \times H_{Bn} \left(\frac{1 + \cos Z}{2} \right) \qquad ...(15)$$

Where:
C : is the diffuse (scatter) factor

3.   The reflected radiation due to terrestrial surface is calculated using the following equation:

$$H_{gt} = H \times \rho g \left(\frac{1 - \cos Z}{2} \right) \qquad ...(16)$$

$$H = H_{Bn} \sin \gamma + C \times H_{Bn} \qquad ...(17)$$

Where:
Pg : is the reflection factor of the earth and usually its value is

4.   The total solar irradiation is calculated using the following equation:

$$Ht = H_{Bt} + H_{dt} + H_{gt} \qquad ...(18)$$

fig. 4 shows the flow chart to calculate sun angles and solar radiation mentioned in the equations above

MPPT based on GA
GA is defined as a kind of randomized method of research that relies on the mechanism of natural choosing and optimization. Moreover, it achieves an optimal global level by combining job evaluation with random exchange and / or well organized information between solutions. One of the key characteristics of GA is superior performance in nonlinear spaces
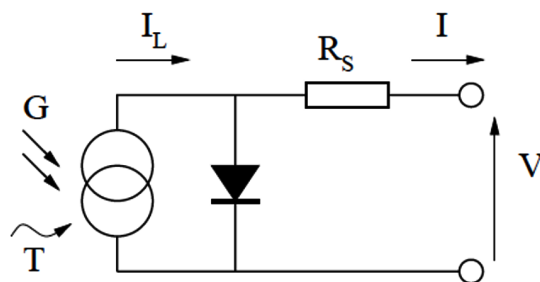

Fig. 5: The circuit diagram of the PV model

compared to other optimization methods. Figure (5) illustrates the flow chart of the General Assembly.

For photovoltaics, the simplest solar cell model was adopted. In this model, the equivalent circuit of the solar cell is made up of a current source parallel to the diode as shown in Fig. 5. A moment that corresponds to the output of the current and the light directed to the cell. The I-V properties of the cell are determined by the diode in the circuit.[17] The model included both temperature dependence of the photo-current I_L and the saturation current of the diode I_0. In addition, the RS resistance series was used instead of conversion resistance. The diode is used in addition to a combination of diode quality factors in order to achieve the best curve match.

where G is the irradiation level (Wm^{-2}), T is the temperature in (C^o), I_L is the photo-current (A), is the output current (A), R_S and series resistance (Ω) .

The output current of this model is given (Shockley equation) as:

$$I = I_L - I_0 \left(e^{q(V + IR_S)/nkT} - 1 \right) \qquad ...(19)$$

where I_0 : is the reverse saturation current of the diode, k : is Boltzmann constant, q : is the electron charge(Coulomb), T :is the temperature ^oK and n : is diode ideality factor.

GA has been applied in this paper as follows:

Step I: Input Initialization
This includes optimization inputs (such as, population size, maximum number of generation, crossover method and probability, mutation method and its probability, stopping criterion, etc) and solar cell related data.

Step II: Generation of Initial Population
In order to consider the variables that should be optimized (the voltage and current of solar cell) ,a random initial population of floating individuals of finite length is created. Each of these individuals concatenated of two chromosomes representing the feasible solution to the problem.

The first chromosome contains the value of the voltage which randomly generated in the range ($0 \leq V \leq V_{OC}$), while the second chromosome contains the value of the current which randomly generated in the range ($0 \leq I \leq I_{SC}$). The initial population is created in such case by repeating these processes as much as the selected population size.

Step III: Fitness Evaluation
The fitness of each independent solution of the initial generation is analyzed by determining the maximum value of the objective function.

Step IV: Creation of New Generation
A new population is created with the elimination of the worse performing individuals, whilst the most highly fit members are selected to pass on information to the next generation.

This includes three main processes, selection, crossover, and mutation. The adopted functions for these processes are deterministic sampling selection, simple crossover with probability , and mutation operation with probability P_M, respectively.

Step V: Repeating Process
Operation of selection, crossover, mutation, and evaluation are repeated until an optimum solution is achieved or the number of generation is reached.

Step VI: Ending Process
The stopping standard is the maximum number of generations. If this number is achieved, stop the process and print the optimal solution.

Simulation Tools, Data and Results
Simulation and Data
The suggested MATLAB programs are developed to calculate the sun's elevation angles, the azimuth ratio, the solar irradiation calculation, and the GA-based maximum power point calculation for photovoltaic panels, then the all previous parameters
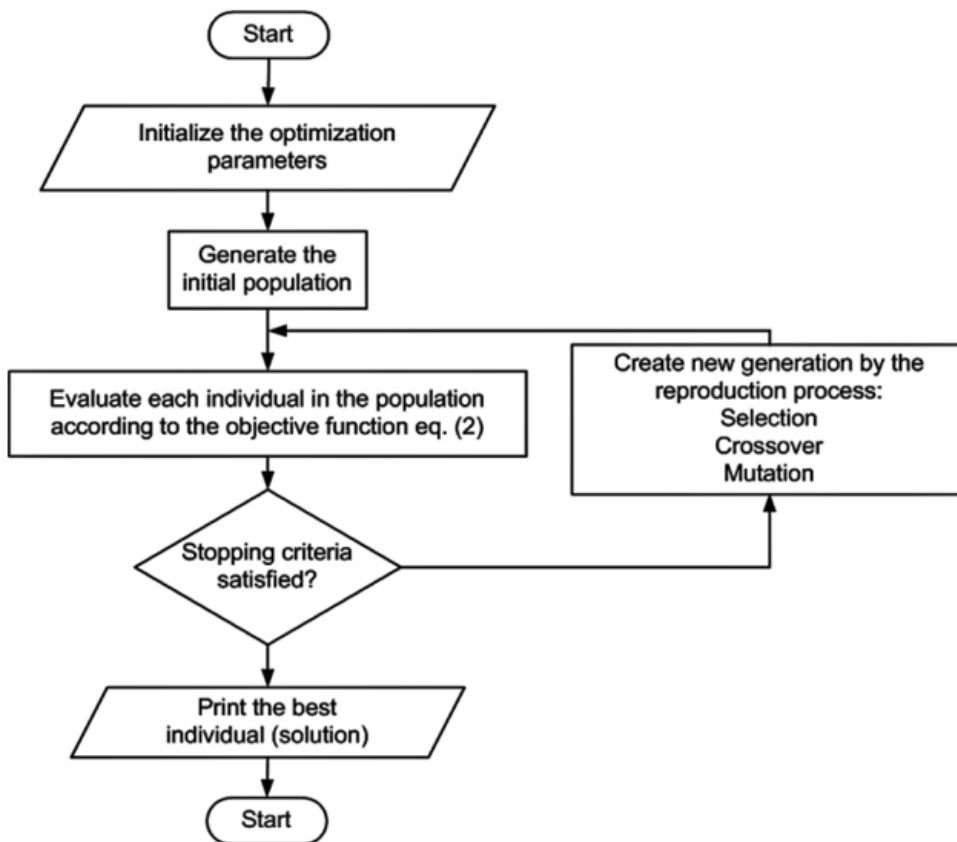

Fig. 6: Flowchart of the implemented GA algorithm

will be used later for analytical purposes in this research.

To confirm the effectiveness and performance of the proposed methodology, advanced algorithms were tested on the SPK200GT solar panel. The data of this solar panel are taken from reference.[22] The temperature is taken as 25 °C.

Simulations are carried out on Pentium IV, 2.66 GHz, and 1GB of RAM computer. The initial parameter values of the implemented GA algorithm are shown in table 1.

Latakia city is located on the coordinates: Latitude: 35° 31' 23" and longitude 35° 47' 28".

Simulation Results

The developed methodology is programmed in Matlab environment. Date and time are used as the only required inputs in order to calculate the results. Then, the program will calculate all the required results. These results include the settings of the solar panel angles (orientation angles, elevation, Zenith, and azimuth), the maximum irradiation corresponding to the settings, and the maximum output power of the solar panel.

Due to the maximum limitation policy of pages per one paper, it's not possible to present all the results that have been obtained. Therefore, some of the results has been presented in this paper the results presented here are just some samples of the results
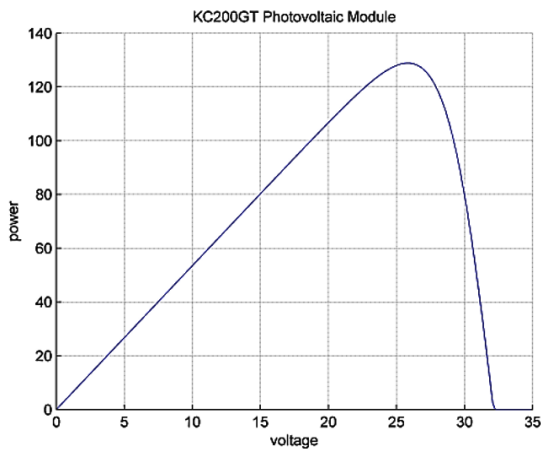
Fig. 7: and P-V feature of SPK200GT solar panel in January 10th
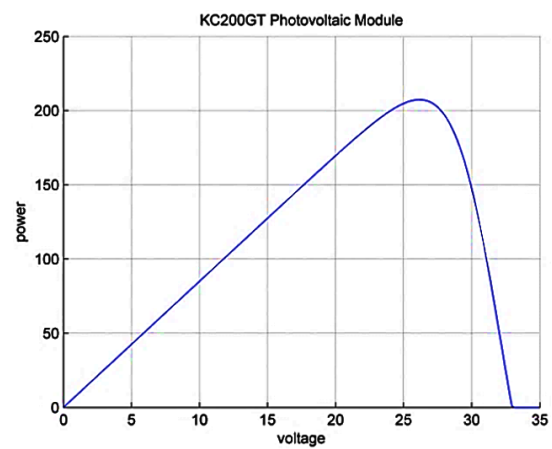
Fig. 8: P-V feature of SPK200GT solar panel in April 10th

Table 1: initial GA parameter values

GA parameters values

Number of parameters	2
Length of each independent solution	3
generation size of solutions	30
Most significant number of generation g_{max}	100
Number of progeny / pair of parents	1
Selection probability P_s	population size
probability Crossover P_c	population size
probability Mutation P_m	population size

we have gotten where dates and times in these results were arbitrary chosen.

Four different dates in different seasons, January 10th, April 10th, July 10th, and December 16th of one calendar year and different times for each day. The obtained results are presented as follows:

For *n*=10 (January 10th), 8:00 Am
For this specified date, the simulations were carried out for am in the morning. The altitude (elevation), Zenith, and azimuth angles were determined according to ASHRAE to keep the solar panel surface perpendicular to the Sun radiation which ensures that the panel can receive the maximum solar irradiation for that particular time. Secondly, the maximum solar irradiation is calculated as indicated previously. Finally, the calculated value of the solar irradiation, corresponding to the specified time, is passed to the GA-based maximum power point (MPP) algorithm to calculate the MPP value. Therefore, the maximum output power of the solar panel corresponding to that specified time is achieved.

Table 2 shows the determined elevation, zenith, and the azimuth angles in degrees the calculated total

solar irradiance in W/m^2, and the obtained maximum output power in W along with the corresponding MPP voltage.

For *n*=100 (April 10th), at 12:00 Pm
The elevation, zenith, and the azimuth angles in degrees, the total solar irradiance in W, and the maximum power of output in are shown in table 3. The P-V feature of the solar panel are also shown in the Fig.8.

For *n*=190 (July 10th), at 16:00 Pm
Table 4 shows the determined elevation, zenith, and the azimuth angles in degrees, the calculated total solar irradiance in W/m^2, and the obtained maximum output power in W along with the corresponding MPP voltage.

The P-V feature of PV panel corresponding to this value of the solar irradiance is shown in the Fig 9.
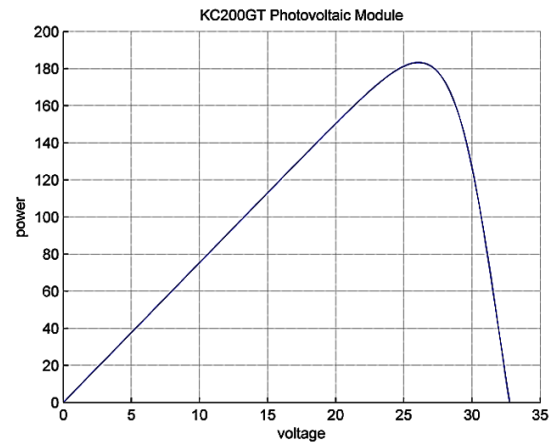
Fig. 9: P-V feature of SPK200GT PV panel in July 10th

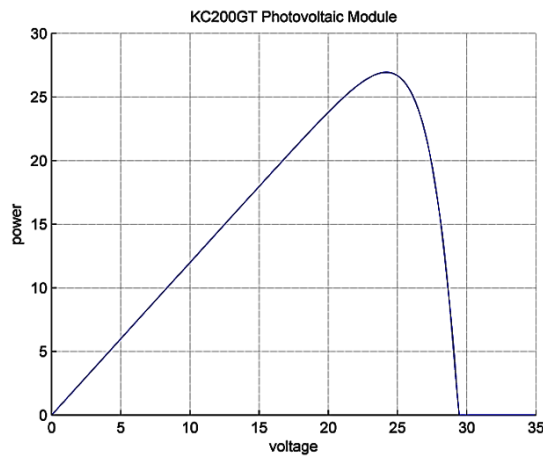**Table 2: the determined values in January 10th (n=10) at 8:00 Am**

Elevation angle	11.7°
Zenith angle	78.3°
Azimuth angle	-51.7°
Solar irradiance (W/m²)	652
Maximum Power - P_{max} (Watt)	128.7
Maximum Power Voltage - V_{mpp} (Volt)	25.55

Table 3: the determined values in April 10th (n=100) at 12:00Pm

Elevation angle	60.6°
Zenith angle	29.4°
Azimuth angle	-19.8°
Solar irradiance (W/m²)	1035.8
Maximum Power - P_{max} (Watt)	207.4
Maximum Power Voltage - V_{mpp} (Volt)	26.33

Table 4: the determined values in July 10th (n=191) at 16:00Pm

Elevation angle	45.1°
Zenith angle	44.9°
Azimuth angle	86.6
Solar irradiance (W/m²)	918.3
Maximum Power - P_{max} (Watt)	183.3
Maximum Power Voltage - V_{mpp} (Volt)	26.03

For *n*=350 (December 16th), at 16:00 Pm

The determined elevation, zenith, and the azimuth angles in degrees, the calculated total solar irradiance in *W/m²*, and the obtained maximum output power in along with the corresponding MPP voltage are shown in table 5.

The P-V feature of the panel corresponding to this value of the solar irradiance is presented in the Fig. 10.

These previous figures show that, the maximum output curves vary from day to day. This value

changes from minimum value (26.9W) at 16:00 (4:00 pm) on December 16th to maximum value (207.4 W) at 12:00 on April 10th.

After that, it can be concluded that there is a real need to follow the Sun and MPP tracking of the PV. Otherwise, the output power of the panel will not be maximized.

Figure 11 shows the maximization of the objective function (the output energy of PV) by GA algorithm. The output power of the solar panel is maximized using GA algorithm after determining the accurate elevation and azimuth angles of the Sun and the corresponding solar irradiation to these angles at specified time and date. The Only case corresponded to maximum output power is presented in (n=100, April 10th).

Fig. 10: P-V feature of SPK200GT solar panel in December 16nd

Table 5: the determined values in July 10th (n=350) at 16:00Pm

Elevation angle	3.7°
Zenith angle	86.3°
Azimuth angle	57.6°
Solar irradiance (W/m²)	146
Maximum Power - P_{max} (Watt)	26.9
Maximum Power Voltage - V_{mpp} (Volt)	24.1
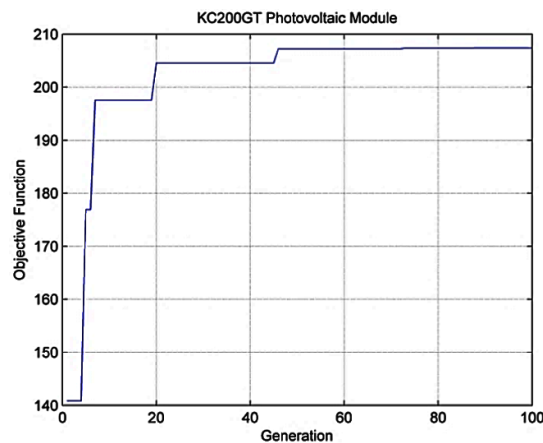
Fig. 11: The convergence feature of the objective function by GA for maximum output power
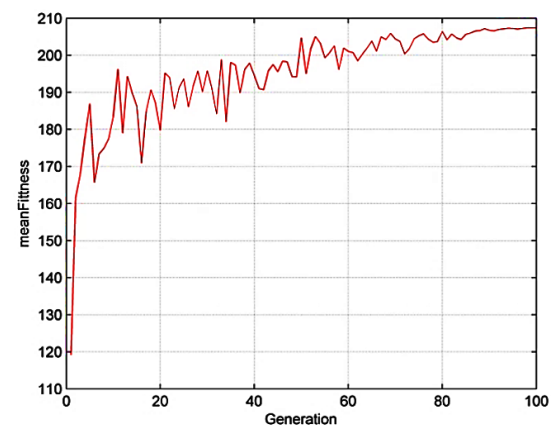
Fig. 12: The mean fitness feature of the objective function by GA for maximum output power case

In Fig. 12 shown the mean fitness feature of the objective function by GA for maximum output power case.

The results show; through the equations mentioned above we can achieve accurate sun tracking, and the genetic algorithm showed of large and infinite accuracy in of maximum power point tracking in the PV systems, thus contributing to increasing the efficiency and reliability of photovoltaic systems.

Conclusion

The maximum output power of PV can be achieved in photovoltaic systems for any given time and date by proper solar tracking and the maximum energy point of the panel. Sun tracking (height and azimuth angles) can be achieved by accurately calculating these angles. Identifying these angles ensures that maximum solar irradiance is received by the surface layer of PV panels. After calculating the solar radiation received, the maximum power point of the solar panel can be improved using a powerful enhancement technique such as GA. Therefore, the maximum solar energy output of PV solar panel can be determined for any time and date. The GA

algorithm can easily and quickly and accurately achieve the maximum energy point of the solar panel even for very small levels of solar radiation. This methodology provides a complete set of data for any design of a separate or continuous control system to direct the solar panel towards sunlight. Additional development may include studying the impact of weather and other atmospheric conditions on the amount of solar irradiance received by the surface layer of PV panels.

In coming research a comparison between two algorithms could be done to show the accuracy and the high performance of each one to achieve the optimum selection. This study could be continued Considering the temperature is a variable parameter, to obtained the effect of this parameter on the efficiency of the PV panels.

Acknowledgement

References

1. S. Mashohor, Kh. Samsudin, Amirullah, M. Noor, A.A. Rahman, "Evaluation of Genetic algorithm based solar tracking system for photovoltaic panels", ICSET, pp. 269-273, 2008

2. S. Hadji, F. Krim, J. P. Guabert, "Development of an Algorithm of Maximum Power Point Tracking for Photovoltaic Systems Using Genetic Algorithms" IEEE USA, pp. 439-449, 2011

3. T. Esram and P.L. Chapman, "Comparison of Photovoltaic array maximum power point tracking techniques, IEEE transaction on energy conversion", Vol. 22, No. 2, 2007

4. B. Koyuncu and K. Balasubramanian, " A microprocessor controlled automatic sun tracker", IEEE Transactions on Consumer Electronics, Vol. 37, No. 4, pp. 913–917, 1991.

5. O. Bingol, A. Altinta, and Y. Oner, "Microcontr-oller based solar-tracking system and its implementation", *Journal of Engineering Sciences*, Vol. 12, pp. 243–248, 2006.

6. H.A. Yousef, "Design and implementation of afuzzy logic computer-controlled sun tracking system," IEEE International Symposium on Industrial Electronics (ISIE), Vol. 3, pp. 1030–1034,1999.

7. A. Yazidi, F. Betin, G. Notton, and G.A. Capolino, "Low cost two-axis solar tracker with high precision positioning", *International Symposium on Environment Identities and Mediterranean Area (ISEIMA)*, pp. 211–216, 2006.

8. R. Tejwani and C.S. Solanki, "360° Sun tracking with automated cleaning system for solar PV modules", 35th IEEE conference on photovoltaic specialists (PVSC), pp. 002895-002898, 2010.

9. S. Dasgupta, F.W. Suwandi, S.K. Sahoo, and S.K. Panda, "Dual axis sun tracking system with PV cell as the sensor, utilizing hybrid electrical characteristics of the cell

to determine insolation" , IEEE international Conference on Sustainable Energy Technologies (ICSET), pp. 1-5, 2010.

10. A.H. Niasar, Z. Zare, and F.R. Far, "A lwo-cost P&Q based maximum power point tracking, combined with two-degree Sun tracker", 6th IEEE conference on Power Electronics, Drives Systems & Technologies, pp. 119-124, 2015.

11. M. Suthar, G.K. Singh, and R.P. Saini, "Performance evaluation of Sun tracking photovoltaic study", Fifth IET International conference on Advances in Recent Technologies in Communication and Computing (ARTCom), pp328-335, 2013.

12. J.F. Lee, N.A. Rahim, "Performance comparison of dual-axis solar tracker vs static solar system in Malaysia", IEEE conference on Clean Energy and Technology (CEAT), pp. 102-107, 2013

13. W.C. Sheng, W.Y. Bo, L.S. Yang, P.Y. Chang, and X.H. Hua, "Study on automatic Sun-

tracking technology in PV generation", IEEE international conference on Electric Utility Deregulation and Restructuring and Power Technologies (DRPT), pp. 2586-2591, 2008.

14. H.C. Lu and T.L. Shih, 'Fuzzy system control design with application to solar panel active dual-axis Sun tracker system", IEEE conference on Systems, Man and Cybernetics (SMC), pp. 1878-1883, 2010.

15. H. Li, C. Zhao, H. Wang, S. Xie, and J. Luo, " An improved PV system based on dual axis solar tracking and MPPT", IEEE conference on Mechatronics and Automation, pp. 204-209, 2014.

16. M.S. Munna, M.A.I. Bhuyan, K.M. Rahman, and M.A. Hoque, "Design, implementation and performance analysis of a dual-axis autonomous solar tracker", 3rd IEEE conference on Green Energy and Technology (ICGET), pp. 1-5, 2015.

17. www.kyocerasolar.com/assets/001/5195.pdf, on September 6th, 2016.