The Comparing Between Genetic Algorithm and Neural Network to Compute of Three-Basic Solar Cell Parameters with Wide Range of Measured Temperature

Z. K Gurgi* , A. I. Ismael, R. A. Mejeed

Departement of Electrical power and Machine Engineering, College of Engineering, Diyala University, Iraq

Abstract— *Solar cell efficiency considers an important part of the PV system, the parameters (I_o, I_L , n, R_s , and R_{sh}) of solar cell is the main part that effected on efficiency. The Matlab simulation program was used to estimate the three parameters' optimization values and evaluated by the Fminsearch method, they calculated for solar cells measured from 0 °C to 100 °C for seven temperatures, then make comparing for the results between the Genetic Algorithm method with Neural Network Algorithm. This paper establishes the results are frequently in GA was better than NNA, with the I_o being $3.0992\ e^{-7}$ and I_L being 3.8059 found by GA. GA is good if they have the same population size and number of iterations. The value of the objective function (fval) in GA is 0.002856 but in NNA is 0.005518. And also second objective function (fvaltemp) in GA is 0.1035 with a 0.1069 value in NNA. From the side, the execution time considers in the Fminsearch method is less than NNA and GA that being 64.9 s, 781 s, and 289 s respectively.*

Keywords— Genetic algorithm, Neural network, Solar cell

NOMENCLATURE

a	The diode ideality factor
EG	Energy gap
F_{val}	The fitness function value at the final point
I	Output current, the unit is (A)
I_L	photo current (A) , the unit is (A)
I_o	The current of saturation, the unit is (A)
I_sc	The short circuit current, the unit is (A)
K	The Boltzman constant
N_s	The series-connected cell
q	The charge of an electron
R_s	The series resistance, the unit is (Ω).
R_sh	The shunt resistance, the unit is (Ω)
T	The cell temperature
$TIPH$	The first order cofficient for I_sc
$TXIS$	Temperature exponent for I_o
V_T	Thermal voltage of PV array
V_oc	The open circuit voltage, the unit is (V)

1. INTRODUCTION

To provide the sustainable electrical power must increase using power generation from solar PV system, it requires an enhanced solar PV estimating technique, most researcher (from 2014 to 2018) that using ANN algorithm application absorption forecasting solar power [1]. Montiê A. Vitorino et al propose solar cell model to get maximum power point that doing by simulation and applied in the laboratory, the model completed by conventional

computational complexity method besides tracking speed was quite satisfactory [2],so some researchers prefer using converter (like SEPIC or Cuk converter) to get maximum power point track of a solar panel, this technique need exrta device and not comparing with artificial intelligence that consider more accuracy [3, 4]. Tor et al fund the relationship between V and I then derived the curve that consider four parameter (I_{sc}, V_{oc}) and also shape parameters, but this work didn't show effect other parameter , it solved by analytical mathematical model can representing empirical current-voltage curves [5]. A different model that styles of the Z-I/ output characteristics in the solar cell per component per array stays stabile, the examination of Photovoltaic systems by using equivalent circuits for diode for constructing mathematical model , An easy methods that does not require difficult numerical equations, as its results are always inaccurate [6, 8].

The effective temperature shows important part at the PV transformation method, and together the power output with the electrical efficiency of a photovoltaic unit considers essentially linearly, on the other hand somewhat powerfully on temperature coefficient will reducing for it. They include three essential basic and easily obtainable environment variables, called, ambient temperature, irradiance of solar, then wind speed, some researcher try find new way to dissipate the heat of the PV surface; like using radiating cooling coating and bi- reflector PV system [9, 10].

Giuseppina and et al illustrate most mathematical (or more than five methods) one diode models for predicting I/V curve of a photovoltaic cell, these methods proposed from different researchers dependent on mathematical and physical assumptions then from point the algorithm steps.. These models decrease the difficult to the determination of five parameters: the photo current I_L then the diode saturation current I_O with ideal influence n, and the parallel and series resistances R_{sh} and R_s [11–13]. Also some researchers interested used numerical iterative techniques like Newton Raphson method and three step method besides Classic Chord procedures have been achieved within limited conditions because photovoltaic cells have a behavior that is Difficult to predict [14, 15]. One of important role in PV system need know how can reduce the temperature of photovoltaic panels [16],
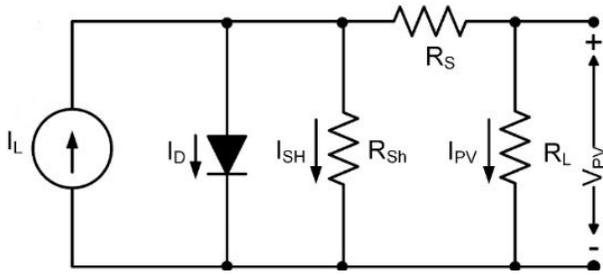
Fig. 1. Equivalent circuit of PV module [25]

Fig. 2. Generating of chromosomes

Fig. 3. Simulation of the Model with Initial Parameter Values
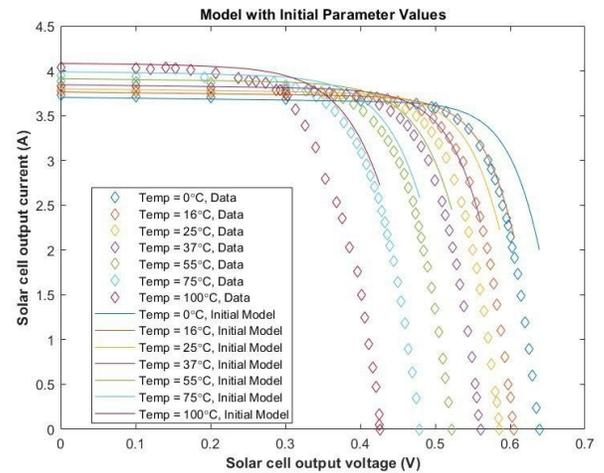
Fig. 4. Simulation of the initial parameters with experimental values (Data)
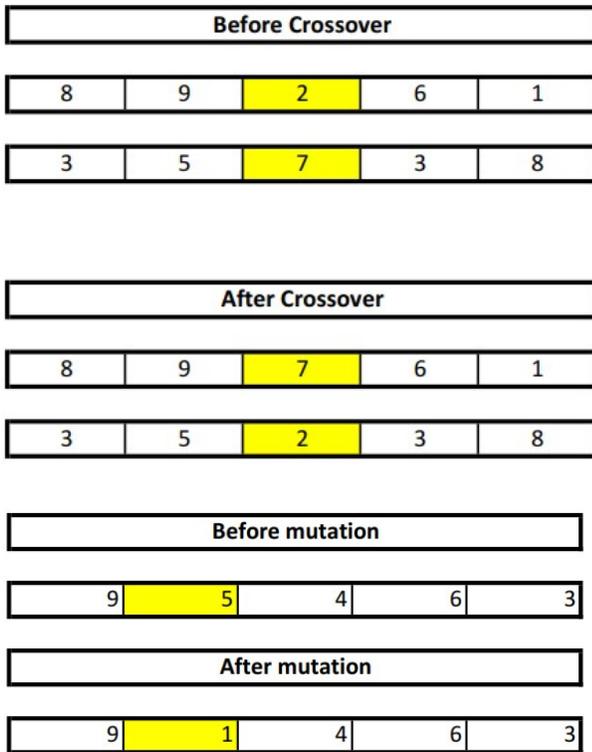
Fminsearch is one of the best method (from point take less time) used to realize the better result that reduce the average total cost/time [17].

A Genetic Algorithm can be solution for optimization problem has been shown that η, R_s and R_{sh} current important variants dependent on the weather situations. The result of R_{sh} illustrations his size is powerfully not linear through the irradiance besides temperature divergence. The algorithm GACCC (Genetic Algorithm through Convex Combination Crossover) consider enhancement form the Genetic Algorithm with convex mixture crossover strategy, these technique tested under limited temperatures', J. D. et al test pv solar cell at only the temperatures 25 ^{o}C,45 ^{o}C and 65 ^{o}C: Naima hamid et al. test the pv solar cell at only temperatures 33 ^{o}C and 45 ^{o}C [18, 19]. The mixture of GA with traditional explicit method calculations lets gaining precise outcome without a straight measurement of (Is.c) and (Vo.c) that is naturally usage at disconnected identification procedures, its need evaluated with NNA [20].

The neural network was used to deal with current and voltage nonlinear relationship. The neural network is learning machine once using some measured current–voltage curves, then the equivalent circuit factors are projected by analysis the illustrations of solar irradiation in addition temperature rapidly without resolving every nonlinear contained e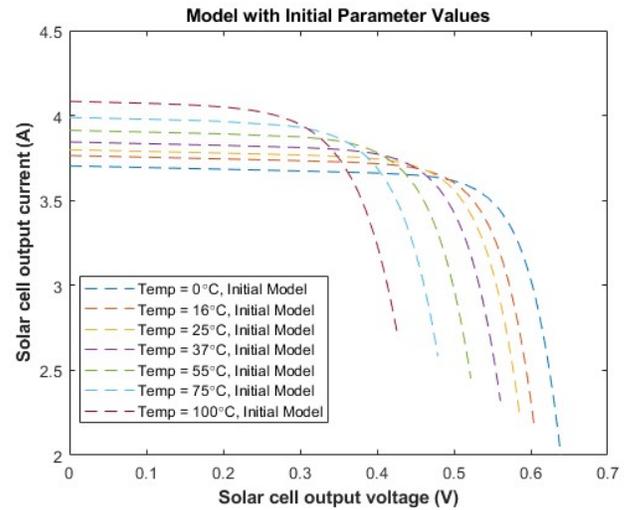quations which essential in conventional procedures [21]. The neural network implementation hybrid system collected through extra procedures, that it compares with multi-linear regression methods try to enhance the accurateness of NNA forecasting, this work only evaluated by R_s values in cold weather conditions [22]. The target of the teaching then information filtering was to deliver a quality information input prior being in progress into NNA structure [23]. A novel metaheuristic optimization algorithm called neural network algorithm (NNA), that generate optimal problem solving through the theories of ANNs in addition biological nervous structures [24]. In this paper, our process measured the experimental result for V/I (voltage and current)in the middle of Iraq, then the model try evaluated with Fminsearch method, after that make comparing between GA with NNA to calculate the main parameters of solar cell in wide range temperatures from 0 ^{o}C to 100 ^{o}C In the middle of the Iraq weather condition, it has usually temperature above 0 ^{o}C until in winter.Then the paper compare some functions values between GA and NNA at the same population sizes and numbers of iterations.

2. THE SOLAR CELL EQUIVALENT CIRCUIT

To distinguish a solar cell an electric performance, it is suitable to make a model is electrical equivalent circuit, then it remains constructed on distinct ideal electrical components. the ideality in the solar cell can be showed via a parallel current source through the diode, happening practice not at all solar cell be perfect. Then the resulting solar cell equivalent circuit is presented in Fig. 1.

Table 1. The parameters of GA

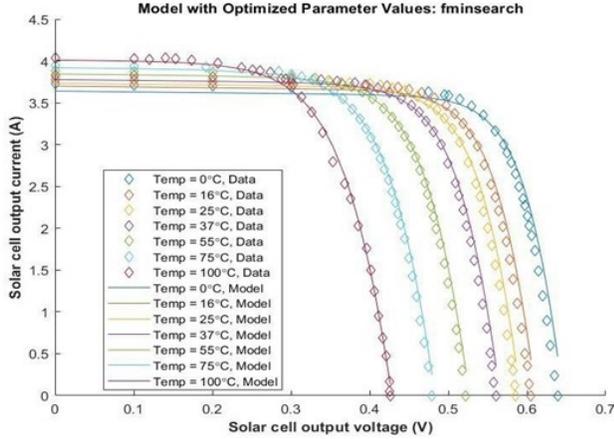| Parameter	Value
Elite Count	ceil(0.05*Population Size)
Crossover Fraction	0.8
Max Generations	8
Selection Fcn	Selectionstochunif
Creation Fcn	Gacreationuniform
Mutation Fcn	mutationgaussian

Fig. 5. Simulation of the optimization result by fminsearch method

When Isc be the current of short circuit and *Io* be the current of saturation, and let, *a* be the constant of diode ideality, with Ns be the cell connected in series, but T be the cell temperature, with the Boltzman constant represented $K= 1.38*10^{-23}$J/K; the electron charge represented $q =1.6*10^{-19}$C, then RS , then Rsh are the series then shunt resistance of the arrangement, one-to-one. Formerly the current of solar cell can be represented in equation one and equation two [26].

$$I = I_L - I_o \left\{ exp \left[\frac{V + IR_S}{\frac{N_s KT}{q}a} \right] - 1 \right\} - \frac{V + IR_S}{R_{sh}} \qquad (1)$$

The equation one maybe rewritten to equation three if the array thermal voltage (V_t) may be substituted like

$$V_t = \frac{N_s KT}{q} \qquad (2)$$

$$I = I_L - I_o \left\{ exp \left[\frac{V + IR_S}{V_t a} \right] - 1 \right\} - \frac{V + IR_S}{R_{sh}} \qquad (3)$$

Where the I is output current of the cell that depend on photo current (I_L) and current of saturation (I_o). where V is voltage of the cell, the R_s and R_{sh} are series and shunt resistances of solar cell respectively.

3.   RESEARCH METHODOLOGY

In this study the system simulated a solar cell in Simulink using initial and optimized parameters values then do comparing between values resulted from using these initial and optimized parameter values. Also, these comparing values obtained using the optimized parameter values and experimental data of a real solar cell to enhancement efficiency the solar cell.

3.1.   Genetic Algorithm

GA is a widely used global optimization technique which is a set of iteration processes [27]:

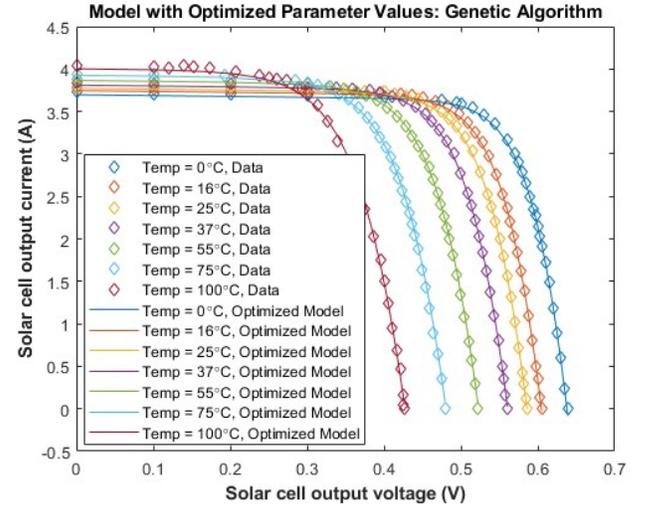Fig. 6. Simulation of the optimization result by GA method

1) Parameter Values are represented as a vector called chromosome where each parameter represents a gene in that chromosome.
2) Population represents a set of chromosomes used in every iteration.
3) Each chromosome can be used to obtain a value for the fitness function.
4) Fitness function is the function which we seek to minimize or maximize.
5) Iteration processes are designed to obtain new set of chromosomes which give better solutions.
6) Number current chromosomes are chosen to be in the new set of chromosomes as the give the best solutions compared to the other chromosome.
7) Number of chromosomes which are taken to be in the new generation is represented by Elite count.
8) The remaining genes are created via crossover with mutation processes.
9) Crossover fraction is the percentage of the new genes created via crossover.
10) The rest of genes are created via mutation.
11) Crossover is the process of choosing one or two genes in a chromosome and exchanging them with the Corresponding genes in another chromosome.
12) Mutation is the process of replacing the value of a gene with another one.
13) Iteration process stops when a termination condition is satisfied.

In this article used GA Function from MATLAB global optimization Toolbox which applies the genetic algorithm on a given objective function and constraints. The parent selection for crossover and mutation was done by a MATLAB function (selectionstochunif) which lays out a line in which each parent corresponds to a section of the line of length proportional to its scaled value. The algorithm moves along the line in steps of equal size. At each step, the algorithm allocates a parent from the section it lands on. The first step is a uniform random number less than step size. Mutation was done by a MATLAB function (mutationgaussian) which adds a random number taken from a Gaussian distribution with mean 0 to each entry of the muted chromosome. The initial Population for GA was done by a MATLAB function, (gacreationuniform) which creates a random initial population with a uniform distribution. The value was default when were not linear constraints, or when were integer constraints. The following Table 1 indicates the most important parameters of GA and their values.

Table 2. Parameters value for initial, optimized by Fminsearch, GA and NNA

Parameters	Initial Parameters	Optimized parameter values obtained by Fminsearch	Optimized parameter values obtained by GA	Optimized parameter values obtained by NNA
I_{os}	$30.e^{-7}$	$3.2305e^{-7}$	$3.0992e^{-7}$	$30.\,e^{-7}$
I_L	3.80	3.7345	3.8059	3.80
N	1.500	1.4177	1.3981	1.396
R_s	0.0040	0.0040	0.0041	0.0040
R_{sh}	1000	10.0963	10.0597	9.9066
TIPH	0.00100	0.00099	0.00081	0.00082
n	1.110	1.1685	1.1295	1.1345
TXIS	3000	3.0536	3.436	3.3136

Table 3. The comparing between GA and NNA cases.

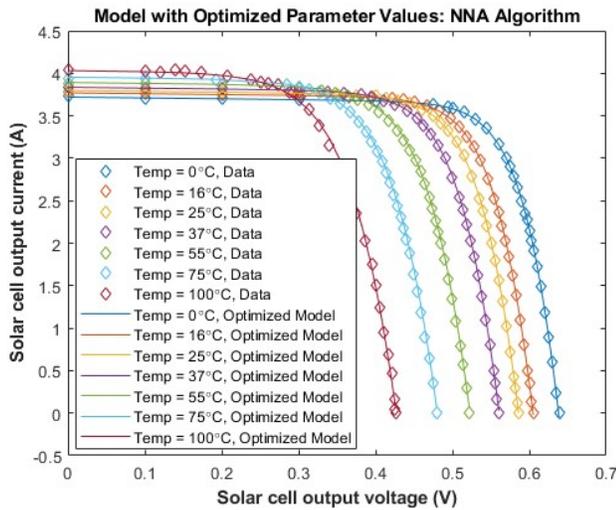|		Fminsearch	GA	NNA
First Objective Function (fval)	Execution Time [sec]	64.9	781	289
	Population Size		47	47
	Number of Iterations	8	8	8
	Value of Objective Function	1.1093	0.002856	0.005518
Second Objective Function (fvaltemp)	Population Size		12	26
	Number of Iterations	8	8	8
	Value of Objective Function	0.1369	0.1035	0.1069

Fig. 7. Simulation of the optimization result by NNA method

3.2. Algorithm of Neural Network

ANNs are computational simulations motivated by the construction and functional aspects of organic neural networks. The D dimension optimized problem, a design solution is an array of 1×D, on behalf of input data in the NNA. The array is clear as given follows:

$$Pattern\ Solution = [x1, x2, x3....x_D]. \qquad (4)$$

The matrix X be randomly produced among lower bound and upper bound of a problem.

Pattern Solutions Population, $X =$

$$\begin{bmatrix} x_1^1 & x_2^1 & x_3^1 & \cdots & x_D^1 \\ \vdots & & \ddots & & \vdots \\ x_1^{Npop} & x_2^{Npop} & x_3^{Npop} \cdots & x_D^{Npop} \end{bmatrix} \qquad (5)$$

The suitability in maximization problems in a pattern resolution was obtained by calculating the cost function called fitness function represented of (C) at the equivalent pattern resolution known as:

$$Ci = f(xi_1,\ xi_2,\ ...,xi_D), i = 1, 2, 3, ..., Npop. \qquad (6)$$

First weights into ANNs stay random numbers that definite as assumed in the next equation;

$W(t) = [W_1, W_2, ..., W_{Npop}]$ every place W is a square matrix

$$= \begin{bmatrix} w_1^1 & w_1^i \cdots & w_1^{Npop} \\ \vdots & \ddots & \vdots \\ w_{Npop}^1 & w_{Npop}^i \cdots & w_{Npop}^{Npop} \end{bmatrix}$$

$$= \begin{bmatrix} w_{11} & w_{i1} \cdots & w_{Npop1} \\ \vdots & \ddots & \vdots \\ w_{1Npop} & w_{iNpop} \cdots & w_{NpopNpop} \end{bmatrix} \qquad (7)$$

Next pattern resolutions ($X\text{text}_{New}$) calculated Afterward forming a weight matrix (W) by using the next equations stimulated by the weight summation technique used in the ANNs:

$$x_j^{New}(t+1) = \sum_{i=1}^{Npop} w_{ij}(t) \times Xi(t), \quad j = 1, 2, 3, ..., N_{pop} \qquad (8)$$

$$X_i(t+1) = x_i(t) + (x_i^{New}(t+1), \quad i = 1, 2, 3, ..., Npop. \qquad (9)$$

When producing the new pattern results after the preceding population into patterns, established on the better weight value that named "target weight", also the matrix of weight must be updated. then next equations propose an updating equation for the matrix of weight.

$$w_i^{update}(t+1) = w_i(t) + 2 \times rand \times (w^{Target}(t) - w_i(t)), \qquad i = 1;\ 2;\ 3;\ 4..., \ Npop \qquad (10)$$

4. RESULTS AND ANALYSIS

4.1. The Results of Work Before and After Optimization Case

In the beginning work represented the relationship between solar cell output voltage and solar cell output current dependent on experimental values in wide range of measured temperatures. Before
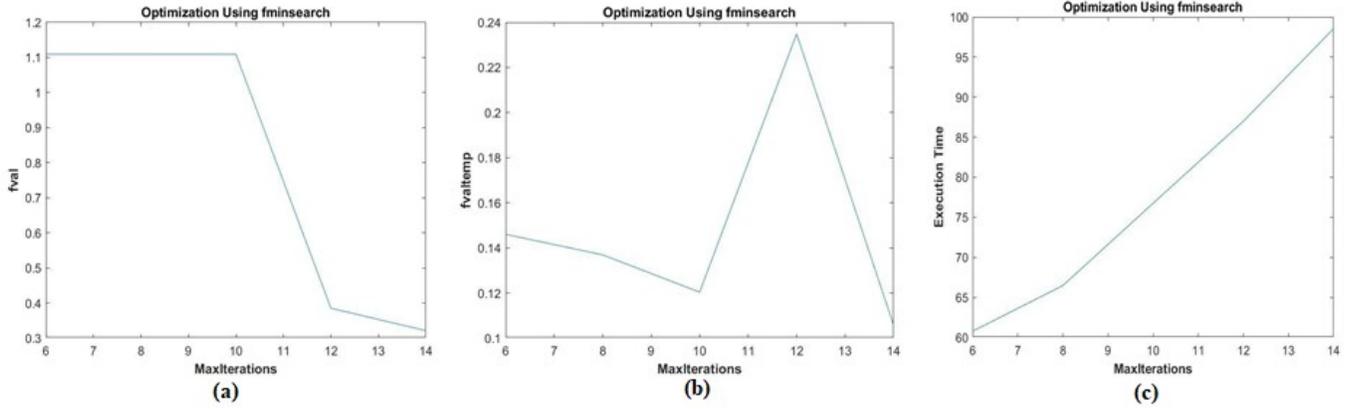
Fig. 8. Fminsearch method for (a. The fitness function value, b. The fitness function value temperature, c. Execution time)
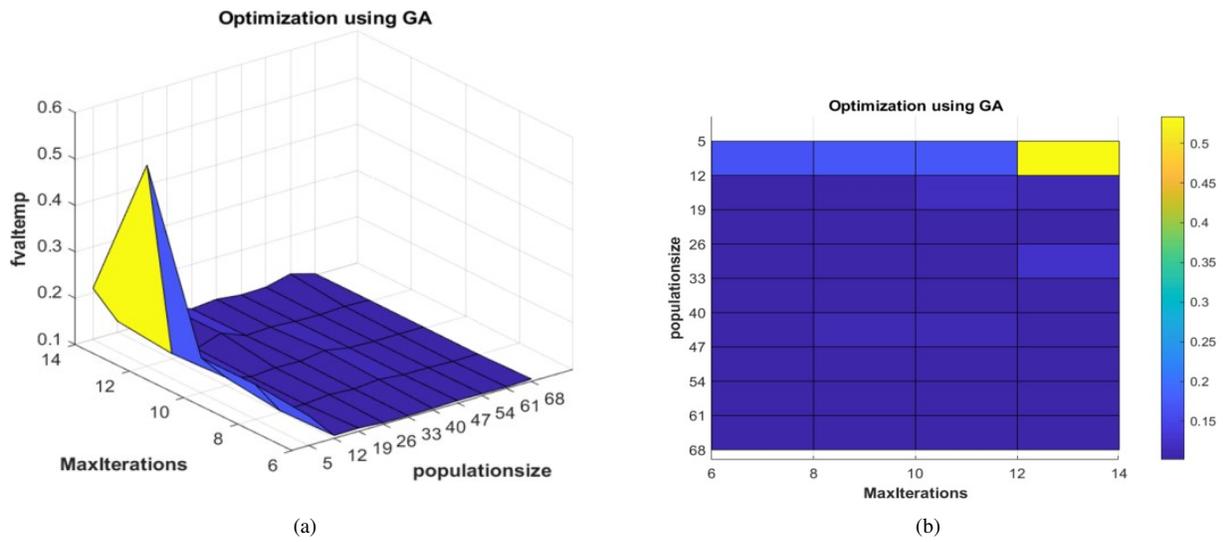

(a)

(b)

Fig. 9. (a) The fitness function temperature value using GA algorithum.(fvaltemp), (b) Selected population size of fvaltemp
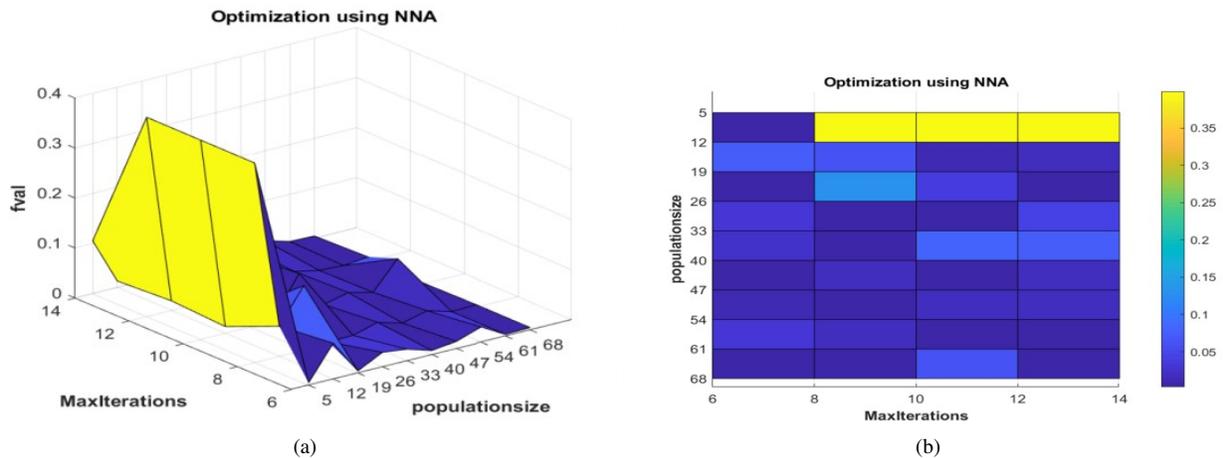

(a)

(b)

Fig. 10. (a) The fitness function value using NNA algorithm, (b) Selected population size in NNA of fval.
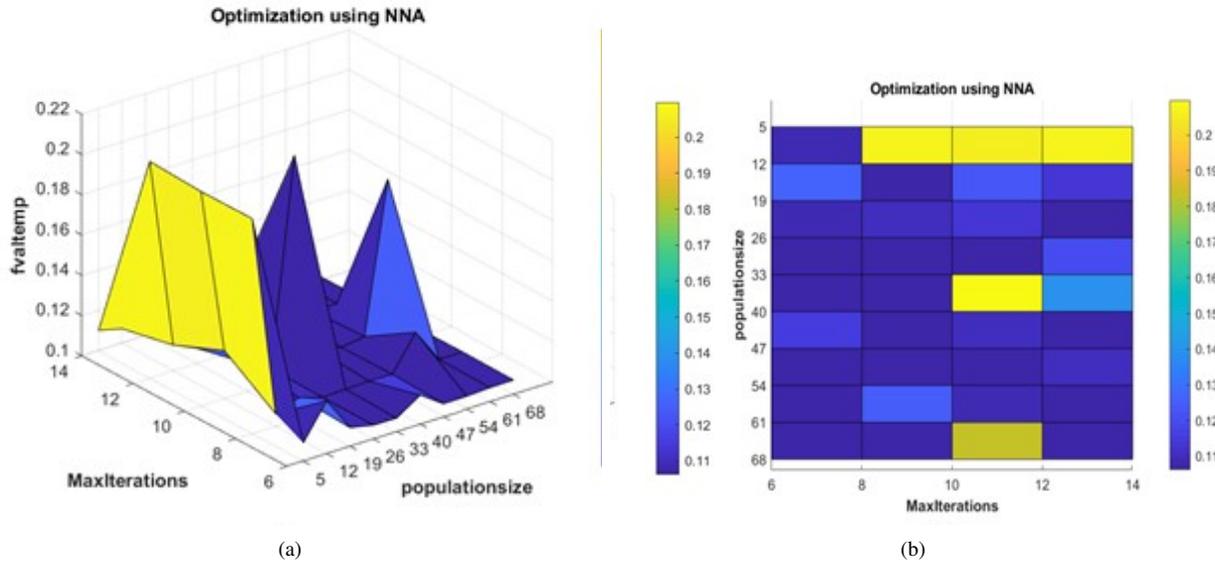
Fig. 11. (a) The fitness function temperature value using NNA algorithm, (b) Selected population size in NNA of fvaltemp
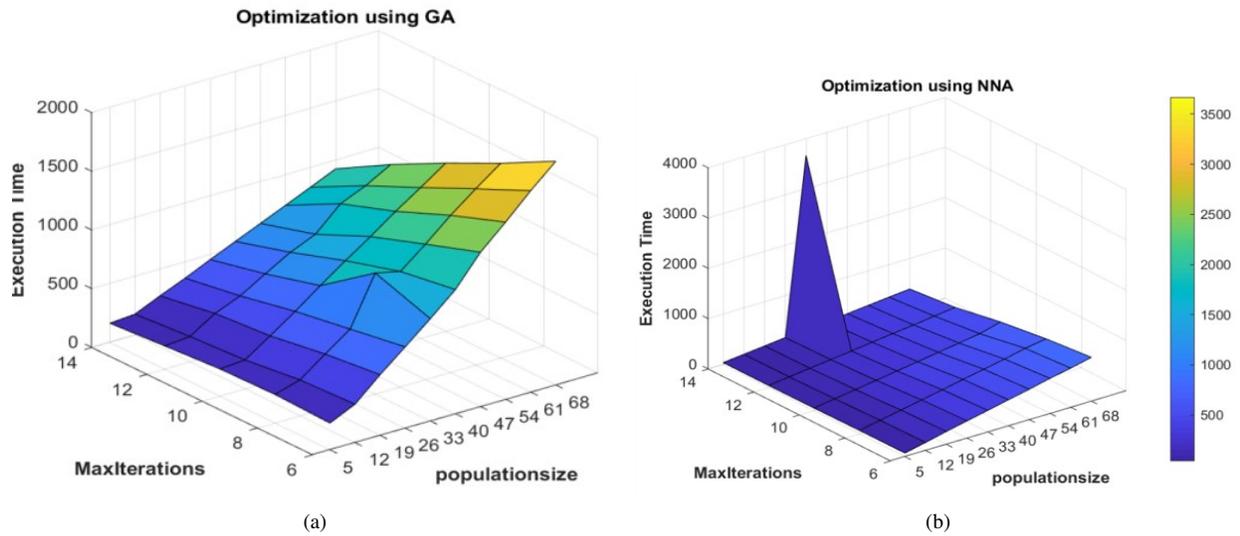

Fig. 12. the execution time for GA and NNA methods. (a) execution time for GA, (b) execution time for NNA).

improvement used initial parameters (I_o , $I_L, n, R_s,$ and R_{sh}) with different values of temperatures to draw the curve V/I characteristics as in the following Fig. 3. The next Fig. 4 evaluated initial parameters with experimental values, a difference was observed between the measured data with initial parameters.

The fminsearch is one of the optimization methods that used simplex search method, its basic method used to compare the experimental data with optimized result by fminsearch method that showed in Fig. 5. The parameters result values obtained evaluated by using Genetic Algorithm, In Fig. 6 the improvement values obtained by GA algorithm that corresponding with experimental data. The other optimization method applied in this work was NNA that shows in Fig. 7, NNA algorithm represented the improvement values corresponding with experimental data. In the three optimization methods that applied in the same number of iterations (8 iterations). The Table 2 explained the values of parameters obtained by initial (I_o , $I_L, n, R_s and R_{sh}$) that comparing with optimized parameters values using: Fminsearch, GA and NNA.

4.2. Selecting fval , fvaltemp and Execution Time for fminsearch

The first optimization method process was fminsearch using to draw relation fval, fvaltemp and execution time with number of iterations. The value of fval function was not content, it was 1.1 until 10 iterations then decrease to 0.4 at 12 iterations. In fvaltemp, it was decrease to 0.12 at 10 iteration with overshot at 12 iteration that become 0.235. For execution time was increase linear to 67 at 8 iteration.at all figures the functions not constant after 8 iterations.

4.3. Selecting Best Population Size besides Iterations Number for GA

To select best population size and number of iterations made an experiment result that executes optimization process at different values from population size besides iterations number.

The population sizes points are: 5, 12, 19, 26, . . . , 68, with numbers of iterations points are: 6, 8, . . . , 14. For first optimization process (fval) function was represented by the Fig. ??

It indicated relation fval function with different population sizes and numbers of iterations.

The previous Fig. 9(a). indicated for relation (fvaltemp) function with different population sizes besides numbers of iterations .then in the Fig. **??** shows obtain good results of "fvaltemp" function, then can choose in GA at 12 as population size and 8 as max. number of iterations (Generations), the overall results indicated that GA is stable.

In the Fig. 10(a) indicated for relation (fval) function with different population sizes besides iterations number, so in Fig. **??** shows how can obtained good results of "fval" function, the stable state choose in NNA algorithm at 47 population size and 8 as max. number of iterations (Generations)

The Fig. 11(a) indicated of relation fvaltemp function in NNA with different population sizes and numbers of iterations. Then in Fig. 11(b) shows who can obtain a good results of "fvaltemp" function , from looking for figure above can choose in NNA at 26 population size and 8 for max. number of iterations (Generations). The result represented for NNA is not stable.

4.4. Execution Time for the Whole Process

In Fig. 12(a) shows the execution time of GA increases drastically with the incensement of population size and number of iterations. Then in Fig. 12(b) shows the execution time of neural network algorithm increases slightly with the incensement of population size besides iterations number. The Table 3 illustrates the comparing between GA besides NNA cases from side (fval) and (fvaltemp) functions, and also from execution time side. Fminsearch function don't have population size with less execution time corresponding with GA and NNA algorithms, but Fminsearch was not stable. Also the value of objective function in fval and fvaltemp functions for GA was less value corresponding with Fminsearch and NNA.

5. Conclusion

In this project tried compute the optimization parameters values of solar cell. The system evaluated by Fminsearch method, this method spend less time comparing with GA and NNA methods, but the GA is more stable and accuracy. The comparing fval function values in GA and NNA at the same population sizes and numbers of iterations. Fminsearch function cannot comparing from point the population size, due to it don't have this facility. In this proposal found that results are often in GA was better than Fminsearch and NNA methods. Then when made comparing in (fvaltemp) values for GA and NNA at the same population sizes and numbers of iterations, so showed the result that obtained from GA often better than NNA. And also the result show the execution time more accuracy in GA when comparing between execution times in GA and NNA at the same population sizes and numbers of iterations. With the end result GA is much better than NNA in results and stable but Fminsearch has less execution time (64, 9 s). The model suitable for hot weather specially in middle of Iraq that check in different seven temperatures.

References

[1] A. R. Pazikadin, et al., "Solar irradiance measurement instrumentation and power solar generation forecasting based on Artificial Neural Networks (ANN): A review of five years research trend," *Sci. Total Environ.* , vol. 715, p. 136848, 2020.

[2] M. A. Vitorino, et al., "Using the model of the solar cell for determining the maximum power point of photovoltaic systems," *Europ. Conf. Power Electro. Appli.*, pp. 1-10, 2007.

[3] H.-H. Chung, et al., "A novel maximum power point tracking technique for solar panels using a SEPIC or Cuk converter," *IEEE trans. power electron.*, vol. 18, pp. 717-724, 2003.

[4] S. Hashemzadeh and M. Hejri, "A Fast and Accurate Global Maximum Power Point Tracking Method for Solar Strings under Partial Shading Conditions," *J. Oper. Autom. Power Eng.*, vol. 8, pp. 245-256, 2020.

[5] T. O. Saetre, et al., "A new analytical solar cell I–V curve model," Renewable Energy, vol. 36, pp. 2171-2176, 2011.

[6] M. A. Hamdy, "A new model for the current-voltage output characteristics of photovoltaic modules," *J. power sources*, vol. 50, pp. 11-20, 1994.

[7] G. Ahmad, et al., "Theoretical analysis and experimental verification of PV modules," *Renewable energy*, vol. 28, pp. 1159-1168, 2003.

[8] V. MILENOV, et al., "Modeling of electrical characteristics of various PV panels," $16^t h$ *Conf. Electri. Machines, Drives Power Syst. (ELMA)*, pp. 1-5, 2019.

[9] E. Skoplaki, et al., "A simple correlation for the operating temperature of photovoltaic modules of arbitrary mounting," *Sol. Energy Mater. Sol. Cells*, vol. 92, pp. 1393-1402, 2008.

[10] Z. Li, et al., "Investigating the effect of radiative cooling on the operating temperature of photovoltaic modules," *Solar RRL*, vol. 5, p. 2000735, 2021.

[11] P. N. Botsaris and J. A. Tsanakas, "Infrared thermography as an estimator technique of a photovoltaic module performance via operating temperature measurements," *Proce. $10^t h$ ECNDT Conf.*, 2010.

[12] G. Ciulla, et al., "A comparison of different one-diode models for the representation of I–V characteristic of a PV cell," *Renewable Sustainable Energy Rev.*, vol. 32, pp. 684-696, 2014.

[13] S. Al-Rawi, "Numerical solution of integral equations using taylor series," *J. College of Educ.*, vol. 5, pp. 51-60, 1992.

[14] E. Duran, et al., "Different methods to obtain the I–V curve of PV modules: A review," in 2008 33rd IEEE Photovoltaic Specialists Conference, 2008, pp. 1-6.

[15] M. S. Rasheed and S. Shihab, "Analysis of Mathematical Modeling of PV Cell with Numerical Algorithm," *Advanced Energy Conver. Materi.*, pp. 70-79, 2020.

[16] M. Rasheed, et al., "A comparative Analysis of PV Cell Mathematical Model," *J. Phys. Conf. Ser.*, p. 012042, 2021.

[17] A. Lupu, et al., "A review of solar photovoltaic systems cooling technologies," IOP Conf. Series: Materi. Scie. Eng., p. 082016, 2018.

[18] M. A. Khan, et al., "Performance evaluation of photovoltaic solar system with different cooling methods and a bi-reflector PV system (BRPVS): an experimental study and comparative analysis," *Energies*, vol. 10, p. 826, 2017.

[19] Y. Bella and F. Kebbab, "Application of Fminsearch Optimization to Minimize Total Maintenance Cost with the Aim of Reducing Environmental Degradation," *Eng. Techno. Applied Science Research*, vol. 12, pp. 8548-8554, 2022.

[20] J. D. Bastidas-Rodriguez, et al., "A genetic algorithm for identifying the single diode model parameters of a photovoltaic panel," *Math. Comput. Simul*, vol. 131, pp. 38-54, 2017.

[21] N. Hamid, et al., "Parameters identification of photovoltaic solar cells and module using the genetic algorithm with convex combination crossover," *Int. J. Ambient Energy*, vol. 40, pp. 517-524, 2019.

[22] G. Petrone, et al., "Online identification of photovoltaic source parameters by using a genetic algorithm," *Applied Sciences*, vol. 8, p. 9, 2018.

[23] E. Karatepe, et al., "Neural network based solar cell model," *Energy Convers. Manage.* , vol. 47, pp. 1159-1178, 2006.

[24] V. Z. Antonopoulos, et al., "Solar radiation estimation methods using ANN and empirical models," *Comput. Electron. Agric.*, vol. 160, pp. 160-167, 2019.

[25] M. J. Wagner, et al., "Optimizing dispatch for a concentrated solar power tower," *Solar Energy*, vol. 174, pp. 1198-1211, 2018.

[26] A. Sadollah, et al., "A dynamic metaheuristic optimization model inspired by biological nervous systems: Neural network algorithm," *Appl. Soft Comput.*, vol. 71, pp. 747-782, 2018.

[27] M. K. Mishu, et al., "An adaptive TE-PV hybrid energy harvesting system for self-powered iot sensor applications," *Sensors*, vol. 21, p. 2604, 2021.

[28] R. B. Roy, et al., "A comparative performance analysis of ANN algorithms for MPPT energy harvesting in solar PV system," *IEEE Access*, vol. 9, pp. 102137-102152, 2021.

[29] H. Dahmardeh, et al., "A novel combined DTC method and SFOC system for three-phase induction machine drives with PWM switching method," J. Oper. Autom. Power Eng., 2022.