Available online at www.qu.edu.iq/journalcm
JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

An efficient Approximate Solution for Non-Linear Solar Cell Equation using Inverse Quadratic Interpolation Method

Mohammed Abdulhadi Sarhan

Mathematics Department, College of Sciences, Al-Mustansiriyah University, Baghdad, Iraq .Email: mohraf_98@yahoo.com , mohraf_98@uomustansiriyah.edu.iq

ARTICLE INFO

Article history:
Received: 28 /10/2020
Rrevised form: 29 /12/2020
Accepted : 31 /12/2020
Available online: 02 /01/2021

Keywords:

Inverse Quadratic Interpolation method; iterative method; Newton's algorithm; non-linear equation.

ABSTRACT

The main purpose of this research is to discuss the numerical solutions of a single-diode nonlinear equation for a solar cell in a more efficient way. The inverse quadratic interpolation technique for finding the root(s) of a function is applied to our study problem. Numerical results show that the proposed three points iterative method is compatible to Newton's method, accurate and effective.

MSC. 41A25; 41A35; 41A36.

DOI : https://doi.org/10.29304/jqcm.2020.12.4.723

1. Introduction

Many problems require finding some or all roots of a non-linear equation. In general, an equation containing one variable can be written as $f(x) = 0$. There are a number of numerical methods to find an approximate value for a given root of the previous equation, the numerical iterative algorithms for example iterative, regular false; Bisection; secant and Newton techniques are used to achieve the approximate numerical solution of these equations [1-5]. All these numerical methods need a rough approximate value of a given equation root to enable it to generate sequential initial values of a given equation root to enable it to generate a sequential of better approximate values for that root. There are many techniques improved on the perfection of convergent Newton's method, in order to obtain a superior convergence order than NRM [6-11].

This paper is attention with the iterative algorithm to get the voltage's value of the photovoltaic cell V_{pv} in the conditions $f(x) = 0$, and $f'(x) \neq 0$ where $f: R \rightarrow R$ be real function. It is systematic as the following steps: section two describes the design of the model chosen (Equation of Non-linear Solar Cell); section three characterizes the two

∗Corresponding author: Mohammed Abdulhadi Sarhan

Email addresses: mohraf_98@yahoo.com , mohraf_98@uomustansiriyah.edu.iq

Communicated by: Alaa Hussein Hamadi

numerical formulas; the proposed method (Inverse Quadratic Interpolation method) have been portrayed; section four results and discussion; finally section five the checked results have been concluded.

2. Equation of Non-linear Solar Cell

The current and voltage characteristics of the solar cell can be illustrated by the following equations [12-16]

$$I_{source} = I_{ph} \tag{1}$$

$$I_D = I_s \times e^{(V_D/nV_T)} - 1 \tag{2}$$

Merge Eq. 1 in Eq. 2, yields

$$I_{source} - I_s\left(e^{(-V\times q/m\times k\times T)} - 1\right) = V/R \text{ [17-19]} \tag{3}$$

In Ohms law; Current $= \frac{\text{Voltage}}{\text{Resistance}}$, Power = Current × Voltage

Then $$I_{pv} = V_{pv}/R;\ P_{pv} = I_{pv} \times V_{pv} \text{ [20-21]} \tag{4}$$

where:

I_s : The reverse saturation current= 10^{-12} measured in Ampere; I_{ph}: The photocurrent measured in Ampere; I_0: The reverse saturation current of the diode measured in Ampere; I_{pv} and V_{pv} are the delivered current and voltage measured in Ampere and Volt respectively; $KT/q = 0.026$ V = 26 mV at room Temperature (T = 25 °C); m : The recombination factor = 1.2; The electron charge $q = 1.6 \times 10^{-19}$ C, The Boltzmann constant $k = 1.38 \times 10^{-23}$J/K [20-21].

3. Numerical Formulas

Definition 3.1 The Newton's method so called Newton Raphson method, is a root- finding algorithm that uses the first few terms of the Taylor series of a function $f(x)$ approximately a suspected root The algorithm is applied iteratively to obtain [17]

$$x_{n+1} = x_n - \frac{f(x_n)}{\acute{f}(x_n)} \text{ for } n = 0, 1, 2, \dots. \tag{5}$$

Definition 3.2 The Inverse quadratic interpolation is a root-finding algorithm, for solving equations of the form $y = f(x) = 0$. The idea is to use quadratic interpolation to approximate the inverse of f. IQIM required three initial values x_0, x_1, x_2 and realized by the recurrence relation

$$x_{n+1} = \frac{f_{n-1}f_n}{(f_{n-2}-f_{n-1})(f_{n-2}-f_n)}x_{n-2} + \frac{f_{n-2}f_n}{(f_{n-1}-f_{n-2})(f_{n-1}-f_n)}x_{n-1} + \frac{f_{n-2}f_{n-1}}{(f_n-f_{n-2})(f_n-f_{n-1})}x_n \tag{6}$$

where $f_n = f(x_n)$

4. Results and Discussion

Consider the Eq. 3, the initial value $x_0 = 1$; the results obtained by IQIM method are shown in Tables 1, 2, 3, 4 and 5 with using load resistance R = 1, 2, 3, 4 and 5. By supposing that $\varepsilon = 10^{-9}$ as the tolerance.

$\sigma = |x_{n+1} - x_n| < \varepsilon$, $|f(x_n)| < \varepsilon$

Tables 1 to 5 show the results for the proposed method when the load resistance R = 1; and Figure 1, 2, 3, 4 and 5 present the acquired results using the standard and proposed methods.

Table 1 - The roots of Eq. 3 using Inverse quadratic interpolation (R = 1).

The load resistance $R = 1$				
Iterations	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε- IQIM
1	0.933205006	0.933205006	0.870871583	0.010781872
2	0.92406215	0.92406215	0.853890857	0.001639015
3	0.922462853	0.922462853	0.850937715	$3.971810E^{-05}$
4	0.922423156	0.922423156	0.850864479	$2.164130E^{-08}$
5	0.922423135	0.922423135	0.850864439	$5.884180E^{-15}$
6	0.922423135	0.922423135	0.850864439	0.000000000

Table 2 - The roots of Eq. 3 using Inverse quadratic interpolation (R = 2).

The load resistance $R = 2$				
Iterations	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε- IQIM
1	0.930694821	0.46534741	0.433096425	0.013659438
2	0.919616307	0.459808154	0.422847076	0.002580925
3	0.917134941	0.458567471	0.42056825	$9.955880E^{-05}$
4	0.917035522	0.458517761	0.420477074	$1.396400E^{-07}$
5	0.917035382	0.458517691	0.420476946	$2.496890E^{-13}$
6	0.917035382	0.458517691	0.420476946	0.000000000

Table 3 - The roots of Eq. 3 using Inverse quadratic interpolation (R = 3).

The load resistance $R = 3$				
Iterations	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε- IQIM
1	0.92805625	0.309352083	0.287096134	0.017652876
2	0.914591297	0.304863766	0.278825747	0.004187923
3	0.910667481	0.303555827	0.27643842	0.000264107
4	0.910404391	0.30346813	0.276278718	$1.017030E^{-06}$
5	0.910403374	0.303467791	0.276278101	$1.362810E^{-11}$
6	0.910403374	0.303467791	0.276278101	0.00000000

Table 4 - The roots of Eq. 3 using Inverse quadratic interpolation (R = 4).

The load resistance $R = 4$				
Iterations	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε- IQIM
1	0.925280086	0.231320021	0.214035809	0.023539484
2	0.908858052	0.227214513	0.20650574	0.00711745
3	0.902502556	0.225625639	0.203627716	0.000761954
4	0.90174946	0.225437365	0.203288022	$8.858440E^{-06}$
5	0.901740603	0.225435151	0.203284029	$1.085660E^{-09}$
6	0.901740602	0.22543515	0.203284028	$1.110220E^{-16}$
7	0.901740602	0.22543515	0.203284028	0.000000000

Table 5 - The roots of Eq. 3 using Inverse quadratic interpolation (R = 5).

The load resistance $R = 5$				
Iterations	**V_{pv}-IQIM**	**I_{pv}-IQIM**	**P_{pv}-IQIM**	**ε- IQIM**
1	0.922356344	0.184471269	0.170148245	0.03326363
2	0.902249489	0.180449898	0.162810828	0.013156774
3	0.891632149	0.17832643	0.159001578	0.002539434
4	0.88919712	0.177839424	0.158134304	0.000104405
5	0.889092881	0.177818576	0.15809723	1.659580E-07
6	0.889092715	0.177818543	0.158097171	3.731460E-13
7	0.889092715	0.177818543	0.158097171	0.000000000

The material below gives the solution of Eq. 3 along with the estimated points solved in MATLAB. The results are found using Newton method. The some discussion on possible improvements. Our allowed tolerance was $\varepsilon = 10^{-9}$.

1) Solutions of Eq. 3 with R = 1,

Estimated point for V_{pv}, at a point V: 0.922423135

Estimated point for I_{pv}, at a point I: 0.9224231350

Estimated point for P_{pv}, at a point P: 0.850864439

with number of iteration = 9.

2) Solutions of Eq. 3 with R = 2,

Estimated point for V_{pv}, at a point V: 0.917035382

Estimated point for I_{pv}, at a point I: 0.458517691

Estimated point for P_{pv}, at a point P: 0.420476946

with number of iteration n = 9.

3) Solutions of Eq. 3 with R = 3,

Estimated point for V_{pv}, at a point V: 0.910403374

Estimated point for I_{pv}, at a point I: 0.303467791

Estimated point for P_{pv}, at a point P: 0.276278101

with number of iteration n = 9.

4) Solutions of Eq. 3 with R = 4,

Estimated point for V_{pv}, at a point V: 0.901740602

Estimated point for I_{pv}, at a point I: 0.225435150

Estimated point for P_{pv}, at a point P: 0.203284028

with number of iteration n = 9.

5) Solutions of Eq. 3 with R = 5,

Estimated point for V_{pv}, at a point V: 0.889092715

Estimated point for I_{pv}, at a point I: 0.1778185430

Estimated point for P_{pv}, at a point P: 0.158097171

with number of iteration $n = 10$.

It would be expected that the IQIM could be as good as or possibly better than the newton method for $R = 1, 2, 3, 4$ and 5. This is an interesting case because we are only using transcendental function

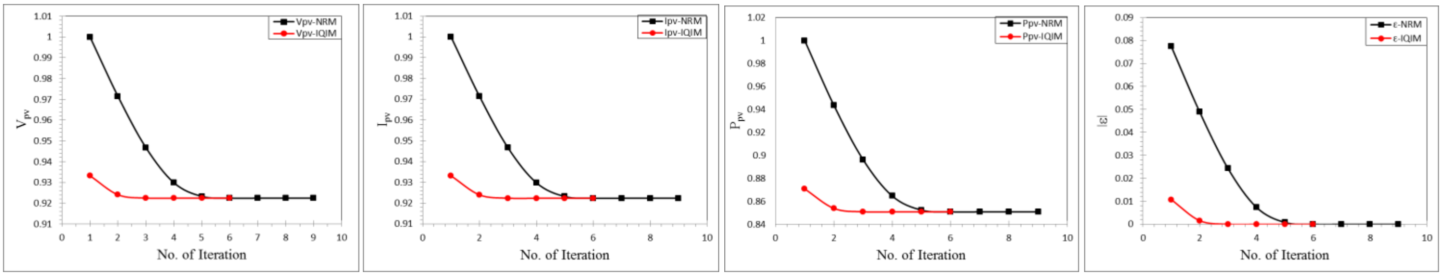

Fig. 1 - The absolute error and numerical results based on Eqns. 5 and 6.

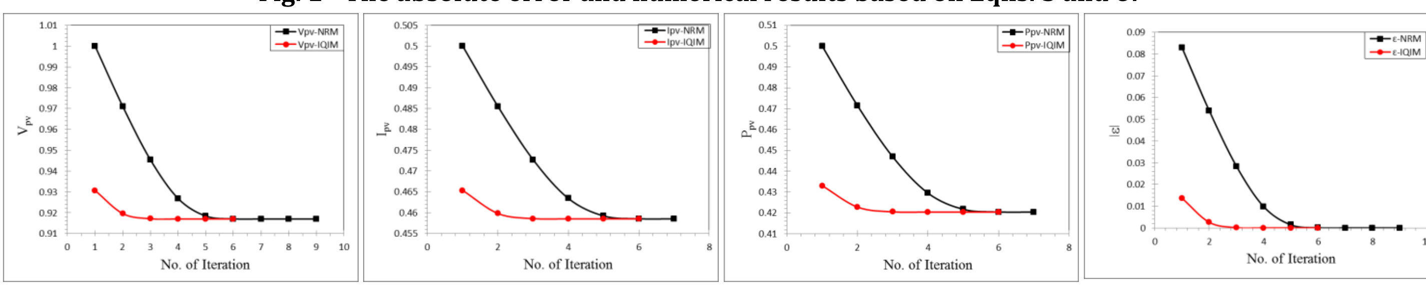

Fig. 2 - The absolute error and numerical results based on Eqns. 5 and 6.

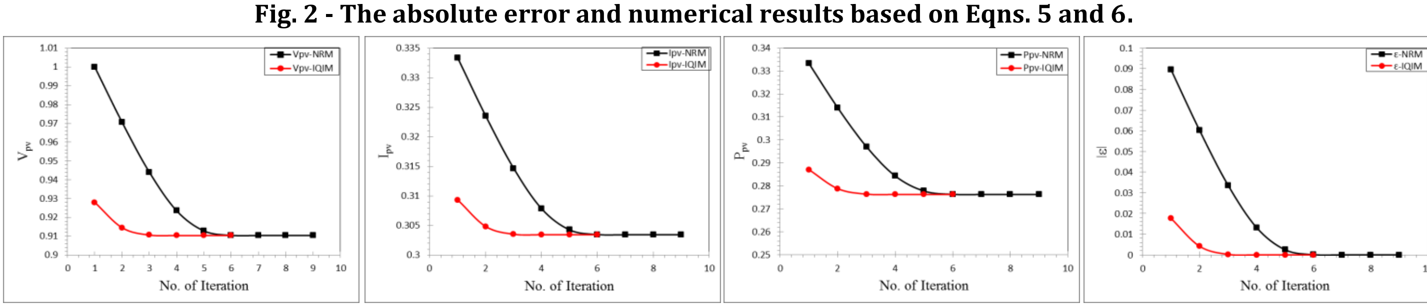

Fig. 3 - The absolute error and numerical results based on Eqns. 5 and 6.

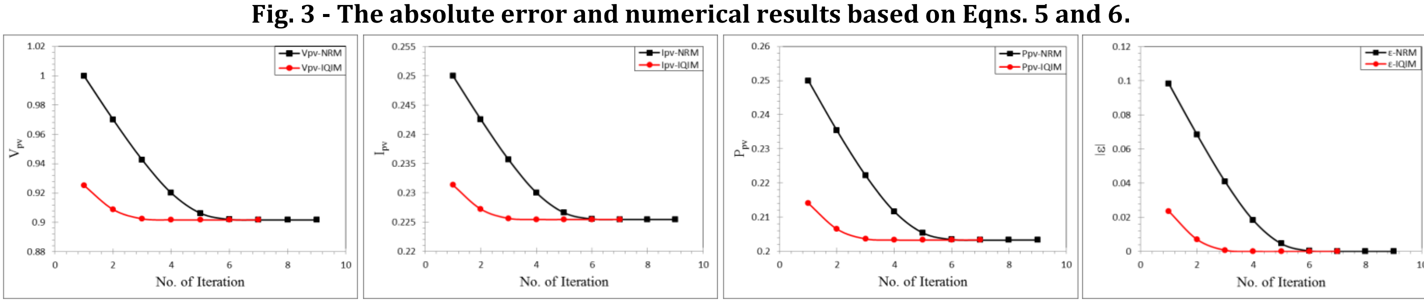

Fig. 4 - The absolute error and numerical results based on Eqns. 5 and 6.

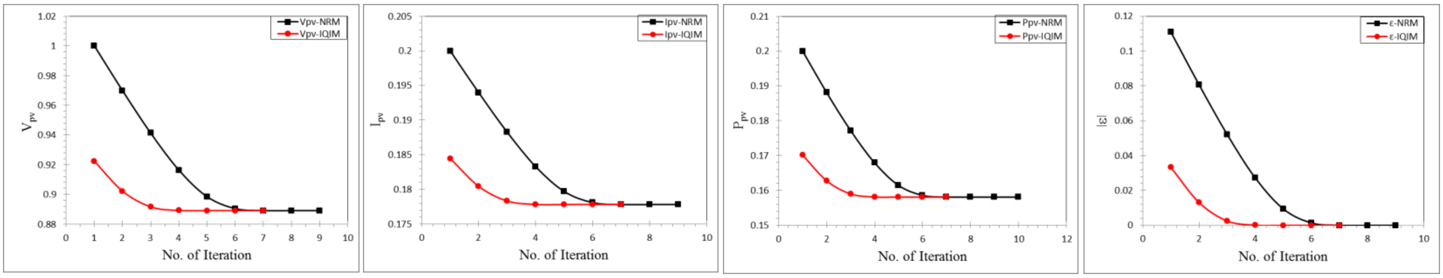

Fig. 5 - The absolute error and numerical results based on Eqns. 5 and 6.

5. Conclusion

We present the results of single-diode non-linear equation numerical tests to compare the efficiencies of the proposed technique. We used IQIM and Newton's techniques for solving non-linear equation of a solar cell. Numerical computations are reported in this paper.

References

[1] M. RASHEED, and M. A. Sarhan, "Solve and Implement the main Equations of Photovoltaic Cell Parameters Using Visual Studio Program", Insight-Mathematics, vol. 1 (1) (2019), pp. 17-25.
[2] M. Rasheed, and M. A. Sarhan, "Characteristics of Solar Cell Outdoor Measurements Using Fuzzy Logic Method", Insight-Mathematics, vol. 1 (1) (2019), pp. 1-8.
[3] M. RASHEED, and M. A. Sarhan, "Measuring the Solar Cell Parameters Using Fuzzy Set Technique", Insight-Electronic, vol. 1 (1) (2019), pp. 1-9.
[4] M. RASHEED, "Linear Programming for Solving Solar Cell Parameters", Insight-Electronic, vol. 1 (1) (2019), pp. 10-16.
[5] M. RASHEED, "Investigation of Solar Cell Factors using Fuzzy Set Technique", Insight-Electronic, vol. 1 (1) (2019), pp. 17-23.
[6] M. RASHEED, and S. SHIHAB, "Analytical Modeling of Solar Cells", Insight Electronics, vol. 1 (2) (2019), pp. 1-9.
[7] S. SHIHAB, and M. RASHEED, "Modeling and Simulation of Solar Cell Mathematical Model Parameters Determination Based on Different Methods", Insight Mathematics, vol. 1 (1) (2019), pp. 1-16.
[8] M. RASHEED, and S. SHIHAB, "Parameters Estimation for Mathematical Model of Solar Cell", Electronics Science Technology and Application, vol. 6, (1) (2019), pp. 20-28.
[9] M. S. Rasheed, "Approximate Solutions of Barker Equation in Parabolic Orbits", Engineering & Technology Journal, vol. 28 (3) (2010), pp. 492-499.
[10] M. S. Rasheed, "An Improved Algorithm For The Solution of Kepler‘s Equation For An Elliptical Orbit", Engineering & Technology Journal, vol. 28 (7) (2010), pp. 1316-1320.
[11] M. S. Rasheed, "Acceleration of Predictor Corrector Halley Method in Astrophysics Application", International Journal of Emerging Technologies in Computational and Applied Sciences, vol. 1 (2) (2012), pp. 91-94.
[12] M. S. Rasheed, "Fast Procedure for Solving Two-Body Problem in Celestial Mechanic", International Journal of Engineering, Business and Enterprise Applications, vol. 1 (2) (2012), pp. 60-63.
[13] M. S. Rasheed, "Solve the Position to Time Equation for an Object Travelling on a Parabolic Orbit in Celestial Mechanics", DIYALA JOURNAL FOR PURE SCIENCES, vol. 9 (4) (2013), pp. 31-38.
[14] M. S. Rasheed, "Comparison of Starting Values for Implicit Iterative Solutions to Hyperbolic Orbits Equation", International Journal of Software and Web Sciences (IJSWS), vol. 1 (2) (2013), pp. 65-71.
[15] M. S. Rasheed, "On Solving Hyperbolic Trajectory Using New Predictor-Corrector Quadrature Algorithms", Baghdad Science Journal, vol. 11 (1) (2014), pp. 186-192.
[16] M. S. Rasheed, "Modification of Three Order Methods for Solving Satellite Orbital Equation in Elliptical Motion", Journal of university of Anbar for Pure science, vol. 14 (1) (2020), pp. 33-37.
[17] M. Rasheed, and S. Shihab, "Numerical Techniques for Solving Parameters of Solar Cell", Applied Physics, vol. 3 (1) (2020), pp. 16-27.
[18] M. RASHEED, and S. SHIHAB, "Modifications to Accelerate the Iterative Algorithm for the Single Diode Model of PV Model", Iraqi Journal of Physics (IJP), vol. 18 (47) (2020), pp. 33-43.
[19] M. S. Rasheed, S. Shihab, "Modelling and Parameter Extraction of PV Cell Using Single-Diode Model". Advanced Energy Conversion Materials, 1 (2) (2020), pp. 96-104. Available from: http://ojs.wiserpub.com/index.php/AECM/article/view/550.
[20] M. S. Rasheed, and S. Shihab, "Analysis of Mathematical Modeling of PV Cell with Numerical Algorithm". Advanced Energy Conversion Materials, vol. 1 (2) (2020), pp. 70-79. Available from: http://ojs.wiserpub.com/index.php/AECM/article/view/328.
[21] M. A. Sarhan, "Effect of Silicon Solar Cell Physical Factors on Maximum Conversion Efficiency Theoretically and Experimentally", Insight-Electronic, vol. 1 (1) (2019), pp. 24-30.