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JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

A Special Iterative Algorithm for Solving Nonlinear Equations

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ARTICLE INFO

Article history:
Received: 22 /03/2020
Rrevised form: 20 /04/2021
Accepted : 25 /05/2021
Available online: 28 /05/2021

Keywords:

Dekker's method; Inverse Quadratic Interpolation method; current voltages; power; load resistance R; roots.

ABSTRACT

In this work, we exhibit some variants iterative techniques free from second derivatives of the function foe solving nonlinear equation of the form f(x) = 0 and observe that number of iterations of the proposed method is five. Many numerical experiments are bearing to interpret the accuracy, performance and efficiency of the new iterative technique.

MSC. 41A25; 41A35; 41A36

DOI : https://doi.org/10.29304/jqcm.2021.13.1.804

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Communicated by: Dr.Rana Jumaa Surayh aljanabi.

1. Introduction

In this article, we examine iterative numerical methods to detect zeros of the nonlinear equations in the type of $f(x) = 0$ for single diode equation of the photovoltaic cell. The classical and standard methods such as Newton's method is often used to calculate the roots of the functions numerically; which are achieved by several researchers for example Rasheed et al.; they demonstrate and determined the roots of nonlinear equations in the physics field like solar cell equation of the single diode [1-115].

IQIM requires 6 evaluations of the function while the other technique (DM) needs 4 evaluation of the function. The following steps are investigate the procedure of this work: section two, three and four investigating the modelling and the root finding of IQIM and DM algorithms respectively while; section five and six indicate the numerical problems, discussion and conclusion results respectively.

2. – Property and Characteristics of a Non-Linear Equation

KCL Kirchhoff's law is employed in order to depict the electrical parameters of PV cell scheme [30-50]

$$I = I_{ph} - I_{Diode}, I_{Diode} = I_0 \left[\exp\left(\frac{-V_{pv}}{nV_T}\right) - 1\right] \quad (1)$$

where:

I_0 is diode reverse saturation current measured in (A), I_{ph} is light current, n is diode ideality factor (unitless), $k = (1.38 \times 10^{-23} J/K)$ is Boltzmann constant, $q = (1.602 \times 10^{-19}\ C)$ is elementary charge, V_T is thermal voltage given by $V_T = \frac{kT}{q}$, $I_{ph}$is the light generated current in the cell, T is temperature (p-n junction), I_D is the voltage dependent current lost to recombination.

The current I_{pv} and power $P_{pv}$of the cell is given by $I_{pv} = \frac{V_{pv}}{R}$; $P_{pv} = I_{pv} \times V_{pv}$

The final equation from the circuit is given by

$$(I_{source}) - 10^{-12}\left(e^{\frac{-V}{1.2*0.026}} - 1\right) = V / R \quad (2)$$

3. Inverse Quadratic Interpolation method (IQIM)

The following steps demonstrate this method

Step 1: $y = f(x) = 0$

Step 2: Assume initial values x_0, x_1, x_2

Step 3: Compute x using the formulae

$$x_{n+1} = \frac{f_{n-1}f_n}{(f_{n-2}-f_{n-1})(f_{n-2}-f_n)}x_{n-2} + \frac{f_{n-2}f_n}{(f_{n-1}-f_{n-2})(f_{n-1}-f_n)}x_{n-1} + \frac{f_{n-2}f_{n-1}}{(f_n-f_{n-2})(f_n-f_{n-1})}x_n \quad (3)$$

Step 4: If$|f(a_n)| \geq |f(b_n)|$, $|f(x_n)| < \varepsilon$, $\varepsilon = 10^{-9}$ as a tolerance; stop else go to Step 3.

4. Dekker's Algorithm (DM)

This method obtain when we combine the Bisection and Secant Methods achieved by Dekker in 1969.

Step 1: The first one called linear interpolation secant method using the following formula

$$x_{n+1} = \begin{cases} x_n - \frac{x_n - x_{n-1}}{f(x_n) - f(x_{n-1})} f(x_n) & \text{if } f(x_{n-1}) \neq f(x_n) \\ m & \text{otherwise} \end{cases} \quad (4)$$

Step 2: the second one can be obtained by bisection method

$$m = \frac{a_n + b_n}{2}$$

Step 3: If$|f(a_n)| \geq |f(b_n)|$, $|f(x_n)| < \varepsilon$, $\varepsilon = 10^{-9}$ as a tolerance; stop else go to Step 1.

where: a_n: the "contrapoint" this means that $f(x_n)$ and $f(b_k)$ have opposite signs, so the interval $[a_n, b_n]$ consist of the solution.

5. Results and Discussion

The estimate for the root of Eq. 2, two numerical iterations is applied to introduce the performance of the algebraic expression (IQIM)-Eq. 3 acquired in the present paper in order to solve non-linear equation with the initial value $x_0 = 1$ and we compare it with other algebraic expression (DM)-Eq. 4 with two initial values x_0 and x_1. For convergence criteria, the distance between two consecutive iterates is based on Eq. 5, less than 10^{-9}.

Five examples have been applied in Eq. 2 for numerical testing, R-values (1-5) ohm-(load resistance) of the circuit. All determinations are carried out with the algorithm precision introduced in Tables and Figures 1 to 5 and the number of function evaluations needed are extracted from the Eq. 2. The numerical examples and the approximate solutions produced by two techniques for solving Eq. 2.

The following Tables and Figs. indicate that IQIM algorithm needs 6 iterations while DM technique need 4 iterations to reach to the convergence which proves that DM is faster than IQIM.

Table 1 - Hybrid techniques solutions IQIM and DM.

Iterations	V_{pv}-IQIM	I_{pv}- IQIM	P_{pv}-IQIM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-IQIM	ε-DM
1	0.933205006	0.933205006	0.870871583	0.922689200	0.922689200	0.851355360	0.010781872	0.000266065
2	0.924062150	0.924062150	0.853890857	0.922424174	0.922424174	0.850866357	0.001639015	1.03962e-06
3	0.922462853	0.922462853	0.850937715	0.922423135	0.922423135	0.850864439	3.97181e-05	1.38503e-11
4	0.922423156	0.922423156	0.850864479	0.922423135	0.922423135	0.850864439	2.16413e-08	0
5	0.922423135	0.922423135	0.850864439				5.88418e-15	
6	0.922423135	0.922423135	0.850864439				0	

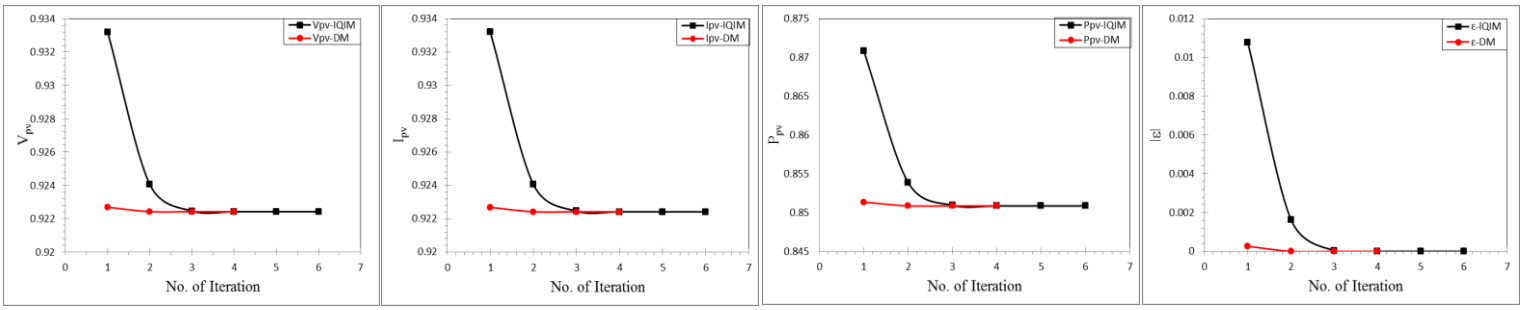

Fig. 1 – IQIM and DM hybrid techniques: solutions of non-Linear Equation.

Table 2 - Hybrid techniques solutions IQIM and DM.

Iterations	V_{pv}-IQIM	I_{pv}- IQIM	P_{pv}-IQIM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-IQIM	ε-DM
1	0.930694821	0.465347410	0.433096425	0.917558449	0.458779225	0.420956754	0.013659438	0.000523067
2	0.919616307	0.459808154	0.422847076	0.917039495	0.458519747	0.420480718	0.002580925	4.11247e-06
3	0.917134941	0.458567471	0.420568250	0.917035383	0.458517691	0.420476947	9.95588e-05	2.25742e-10
4	0.917035522	0.458517761	0.420477074	0.917035382	0.458517691	0.420476946	1.3964e-07	0
5	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	2.49689e-13	
6	0.917035382	0.458517691	0.420476946				0	

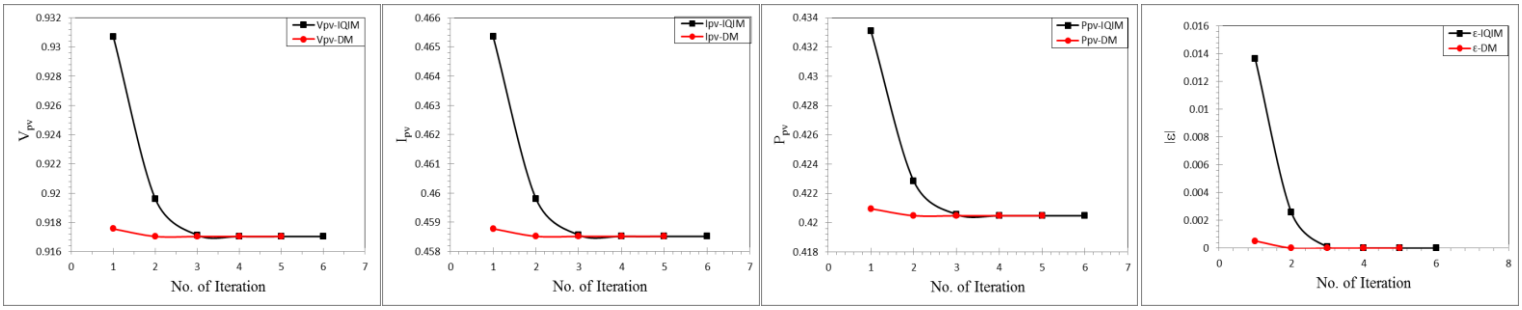

Fig. 2 – IQIM and DM hybrid techniques: solutions of non-Linear Equation.

Table 3 - Hybrid techniques solutions IQIM and DM.

Iterations	V_{pv}-IQIM	I_{pv}- IQIM	P_{pv}-IQIM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-IQIM	ε-DM
1	0.928056250	0.309352083	0.287096134	0.911476217	0.303825406	0.276929631	0.017652876	0.001072843
2	0.914591297	0.304863766	0.278825747	0.910421101	0.303473700	0.276288860	0.004187923	1.77265e-05
3	0.910667481	0.303555827	0.276438420	0.910403378	0.303467793	0.276278104	0.000264107	4.41091e-09
4	0.910404391	0.303468130	0.276278718	0.910403374	0.303467791	0.276278101	1.01703e-06	2.22045e-16
5	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	1.36281e-11	0
6	0.910403374	0.303467791	0.276278101				0	

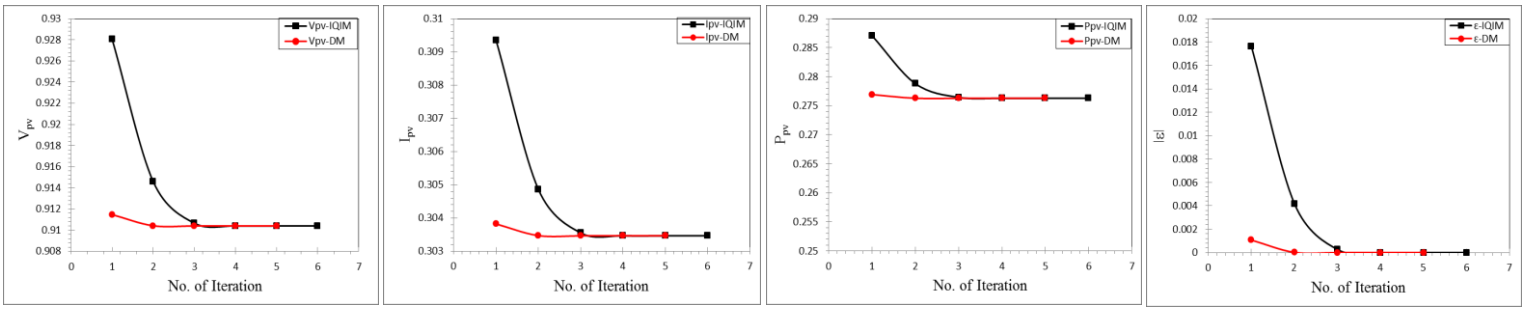

Fig. 3 – IQIM and DM hybrid techniques: solutions of non-Linear Equation.

Table 4 - Hybrid techniques solutions IQIM and DM.

Iterations	V_{pv}-IQIM	I_{pv}- IQIM	P_{pv}-IQIM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-IQIM	ε-DM
1	0.925280086	0.231320021	0.214035809	0.904086403	0.226021601	0.204343056	0.023539484	0.002345801
2	0.908858052	0.227214513	0.206505740	0.901827381	0.225456845	0.203323156	0.007117450	8.67789e-05
3	0.902502556	0.225625639	0.203627716	0.901740715	0.225435179	0.203284079	0.000761954	1.12837e-07
4	0.901749460	0.225437365	0.203288022	0.901740602	0.225435150	0.203284028	8.85844e-06	1.61537e-13
5	0.901740603	0.225435151	0.203284029	0.901740602	0.225435150	0.203284028	1.08566e-09	0
6	0.901740602	0.225435150	0.203284028				1.11022e-16	
7	0.901740602	0.225435150	0.203284028				0	

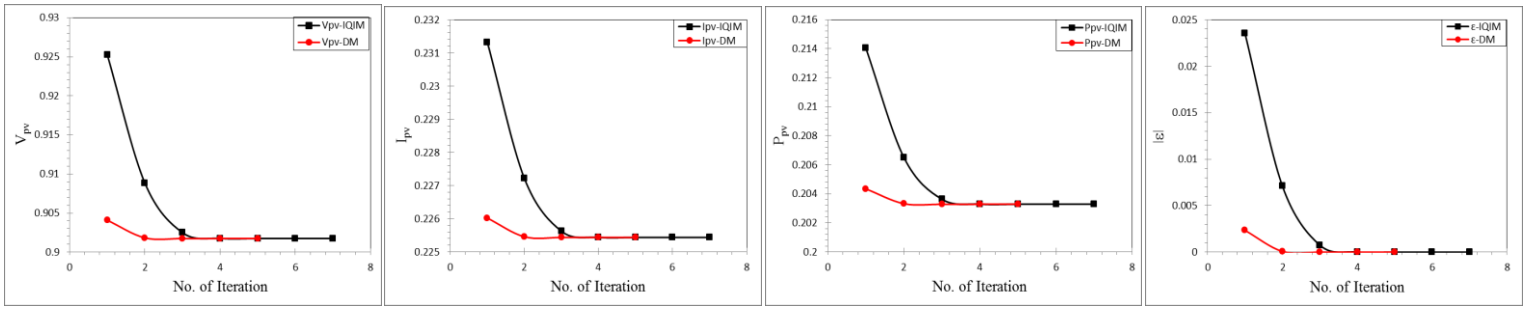

Fig. 4 – IQIM and DM hybrid techniques: solutions of non-Linear Equation.

Table 5 - Hybrid techniques solutions IQIM and DM.

Iterations	V_{pv}-IQIM	I_{pv}- IQIM	P_{pv}-IQIM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-IQIM	ε-DM
1	0.922356344	0.184471269	0.170148245	0.894834460	0.178966892	0.160145742	0.033263630	0.005741746
2	0.902249489	0.180449898	0.162810828	0.889620491	0.177924098	0.158284924	0.013156774	0.000527777
3	0.891632149	0.178326430	0.159001578	0.889097290	0.177819458	0.158098798	0.002539434	4.5757e-06
4	0.889197120	0.177839424	0.158134304	0.889092715	0.177818543	0.158097171	0.000104405	3.04366e-10
5	0.889092881	0.177818576	0.158097230	0.889092715	0.177818543	0.158097171	1.65958e-07	0
6	0.889092715	0.177818543	0.158097171				3.73146e-13	
7	0.889092715	0.177818543	0.158097171				0	

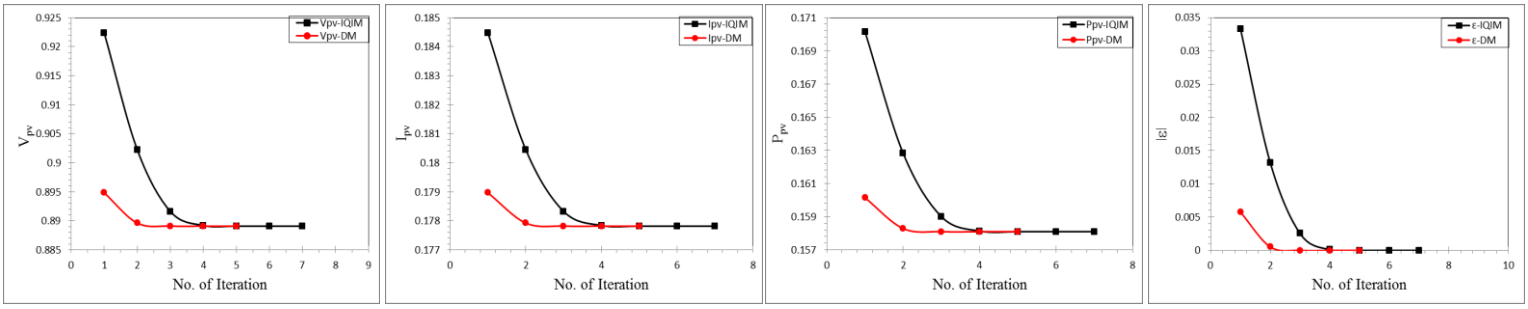

Fig. 5 – IQIM and DM hybrid techniques: solutions of non-Linear Equation.

6. Conclusion

In this work, we introduced some variant iterative methods free from second derivatives of the functions in order to solve the nonlinear equation for electronic applications.

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