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

Various Iterative Methods for Solving Nonlinear Equation

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ARTICLE INFO

Article history:
Received: 20 /03/2020
Rrevised form: 20 /04/2021
Accepted : 23 /05/2021
Available online: 28/05/2021

Keywords:

Dekker's Algorithm; False Position Method; iterative methods; zeroes; numerical examples; solar cell single diode's.

ABSTRACT

In recent articles, many researchers settled some refinements in iterative methods have been published in many scientific journals for solving nonlinear equations of a single diode mode of a solar cell. Thus, in our article, we have improved these numerical algorithms. We have compared the new iterative algorithm "Dekker's Algorithm" with other iterative of sixth order convergence methods; which appears that this new proposed method is a strong one. Many numerical examples are presented to clarify the accuracy, efficiency and performance of the new proposed method.

MSC. 41A25; 41A35; 41A36

DOI : https://doi.org/10.29304/jqcm.2021.13.2.801

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Communicated by : Dr.Rana Jumaa Surayh aljanabi.

1. Introduction

In modern years, many iterative numerical methods have been involved using polynomial series such as Taylor series, quadrature form and decomposition formulae can see in many articles and the references therein. Using the algorithm of squeezing the solution, Rasheed et al. have proposed and demonstrated a sixth order iterative method for solving the nonlinear equations of a single diode mode for solar cell and electronic applications. They modified these algorithms and belay that the improved algorithm has sixth order of convergence. We introduce the comparison of the proposed algorithm with the some numerical methods with the absolute error of them. Our algorithm is the best or somewhere equal in accuracy and efficiency with other sixth order algorithm, based on several numerical examples to explain the accuracy, robustness and efficiency of the new proposed algorithm [1-115].

RFM 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 RFM and DM algorithms respectively while; section five and six indicate the numerical problems, discussion and conclusion results respectively.

2. - Non-Linear Equation Formula

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 $V_T = kT/q$, 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. False Position Method (RFM)

For a given x_0, compute the approximate solution x_{n+1} by the iterative scheme

Step 1: Suppose $f(x_1) = b_1, f(x_2) = b_2$

Step 2: $f(x) = ax + b;$

Step 3: $x = \frac{b_1 x_2 - b_2 x_1}{(b_1 - b_2)}$ (3)

Step 4: if $|x_{n+1} - x_n| < \varepsilon$, $|f(x_n)| < \varepsilon$, $\varepsilon = 10^{-9}$ 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. (5)

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 (RFM)-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 RFM algorithm needs 6 iterations while DM technique need 4 iterations to reach to the convergence which proves that DM is faster than RFM.

Table 1 - Numerical algorithms for solving non-Linear Equation (Eq. 2).

Iterations	V_{pv}-RFM	I_{pv}- RFM	P_{pv}-RFM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-RFM	ε-DM
1	0.935676402	0.935676402	0.87549033	0.922905033	0.922905033	0.851753700	0.013253267	0.000481898
2	0.924881651	0.924881651	0.85540607	0.922426829	0.922426829	0.850871255	0.002458516	3.6943E-06
3	0.922517679	0.922517679	0.85103887	0.922423135	0.922423135	0.850864440	9.45447E-05	2.18963E-10
4	0.922423278	0.922423278	0.85086470	0.922423135	0.922423135	0.850864439	1.43773E-07	0
5	0.922423135	0.922423135	0.85086444				3.33178E-13	
6	0.922423135	0.922423135	0.85086444				0	

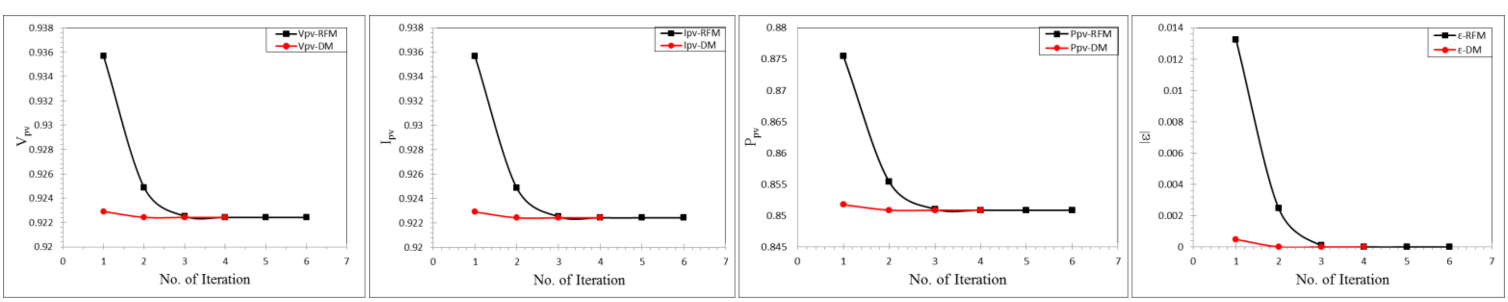

Fig. 1 – Determination of results acquired by RFM and DM numerical methods.

Table 2 - Numerical algorithms for solving non-Linear Equation (Eq. 2).

Iterations	V_{pv}-RFM	I_{pv}- RFM	P_{pv}-RFM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-RFM	ε-DM
1	0.933452268	0.466726134	0.435666569	0.917911499	0.458955750	0.421280760	0.016416886	0.000876117
2	0.920708719	0.460354360	0.423852273	0.917047635	0.458523817	0.420488182	0.003673337	1.22522E-05
3	0.917245199	0.458622600	0.420669378	0.917035385	0.458517692	0.420476949	0.000209817	2.42601E-09
4	0.917036095	0.458518047	0.420477600	0.917035382	0.458517691	0.420476946	7.12519E-07	1.11022E-16
5	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	8.24774E-12	0
6	0.917035382	0.458517691	0.420476946				0	

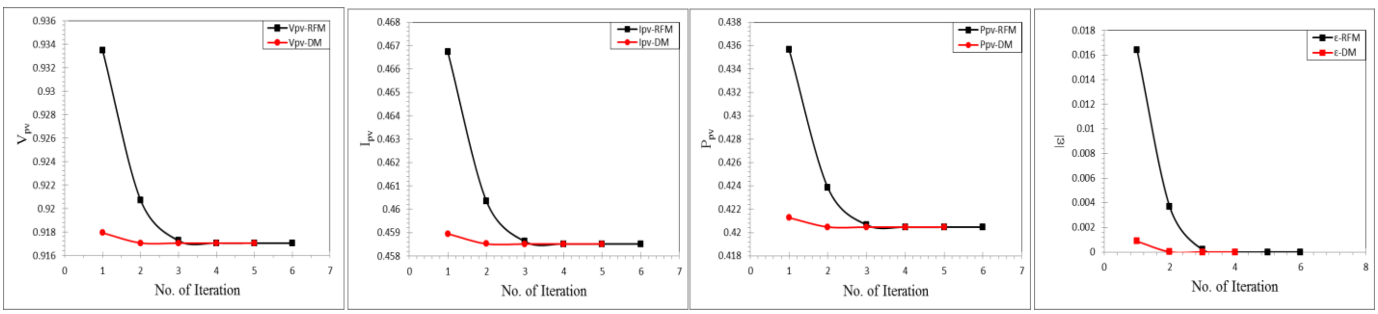

Fig. 2 – Determination of results acquired by RFM and DM numerical methods.

Table 3 - Numerical algorithms for solving non-Linear Equation (Eq. 2).

Iterations	V_{pv}-RFM	I_{pv}- RFM	P_{pv}-RFM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-RFM	ε-DM
1	0.931130761	0.310376920	0.289001498	0.912060122	0.304020041	0.277284556	0.020727387	0.001656748
2	0.916050375	0.305350125	0.279716096	0.910447324	0.303482441	0.276304776	0.005647001	4.39496E-05
3	0.910893770	0.303631257	0.276575820	0.910403406	0.303467802	0.276278120	0.000490396	3.15643E-08
4	0.910407299	0.303469100	0.276280483	0.910403374	0.303467791	0.276278101	3.92473E-06	1.64313E-14
5	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	2.53289E-10	0
6	0.910403374	0.303467791	0.276278101				0	

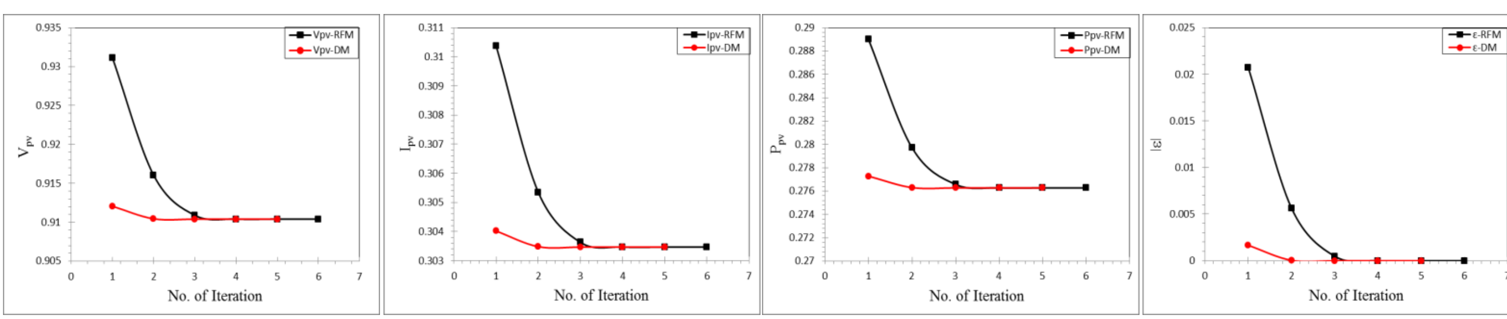

Fig. 3 – Determination of results acquired by RFM and DM numerical methods.

Table 4 - Numerical algorithms for solving non-Linear Equation (Eq. 2).

Iterations	V_{pv}-RFM	I_{pv}- RFM	P_{pv}-RFM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-RFM	ε-DM
1	0.928705897	0.232176474	0.215623661	0.905065248	0.226266312	0.204785776	0.026965295	0.003324646
2	0.910811452	0.227702863	0.207394375	0.901917691	0.225479423	0.203363880	0.009070850	0.000177089
3	0.902978861	0.225744715	0.203842706	0.901741124	0.225435281	0.203284264	0.001238259	5.22069E-07
4	0.901765899	0.225441475	0.203295434	0.901740602	0.225435150	0.203284028	2.52971E-05	4.56313E-12
5	0.901740613	0.225435153	0.203284033	0.901740602	0.225435150	0.203284028	1.07408E-08	0
6	0.901740602	0.225435150	0.203284028				1.88738E-15	
7	0.901740602	0.225435150	0.203284028				0	

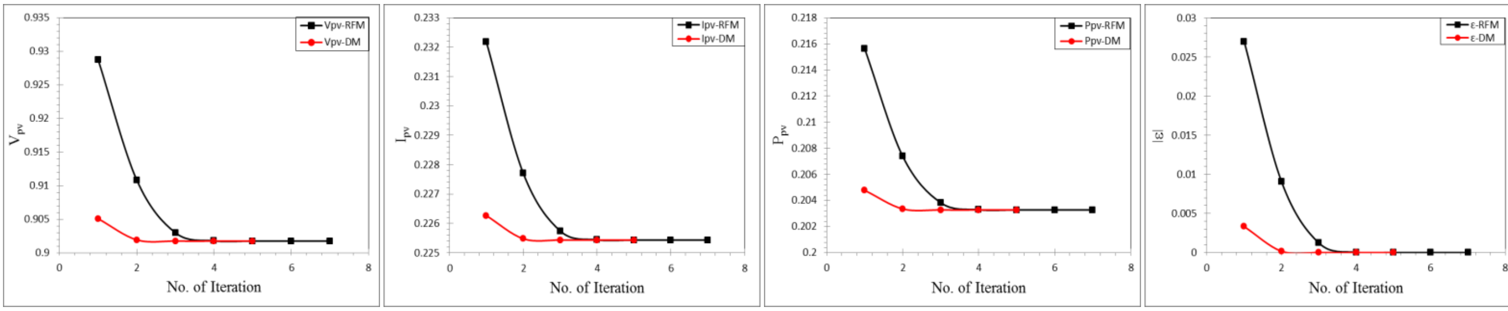

Fig. 4 – Determination of results acquired by RFM and DM numerical methods.

Table 5 - Numerical algorithms for solving non-Linear Equation (Eq. 2).

Iterations	V_{pv}-RFM	I_{pv}- RFM	P_{pv}-RFM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-RFM	ε-DM
1	0.926171251	0.185234250	0.171558637	0.896503075	0.179300615	0.160743553	0.037078536	0.00741036
2	0.904871952	0.180974390	0.163758650	0.889962786	0.177992557	0.158406752	0.015779238	0.000870071
3	0.892667280	0.178533456	0.159370975	0.889105769	0.177821154	0.158101814	0.003574566	1.3054e-05
4	0.889306005	0.177861201	0.158173034	0.889092718	0.177818544	0.158097172	0.00021329	2.98126e-09
5	0.889093511	0.177818702	0.158097454	0.889092715	0.177818543	0.158097171	7.96313e-07	3.33067e-16
6	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171	1.11465e-11	0
7	0.889092715	0.177818543	0.158097171				0	

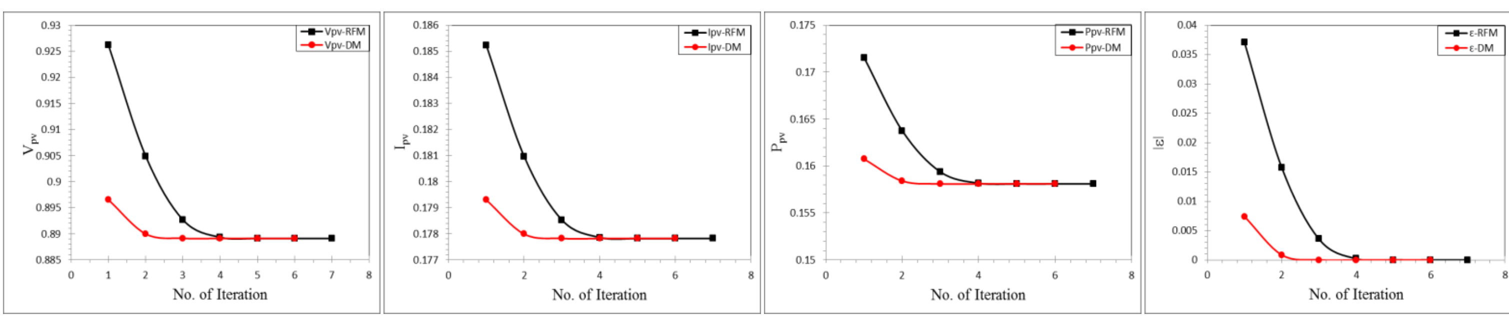

Fig. 5 – Determination of results acquired by RFM and DM numerical methods.

6. Conclusion

In Tables 1 to 5, survey that our proposed iterative method Dekker's Algorithm is comparable with all the other numerical methods cited in these Tables and bears the best results. With the utilize of the algorithm and the procedure of this article one can progress multi step iterative algorithms in order to solve nonlinear equations of a PV cell based on single diode model.

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