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Numerical Solving of Nonlinear Equation Using Iterative Algorithms

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ABSTRACT

In the given algorithm, we propose a development to the evaluations of Newton's numerical algorithm. Derivation of the standard method (Newton Raphson method) involves first derivative of the function. It is shown that the number of iterations of the new method is six and determined results support this technique. The results obtained show that the new proposed method is more accurate, easy to use, and efficient than other numerical methods are indicated.

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1. Introduction

Newton's technique that approximates the zeros of a nonlinear equation including one variable by the value of the function and it is first derivative. This method is standard and very common, best known and most widely method for getting the roots of the functions from free second derivative. We suggested and analyzed some iterative techniques free from second derivatives of the function for solving nonlinear equation of a single diode of a solar cell based on it's equivalent circuit. There are many ways improved on the advancement the convergence of Newton's method, in order to attain lesser iterations than it [1-113].

The suggested algorithm TSM2 requires 5 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 TSM2 and DM algorithms respectively while; section five and six indicate the numerical problems, discussion and conclusion results respectively.

2. Determination of PV Equation

KCL Kirchhoff's law is employed in order to depict the electrical parameters of PV cell scheme [21-31]

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

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. Three Step Method (TSM2M)

The following steps introduce this method

Step 1: let the starting value x_0

Step 2: calculate algorithm 1: Newton Raphson Method (NRM)

$$D_{n+1} = D_n - \frac{f(D_n)}{f'(D_n)}$$

Step 3: determine algorithm 2: Two Step Method (TM)

$$y_n = D_n - \frac{f(D_n)}{f'(D_n)}$$

$$D_{n+1} = y_n - \frac{f(D_n) - 2 \times f(y_n)}{f(D_n) - 4 \times f(y_n)}\left(\frac{f(y_n)}{f'(D_n)}\right)$$

Step 4: compute algorithm 3: Three Step Method (TSM): given by the following formulas

$$y_n = D_n - \frac{f(D_n)}{\acute{f}(D_n)}$$

$$z_n = y_n - \frac{f(D_n) - 2 \times f(y_n)}{f(D_n) - 4 \times f(y_n)} - \frac{f(y_n)}{\acute{f}(D_n)}$$

$$D_{n+1} = z_n - \frac{f(z_n)}{\acute{f}(z_n)} \text{ for } n = 0, 1, 2, \ldots \tag{3}$$

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

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

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

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

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.

For the two algorithms, the tolerance is If$|f(a_n)| \geq |f(b_n)|$, $|f(x_n)| < \varepsilon$, $\varepsilon = 10^{-9}$.

5. Results and Discussion

Two numerical iterations is suggested to introduce the performance of the Three Step Method (TSM2) represented in 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 Dekker's Algorithm (DM) represented in 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 in Eq. 2 are used for numerical testing with the R values from 1-5 ohm, represents (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 TSM algorithm needs 5 iterations while DM technique need 4 iterations to reach to the convergence which proves that DM is faster than TSM.

Table 1 - Study numerical techniques of PV model.

Iterations	V_{pv}-TSM2	I_{pv}- TSM2	P_{pv}-TSM2	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM2	ε-DM
1	0.979429776	0.979429776	0.959282686	0.943772456	0.943772456	0.890706449	0.057006642	0.021349322
2	0.958997978	0.958997978	0.919677122	0.914185312	0.914185312	0.835734785	0.036574844	0.008237822
3	0.905989832	0.905989832	0.820817575	0.922437516	0.922437516	0.850890971	0.016433303	1.43814e-05
4	0.922373301	0.922373301	0.850772506	0.922423135	0.922423135	0.850864439	4.9834e-05	5.7061e-12
5	0.922423127	0.922423127	0.850864426	0.922423135	0.922423135	0.850864439	7.10254e-09	0
6	0.922423135	0.922423135	0.850864439				1.11022e-16	
7	0.922423135	0.922423135	0.850864439				0	

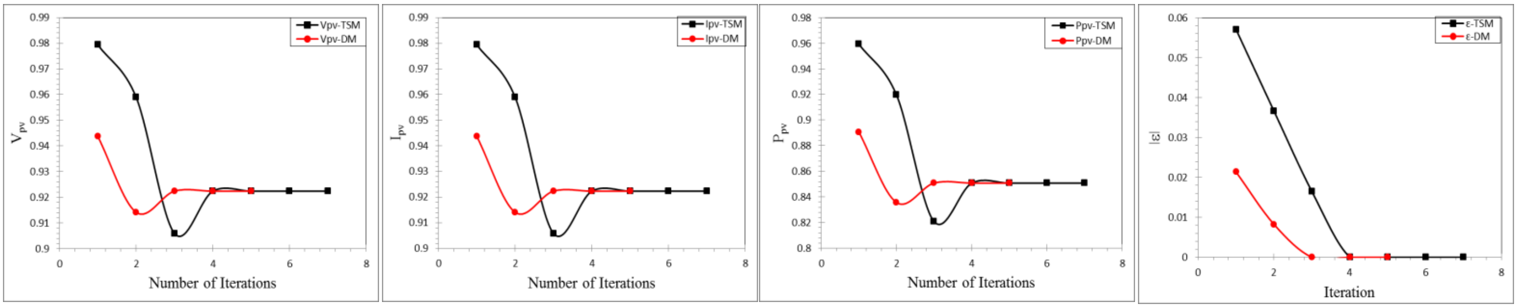

Fig. 1 – Numerical algorithms for Examples based on Eq. 2.

Table 2 - Study numerical techniques of PV model.

Iterations	V_{pv}-TSM2	I_{pv}- TSM2	P_{pv}-TSM2	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM2	ε-DM
1	0.978756325	0.489378163	0.478981972	0.941063878	0.470531939	0.442800611	0.061720943	0.024028495
2	0.956222512	0.478111256	0.457180746	0.730480104	0.365240052	0.266800591	0.039187129	0.186555278
3	0.653711503	0.326855751	0.213669364	0.918447522	0.459223761	0.421772926	0.263323880	0.00141214
4	0.916875700	0.458437850	0.420330525	0.917035383	0.458517691	0.420476946	0.000159682	1.58242e-10
5	0.917035321	0.458517661	0.420476890	0.917035382	0.458517691	0.420476946	6.09416e-08	0
6	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	1.54321e-14	
7	0.917035382	0.458517691	0.420476946				0	

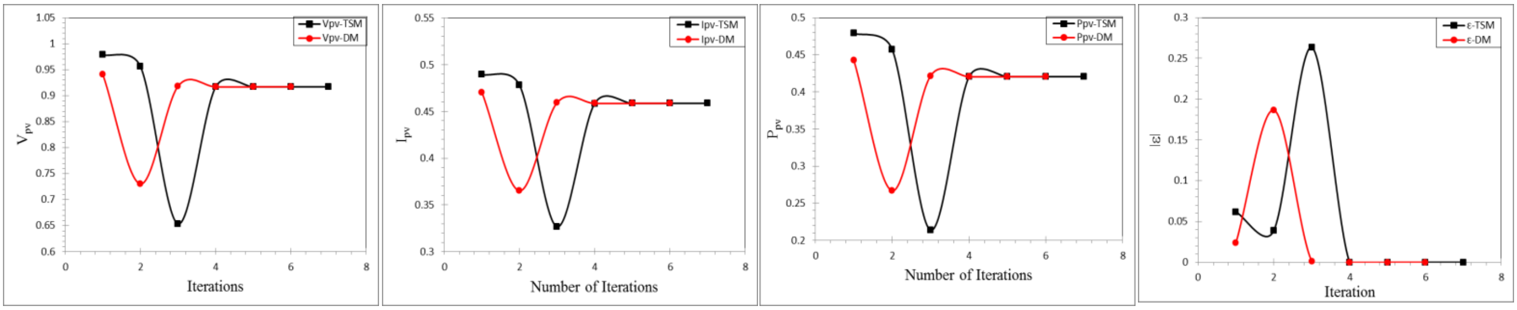

Fig. 2 – Numerical algorithms for Examples based on Eq. 2.

Table 3 - Study numerical techniques of PV model.

Iterations	V_{pv}-TSM2	I_{pv}- TSM2	P_{pv}-TSM2	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM2	ε-DM
1	0.978098497	0.3260330	0.318892223	0.938379546	0.312793182	0.293518724	0.067695123	0.027976172
2	0.953715087	0.3179050	0.303190822	0.931605187	0.310535062	0.289296075	0.043311713	0.021201813
3	0.956925450	0.3189750	0.305235439	0.910062390	0.303354130	0.276071185	0.046522076	0.000340984
4	0.909809334	0.3032700	0.275917675	0.910403380	0.303467793	0.276278105	0.000594040	5.98923e-09
5	0.910402763	0.30346800	0.276277730	0.910403374	0.303467791	0.276278101	6.10917e-07	0
6	0.910403374	0.30346800	0.276278101	0.910403374	0.303467791	0.276278101	1.49014e-12	
7	0.910403374	0.30346800	0.276278101				0	

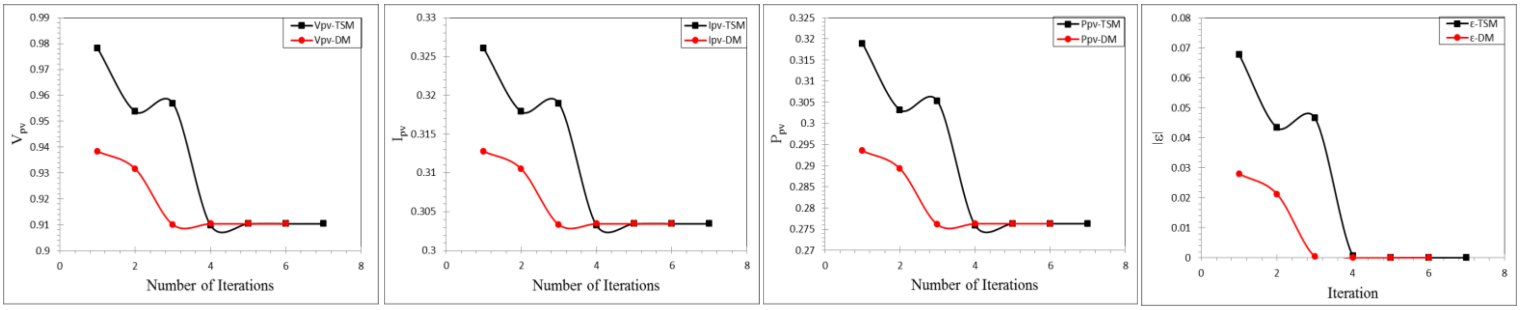

Fig. 3 – Numerical algorithms for Examples based on Eq. 2.

Table 4 - Study numerical techniques of PV model.

Iterations	V_{pv}-TSM2	I_{pv}- TSM2	P_{pv}-TSM2	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM2	ε-DM
1	0.977454460	0.24436400	0.238854306	0.935675646	0.233919000	0.218872229	0.075713859	0.033935044
2	0.951381278	0.23784500	0.226281584	0.920363583	0.230091000	0.211767281	0.049640676	0.018622981
3	0.936530256	0.23413300	0.219272230	0.900292818	0.225073000	0.202631789	0.034789654	0.001447784
4	0.898678908	0.22467000	0.201905945	0.901741013	0.225435000	0.203284214	0.003061694	4.1086e-07
5	0.901732761	0.22543300	0.203280493	0.901740602	0.225435000	0.203284028	7.8406e-06	2.94209e-14
6	0.901740602	0.22543500	0.203284028	0.901740602	0.225435000	0.203284028	2.22257e-10	0
7	0.901740602	0.22543500	0.203284028				0	

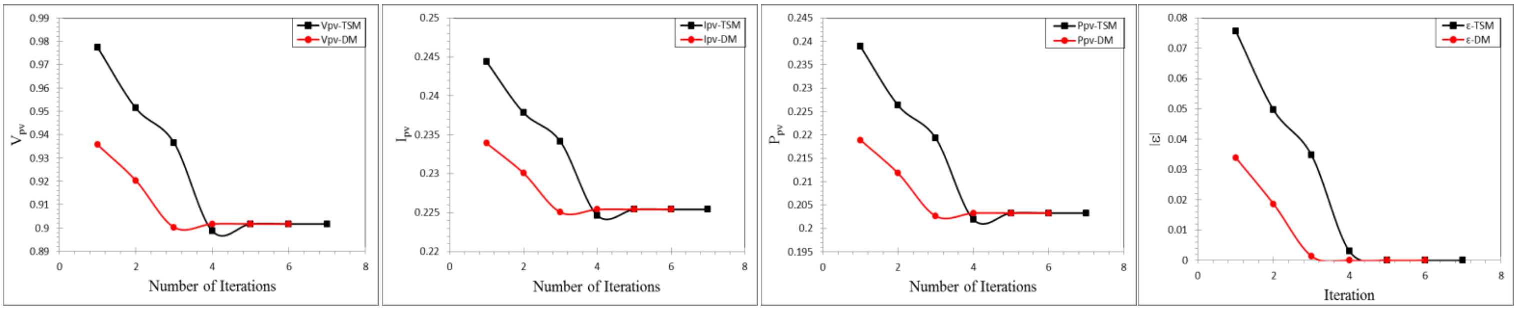

Fig. 4 – Numerical algorithms for Examples based on Eq. 2.

Table 5 - Study numerical techniques of PV model.

Iterations	V_{pv}-TSM2	I_{pv}- TSM2	P_{pv}-TSM2	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM2	ε-DM
1	0.976822639	0.195364528	0.190836493	0.932920947	0.186584189	0.174068299	0.087729924	0.043828232
2	0.949161044	0.189832209	0.180181338	0.912513377	0.182502675	0.166536133	0.06006833	0.023420663
3	0.927351432	0.185470286	0.171996136	0.719612804	0.143922561	0.103568517	0.038258717	0.169479911
4	0.690900718	0.138180144	0.095468760	0.891970447	0.178394089	0.159122256	0.198191997	0.002877732
5	0.888927794	0.177785559	0.158038525	0.889092715	0.177818543	0.158097171	0.00016492	2.0759e-10
6	0.889092643	0.177818529	0.158097146	0.889092715	0.177818543	0.158097171	7.15221e-08	0
7	0.889092715	0.177818543	0.158097171				2.33147e-14	
8	0.889092715	0.177818543	0.158097171				0	

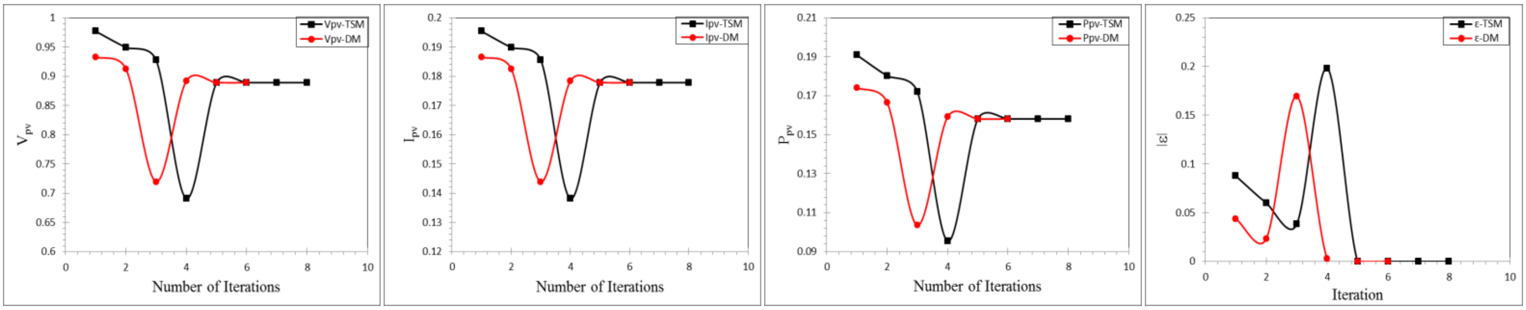

Fig. 5 – Numerical algorithms for Examples based on Eq. 2.

6. Conclusion

We have observed that DM has sixth computations provided first derivatives of the function exist. the most important analyze of the Dekker's algorithm is that unlike the other three step methods because it is not required to determine the second derivative of the function just need first derivative of it to carry out the evaluations. Determined results [Table 1, 2, 3, 4 and 5] reveal the accuracy and efficient and absolute error of the proposed method compared by the other ones. In addition for the computed results [Tables] that the total number of function computations needed less than that of the standard one.

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