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Hybrid Algorithms for Numerical Solution of Optoelectronics Applications

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ABSTRACT

In the present work, we approach and introduce some new iterative techniques free from second derivative of the given function. Per iteration, these new techniques run out five or four computations of the required function with it's first derivative. Absolute error of these techniques is also considered. Many examples numerically are chosen to indicate the accuracy and performance of these new techniques. These new techniques may be seen as an alternative to the popular methods.

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1. Introduction

It is popular that a wide family of example which arises in many fields of engineering and science can be discussed of the nonlinear equations for give the roots of the functions. Several iterative experiments have been analyzed using different numerical methods such as implicit method; false position method; Predictor-Corrector Hally method; Accelerated Predictor-Corrector Hally method; two step method; Horner algorithm; Improved Newton-Horner algorithm; Newton's method; Classic Chord algorithm; Inverse Quadratic Interpolation method; Illinois algorithm; Dekker's technique; Improved Double False Position method; homotopy perturbation method; Aitken's extrapolation algorithm; (Rasheed et al. 2019). These iterative techniques have been used in order to obtain the zeros of the required nonlinear equation in pure and science fields [1-115].

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

2. Basis of a Non-Linear Equation

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

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

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

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

3. Three Step Technique (TSM)

The following steps interpretation this method

Step1: Let $f(x) = 0$ is a nonlinear equation, suppose x_0 as an initial value, so y_n can be calculated using Newton's expression

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

Step 2: determine z_n from the following formula

$$z_n = x_n - [\frac{f(x_n) + f(y_n)}{\acute{f}(x_n)}]$$

Step 3: The iteration results x_{n+1} can be calculated using the following scheme

$$x_{n+1} = z_n - \frac{f(z_n) \times f(x_n)}{\acute{f}(y_n)[f(x_n) + f(y_n)] - \acute{f}(x_n) \times f(y_n)} \tag{3}$$

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

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

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 Technique (TSM) 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 - TSM and DM algorithms for a non-linear model.

Iterations	V_{pv}-TSM	I_{pv}- TSM	P_{pv}-TSM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM	ε-DM
1	0.955060555	0.955060555	0.91214066	0.922193891	0.922193891	0.850441572	0.03263742	0.00022924
2	0.926716455	0.926716455	0.85880339	0.922394347	0.922394347	0.850811332	0.004293321	2.8787e-05
3	0.922427705	0.922427705	0.85087287	0.922423135	0.922423135	0.850864439	4.57089e-06	4.9516e-14
4	0.922423135	0.922423135	0.85086444	0.922423135	0.922423135	0.850864439	1.11022e-16	0
5	0.922423135	0.922423135	0.85086444				0	

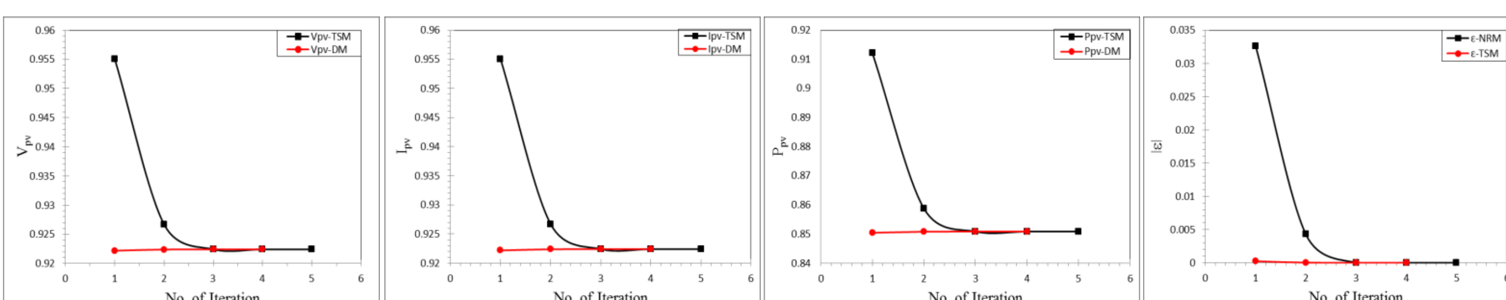

Fig. 1 – The ascendency of numerical techniques in PV design.

Table 2 - TSM and DM algorithms for a non-linear model.

Iterations	V_{pv}-TSM	I_{pv}- TSM	P_{pv}-TSM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM	ε-DM
1	0.954223662	0.477111831	0.455271398	0.919933891	0.459966946	0.423139182	0.037188279	0.002898509
2	0.923160241	0.46158012	0.426112415	0.917037075	0.458518537	0.420478498	0.006124858	1.69211e-06
3	0.917052987	0.458526494	0.420493091	0.917035382	0.458517691	0.420476946	1.7605e-05	0
4	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	1.55431e-15	
5	0.917035382	0.458517691	0.420476946				0	

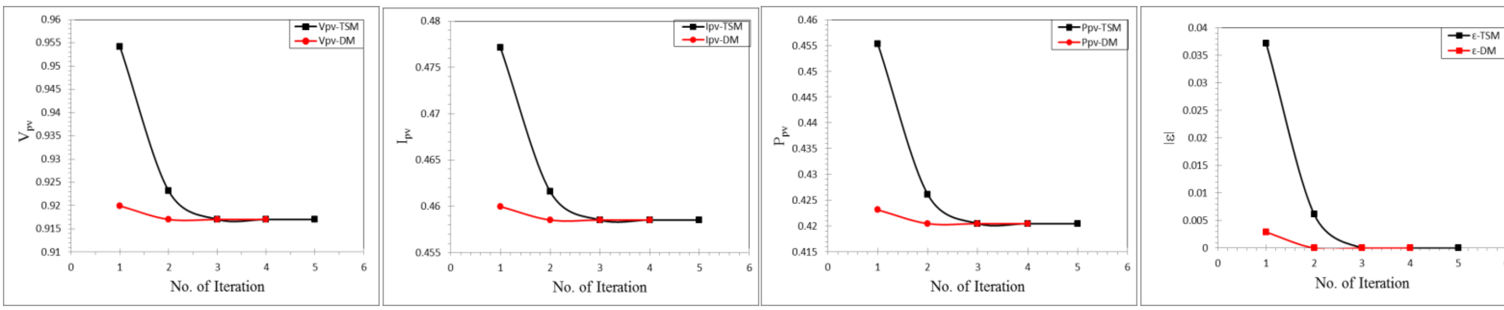

Fig. 2 – The ascendency of numerical techniques in PV design.

Table 3 - TSM and DM algorithms for a non-linear model.

Iterations	V_{pv}-TSM	I_{pv}- TSM	P_{pv}-TSM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM	ε-DM
1	0.953380693	0.317793564	0.302978249	0.915091041	0.305030347	0.279130538	0.042977319	0.004687667
2	0.919321269	0.306440423	0.281717198	0.910413201	0.303471067	0.276284066	0.008917895	9.82711e-06
3	0.910474010	0.303491337	0.276320974	0.910403374	0.303467791	0.276278101	7.06356e-05	5.55112e-16
4	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	4.41314e-13	0
5	0.910403374	0.303467791	0.276278101				0	

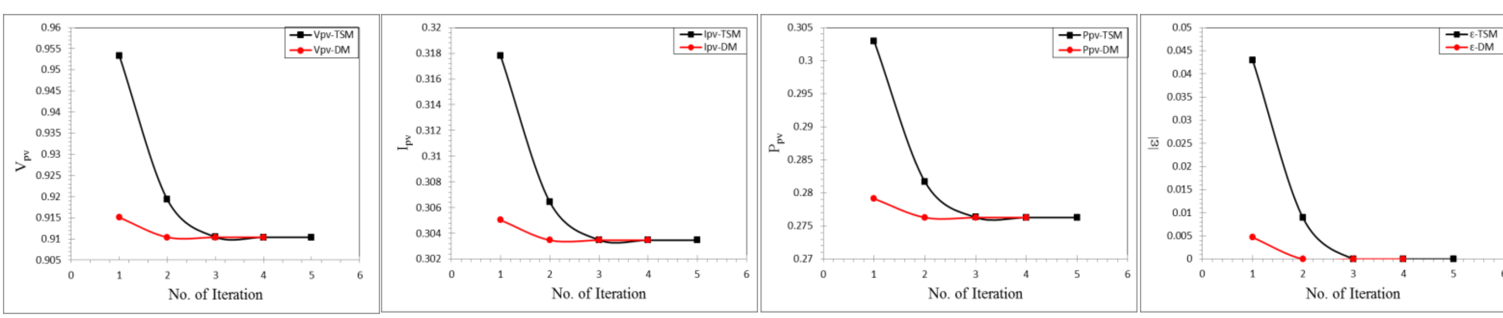

Fig. 3 – The ascendency of numerical techniques in PV design.

Table 4 - TSM and DM algorithms for a non-linear model.

Iterations	V_{pv}-TSM	I_{pv}- TSM	P_{pv}-TSM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM	ε-DM
1	0.952531681	0.238132920	0.226829151	0.909634627	0.227408657	0.206858789	0.050791079	0.007894025
2	0.915170632	0.228792658	0.209384321	0.901803127	0.225450782	0.203312220	0.013430030	6.25245e-05
3	0.902042574	0.225510644	0.203420201	0.901740602	0.225435150	0.203284028	0.000301972	7.84595e-13
4	0.901740602	0.225435151	0.203284028	0.901740602	0.225435150	0.203284028	1.54978e-10	0
5	0.901740602	0.225435150	0.203284028				0	

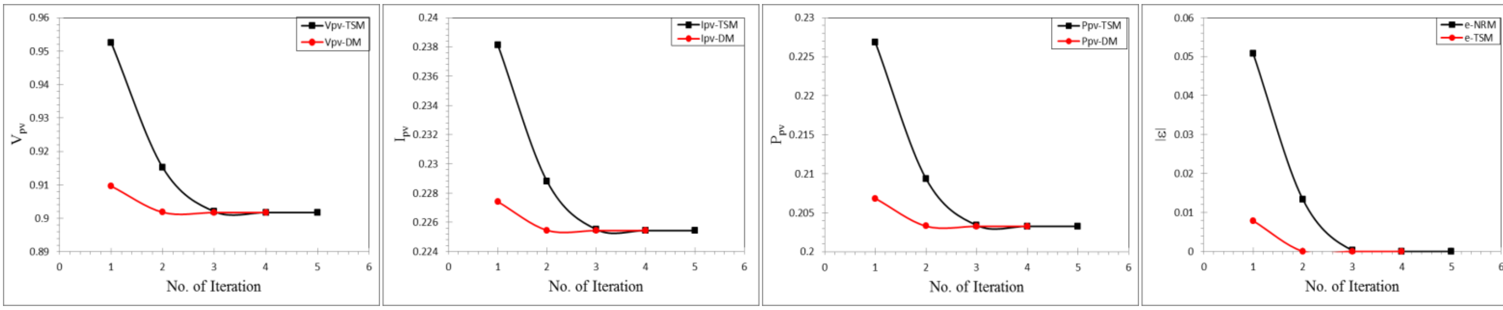

Fig. 4 – The ascendency of numerical techniques in PV design.

Table 5 - TSM and DM algorithms for a non-linear model.

Iterations	V_{pv}-TSEM	I_{pv}- TSM	P_{pv}-TSM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-TSM	ε-DM
1	0.951676656	0.190335331	0.181137692	0.906791814	0.181358363	0.164454279	0.062583942	0.017699099
2	0.916175072	0.183235014	0.167875352	0.890944177	0.178188835	0.158756305	0.027082357	0.001851462
3	0.893907312	0.178781462	0.159814056	0.889096659	0.177819332	0.158098574	0.004814597	3.94445e-06
4	0.889140928	0.177828186	0.158114318	0.889092715	0.177818543	0.158097171	4.82129e-05	3.40838e-14
5	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171	4.02242e-11	0
6	0.889092715	0.177818543	0.158097171				0	

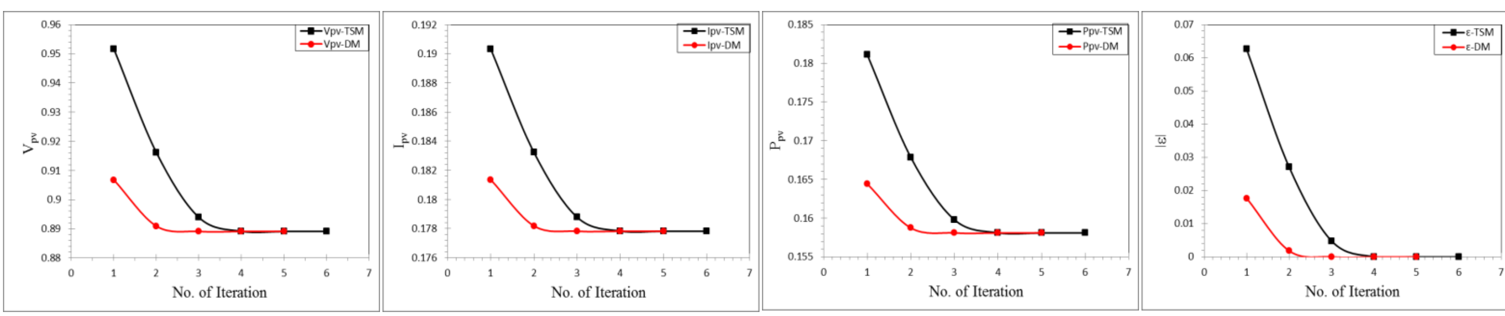

Fig. 5 – The ascendency of numerical techniques in PV design.

6. Conclusion

In this paper, we have proposed new iterative methods free from second derivative of the function f in order to solving the roots of nonlinear equation. The absolute error of these techniques has been discussed too. Many numerical experiments are conferred to explicate the accuracy and efficiency of these techniques. Using the aim of this paper, we can proposed and demonstrate multi step iterative techniques for solving nonlinear equations in computational mathematics.

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