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Two Numerical Algorithms for Solving Nonlinear Equation of Solar Cell

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ABSTRACT

In this paper, we propose a new iterative method that has free from the second derivative of functions for solving nonlinear equations of a PV cell including different data for R (load resistance). These equations are determined using Kirchhoff's current law (KCL) applied on a closed network. Some numerical experiments are offered to illustrate that the Dekker's formula has more efficient and accurate than other iterative method Predictor-Corrector Type.

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1. Introduction

Many examples in pure, engineering and applied mathematics areas are employed to find the approximate solutions of nonlinear equations. Variant methods are demonstrated by several researchers for solving nonlinear equations for example Rasheed et al. Newton Raphson's method is largely utilized for solving nonlinear equations in the style of $f(x) = 0, \acute{f}(x) \neq 0$. Many authors have suggested a variant of modification on the classical and popular Newton's method for solving this kind of equations [1-66].

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In the present paper, some new numerical iterative methods Dekker's Formula with the Newton's and Predictor-Corrector algorithms are implemented and investigated in order to solve a roots of non-linear equation for optoelectronic applications. The procedure of this work is: in section two reports the non-linear equation; in section three investigates the zeros for Predictor-Corrector technique; in section four Dekker's Formula has been analyzed; in section five the results and discussion; finally, in section six the conclusion.

2. Solar PV Cell: Non-Linear Equation

The voltage drop in a closed network, Figure 1 shows (KCL) Kirchhoff's current law calculates circuit of single-diode model

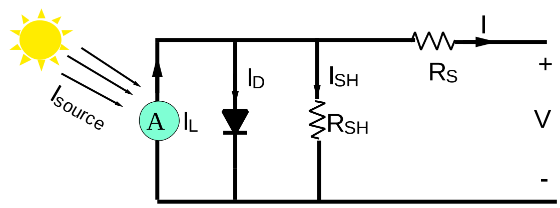

Fig. 1 – Circuit of a single-diode model.

The voltage drop in a closed network is calculated by (KCL) Kirchhoff's current law

$$I = I_{ph} - I_D \tag{1}$$

$$I_D = I_0 \times (e^{(-V_{pv}/mV_T)} - 1) \tag{2}$$

$$I = I_{ph} - I_0\left(e^{(-V_{pv}/mV_T)} - 1\right) \tag{3}$$

where:

$1 < m < 2$, I_{ph}, k, $V_T = kT/q = 26$ mV, q, and T and I_0: the recombination factor, the photocurrent (A), Boltzmann constant= 1.38×10^{-23}J/K, thermic voltage, the electron charge= 1.6×10^{-19} C, temperature (K) and reverse saturation current respectively.

$$I_{ph} = I_{source} \tag{4}$$

$$I_D = I_s \times \left(e^{(V_D/mV_T)} - 1\right) \tag{5}$$

Amalgamate Eq. 4 in Eq. 5 yields

$$(I_{source}) - 10^{-12}\left(e^{(-V/1.2\times 0.026)} - 1\right) = V/R \tag{6}$$

$$I_{pv} = V_{pv}/R;\ P_{pv} = I_{pv} \times V_{pv} \tag{7}$$

where I_s reverse saturation current= 10^{-12}A. In parallel, $V = V_D = V_{pv}$

3. Predictor – Corrector Type (A1)

1. Assume the initial value as H_0
2. Put H_0 initial value, calculate H_{n+1} which is an approximation.

$$H_{n+1} = H_n - \frac{f(H_n)}{f́(H_n)} \tag{8}$$

$$H_{n+1} = H_n - \frac{6\times f(H_n)}{f́(H_n) + 4\times f́\left(\frac{H_n + H^*_{n+1}}{2}\right) + f́(H^*_{n+1})},\ n = 0, 1, 2, 3, \ldots \tag{9}$$

3. If $|H_{n+1} - H_n| < \varepsilon$, $|f(H_n)| < \varepsilon$, $\varepsilon = 10^{-9}$ as a tolerance; stop else go to Step 1.

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

$$x_{n+1} = x_n - [\, x_n - x_{n-1} / \, f(x_n) - f(x_{n-1})] \times f(x_n) \quad \text{if } f(x_n) \neq f(x_{n-1}) \tag{10}$$

$$x_{n+1} = m \quad \text{otherwise} \tag{11}$$

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

$$m = a_k + b_k/2 \tag{12}$$

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. Numerical Results

The present two techniques are given by (9) and (10) is employed for solving the zeros of Eq. 6 which is a non-linear with an estimate guess x_0. To investigate the performance of these techniques Eq. 6 non-linear equation is used. The consistency and stability of the results by testing the convergence for the suggested techniques are calculated. The approximate solutions produced by the techniques regarded and list the errors acquired by the two techniques. There are five cases with the use of Eq. 6, which are based on the R values from 1 to 5 ohm. From Tables 1 to 5 and Figures 2 to 6, the results show that DM need 5 iterations whereas A1 need 7 iterations in order to reach to the convergence, this prove that DM is better than A1.

Table 1 - Comparison of A1 and DM.

Iterations	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-A1	ε- DM
1	0.956353318	0.956353318	0.914611669	0.928080315	0.928080315	0.861333072	0.033930183	0.005657181
2	0.935681181	0.935681181	0.875499273	0.922905319	0.922905319	0.851754227	0.013258047	0.000482184
3	0.924882295	0.924882295	0.85540726	0.92242683	0.92242683	0.850871257	0.002459161	3.69546E-06
4	0.922517684	0.922517684	0.851038878	0.922423135	0.922423135	0.85086444	9.45499E-05	2.18976E-10
5	0.922423278	0.922423278	0.850864704	0.922423135	0.922423135	0.850864439	1.43773E-07	0
6	0.922423135	0.922423135	0.850864439				3.33067E-13	
7	0.922423135	0.922423135	0.850864439				0	

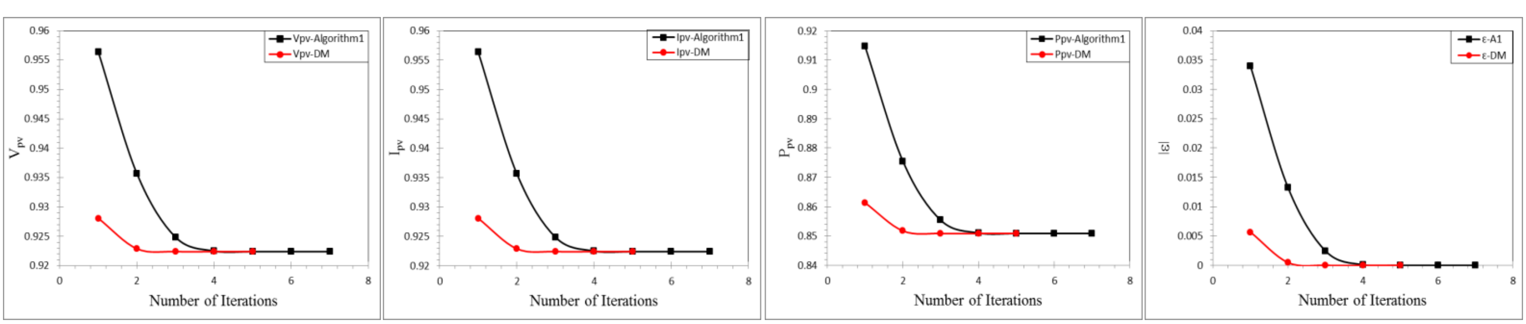

Fig. 2 – Test function Eq. 6 with initial guess V_0, R = 1 and error ε.

Table 2 - Comparison of A1 and DM.

Iterations	V_{pv}-A1	I_{pv}- A1	P_{pv}-A1	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-A1	ε- DM
1	0.955521013	0.477760507	0.456510203	0.924717223	0.462358612	0.427550971	0.038485631	0.007681841
2	0.93345809	0.466729045	0.435672003	0.917912033	0.458956016	0.42128125	0.016422708	0.000876651
3	0.920709796	0.460354898	0.423853264	0.917047639	0.45852382	0.420488186	0.003674413	1.22567E-05
4	0.917245217	0.458622609	0.420669394	0.917035385	0.458517692	0.420476949	0.000209835	2.42622E-09
5	0.917036095	0.458518047	0.4204776	0.917035382	0.458517691	0.420476946	7.12521E-07	1.11022E-16
6	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	8.24774E-12	0
7	0.917035382	0.458517691	0.420476946				0	

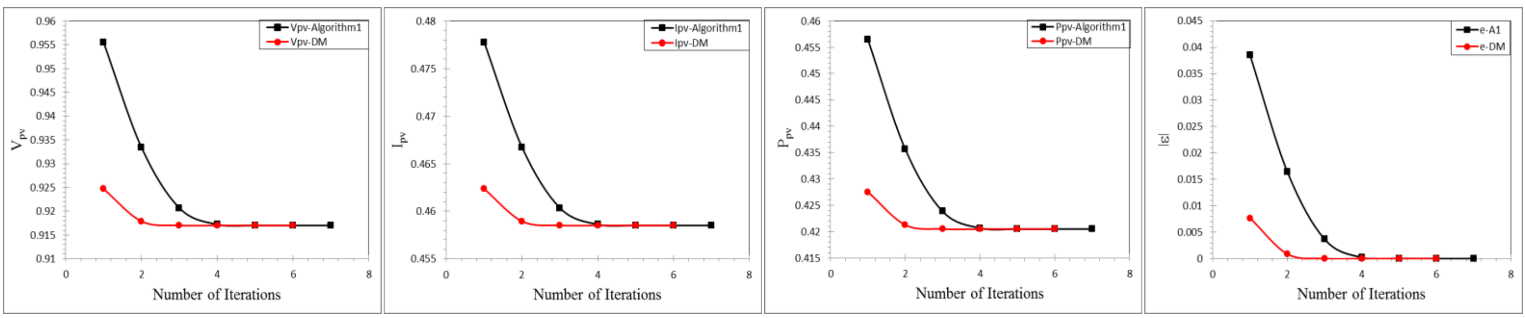

Fig. 3 - Test function Eq. 6 with initial guess V_0, $R = 2$ and error ε.

Table 3 - Comparison of A1 and DM.

Iterations	V_{pv}-A1	I_{pv}- A1	P_{pv}-A1	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-A1	ε- DM
1	0.954680538	0.318226846	0.303804977	0.921083297	0.307027766	0.282798147	0.044277164	0.044265127
2	0.931137845	0.310379282	0.289005896	0.912061136	0.304020379	0.277285172	0.020734471	0.020727387
3	0.916052182	0.305350727	0.2797172	0.910447343	0.303482448	0.276304788	0.005648808	0.005647001
4	0.910893833	0.303631278	0.276575858	0.910403406	0.303467802	0.27627812	0.000490459	0.000490396
5	0.910407299	0.3034691	0.276280483	0.910403374	0.303467791	0.276278101	3.92476E-06	3.92473E-06
6	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	2.53289E-10	2.53289E-10
7	0.910403374	0.303467791	0.276278101				0	0

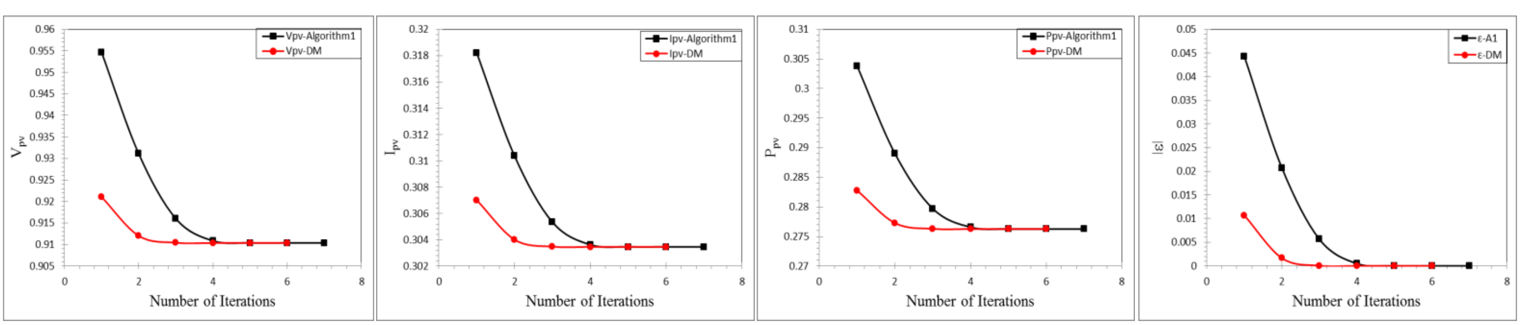

Fig. 4 - Test function Eq. 6 with initial guess V_0, $R = 3$ and error ε.

Table 4 - Comparison of NRM and DM.

Iterations	V_{pv}-A1	I_{pv}- A1	P_{pv}- A1	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-A1	ε- DM
1	0.953831829	0.238457957	0.227448789	0.917144663	0.229286166	0.210288583	0.052091227	0.015404061
2	0.928714508	0.232178627	0.215627659	0.905067209	0.226266802	0.204786663	0.026973906	0.003326607
3	0.910814499	0.227703625	0.207395763	0.90191778	0.225479445	0.20336392	0.009073897	0.000177178
4	0.902979093	0.225744773	0.20384281	0.901741124	0.225435281	0.203284264	0.001238491	5.22178E-07
5	0.9017659	0.225441475	0.203295434	0.901740602	0.22543515	0.203284028	2.52977E-05	4.56324E-12
6	0.901740613	0.225435153	0.203284033	0.901740602	0.22543515	0.203284028	1.07408E-08	0
7	0.901740602	0.22543515	0.203284028				0	
8	0.901740602	0.22543515	0.203284028					

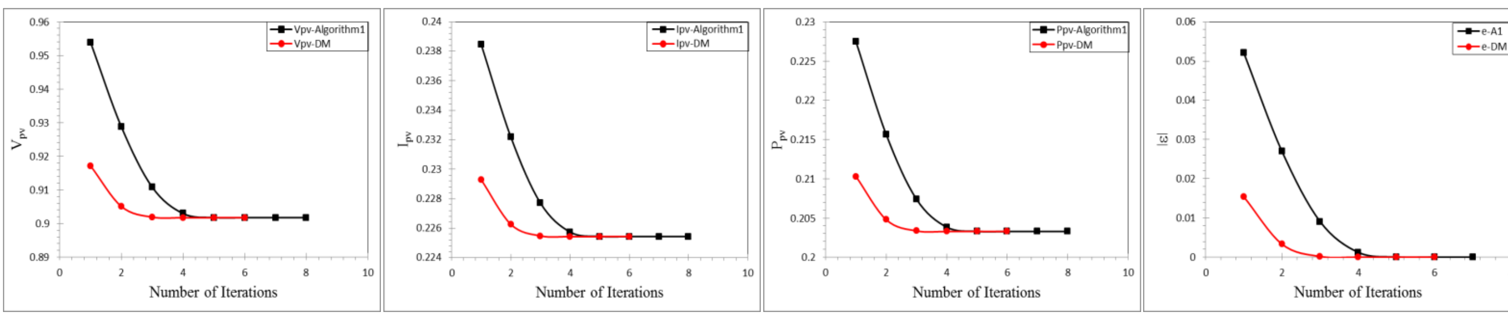

Fig. 5 - Test function Eq. 6 with initial guess V_0, R = 4 and error ε.

Table 5 - Comparison of A1 and DM.

Iterations	V_{pv}-A1	I_{pv}- A1	P_{pv}-A1	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-A1	ε- DM
1	0.952974818	0.190594964	0.181632201	0.912862081	0.182572416	0.166663436	0.063882103	0.023769366
2	0.926181706	0.185236341	0.171562511	0.896506952	0.17930139	0.160744943	0.037088991	0.007414237
3	0.904877121	0.180975424	0.163760521	0.889963259	0.177992652	0.158406921	0.015784406	0.000870545
4	0.892668197	0.178533639	0.159371302	0.889105773	0.177821155	0.158101815	0.003575482	1.30582E-05
5	0.88930602	0.177861204	0.15817304	0.889092718	0.177818544	0.158097172	0.000213306	2.98148E-09
6	0.889093511	0.177818702	0.158097454	0.889092715	0.177818543	0.158097171	7.96314E-07	2.22045E-16
7	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171	1.11464E-11	0
8	0.889092715	0.177818543	0.158097171				0	

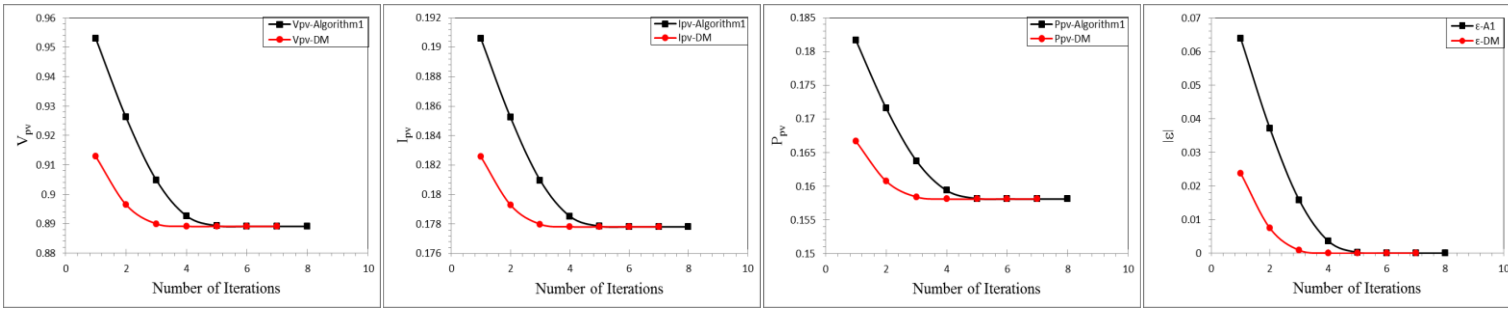

Fig. 6 - Test function Eq. 6 with initial guess V_0, $R = 5$ and error ε.

6. Conclusion

In this paper, a simple approach to construct a new modification of Predictor-Corrector type for finding zeros of nonlinear equations have been presented. The absolute error value of these two methods is calculated. Several numerical experiments have been examined and show the suggested technique is accurate, efficient and implements number of iteration better than other methods.

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