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Application of Numerical Analysis for Solving Nonlinear Equation

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ABSTRACT

For the last years, the various of Newton's formula have become common iterative numerical techniques to realize approximate solutions to the zeros of nonlinear equations of PV cell (single diode) model foe electronic applications. These techniques do not necessitate the computation of second derivative of the functions but it need only first derivative of it's functions. In this paper, we introduce a new proposed method Dekker's Formula with five evaluations per iterations based on Accelerated Predictor-Corrector Halley's method. Numerical experiments produce that the new algorithm can determine with the standard Newton's algorithm.

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1. Introduction

One of the most interest examples in numerical computations is solving nonlinear equations. In this paper, we examine iterative methods to obtain the zeros of nonlinear equation of PV cell for electronic device. Generally, the form of the nonlinear expression equation is $f(x) = 0$ where x including the real numbers. The standard Newton's method for a single nonlinear equation require first derivative of the function, which is basic and important method. There are many iterative methods have been used recently for solving nonlinear equations and improved on the advancement the convergence of Newton's method, in order to attain lesser iterations than it [1-115].

The suggested algorithm AHM requires 8 evaluations of the function while the other technique (DM) needs 5 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 AHM and DM algorithms respectively while; section five and six indicate the numerical problems, discussion and conclusion results respectively.

2. Principles and Analysis of A Nonlinear Equation

KCL Kirchhoff's law is employed in order to depict the electrical parameters of PV cell scheme [15-20]

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

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. Accelerated Predictor-Corrector Halley's Method (AHM)

The following steps describe this method

Step 1: let x_n is initial value

Step 2: calculate Algorithm 1: Newton's Method (NRM) using the equation

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}, n = 0, 1, 2, 3, \ldots$$

Step 3: determine Algorithm 2: Predictor- Corrector Hally Method (HM) using the equations

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

$$x_{n+1} = y_n - \frac{2 \times f(y_n) f'(y_n)}{2 \times f'(y_n)^2 - f(y_n) \times f''(y_n)}$$

Step 3: examine Algorithm 3: Accelerated Predictor- Corrector Hally Method (AHM) using the equations

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

$$x_{n+1} = y_n - \frac{2\times f(y_n)\acute{f}(y_n)}{2\times \acute{f}(y_n)^2 - f(y_n)\times \acute{\acute{f}}(y_n)}, n = 0, 1, 2, 3, \ldots$$

$$z_n = x_n - \frac{(x_{n+1} - x_n)^2}{x_{n+2} - 2\times x_{n+1} + x_n}, \ n = 0, 1, 2, 3, \ldots \quad (3)$$

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 Accelerated Predictor-Corrector Halley's Method (AHM) 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 AHM algorithm needs 8 iterations while DM technique need 5 iterations to reach to the convergence which proves that DM is faster than AHM.

Table 1 - Mathematical modeling of nonlinear equation.

Iterations	V_{pv}-AHM	I_{pv}- AHM	P_{pv}-AHM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-AHM	ε-DM
1	0.971416840	0.971416840	0.943650676	0.935676361	0.935676361	0.875490253	0.048993705	0.013253227
2	0.946732533	0.946732533	0.896302490	0.924881618	0.924881618	0.855406007	0.024309399	0.002458483
3	0.929865621	0.929865621	0.864650074	0.922517676	0.922517676	0.851038863	0.007442487	9.45419e-05
4	0.923247877	0.923247877	0.852386643	0.922423278	0.922423278	0.850864704	0.000824743	1.43768e-07
5	0.922434000	0.922434000	0.850884484	0.922423135	0.922423135	0.850864439	1.08652e-05	3.33178e-13
6	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439	1.90246e-09	0
7	0.922423135	0.922423135	0.850864439				1.11022e-16	
8	0.922423135	0.922423135	0.850864439				0	

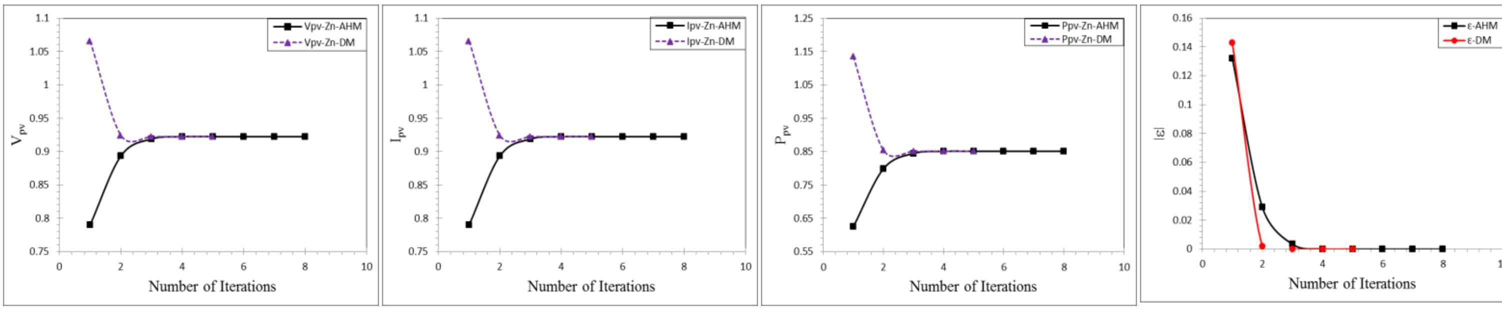

Fig. 1 – Implementation of numerical technique using nonlinear equation.

Table 2 - Mathematical modeling of nonlinear equation.

Iterations	V_{pv}-AHM	I_{pv}- AHM	P_{pv}-AHM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-AHM	ε-DM
1	0.971030449	0.485515224	0.471450066	0.933452217	0.466726109	0.435666521	0.053995066	0.016416835
2	0.945421879	0.47271094	0.446911265	0.920708663	0.460354331	0.423852221	0.028386497	0.00367328
3	0.926834345	0.463417173	0.429510952	0.917245191	0.458622596	0.420669370	0.009798963	0.000209809
4	0.918438709	0.459219354	0.421764831	0.917036095	0.458518047	0.420477600	0.001403327	7.1248e-07
5	0.917066884	0.458533442	0.420505835	0.917035382	0.458517691	0.420476946	3.15015e-05	8.24729e-12
6	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946	1.61171e-08	0
7	0.917035382	0.458517691	0.420476946				4.21885e-15	
8	0.917035382	0.458517691	0.420476946				0	

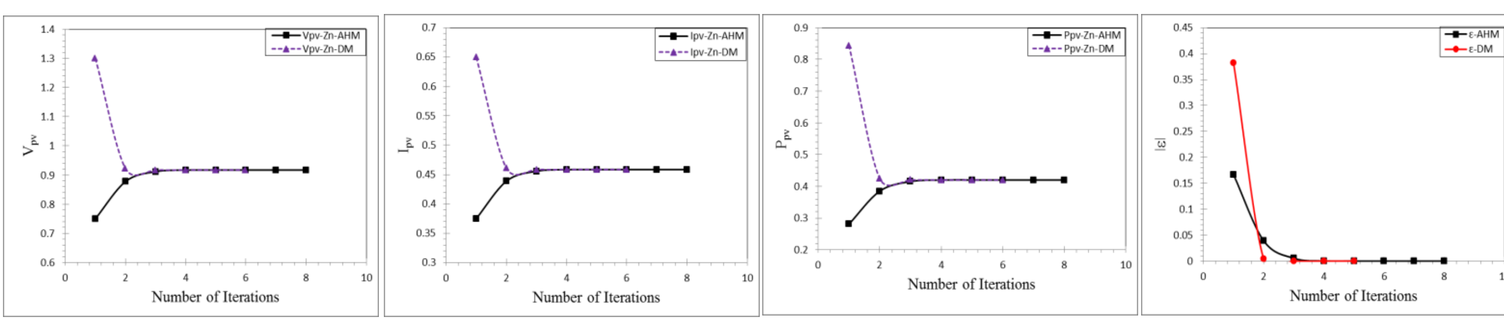

Fig. 2 – Implementation of numerical technique using nonlinear equation.

Table 3 - Mathematical modeling of nonlinear equation.

Iterations	V_{pv}-AHM	I_{pv}- AHM	P_{pv}-AHM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-AHM	ε-DM
1	0.970643767	0.323547922	0.314049774	0.931130698	0.310376899	0.289001459	0.060240393	0.020727324
2	0.944084126	0.314694709	0.297098279	0.916050276	0.305350092	0.279716036	0.033680752	0.005646902
3	0.923594034	0.307864678	0.284341980	0.910893745	0.303631248	0.276575805	0.01319066	0.000490371
4	0.912877747	0.304292582	0.277781927	0.910407298	0.303469099	0.276280483	0.002474373	3.92441e-06
5	0.910501258	0.303500419	0.276337514	0.910403374	0.303467791	0.276278101	9.78838e-05	2.53266e-10
6	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101	1.5741e-07	0
7	0.910403374	0.303467791	0.276278101				4.07563e-13	
8	0.910403374	0.303467791	0.276278101				0	

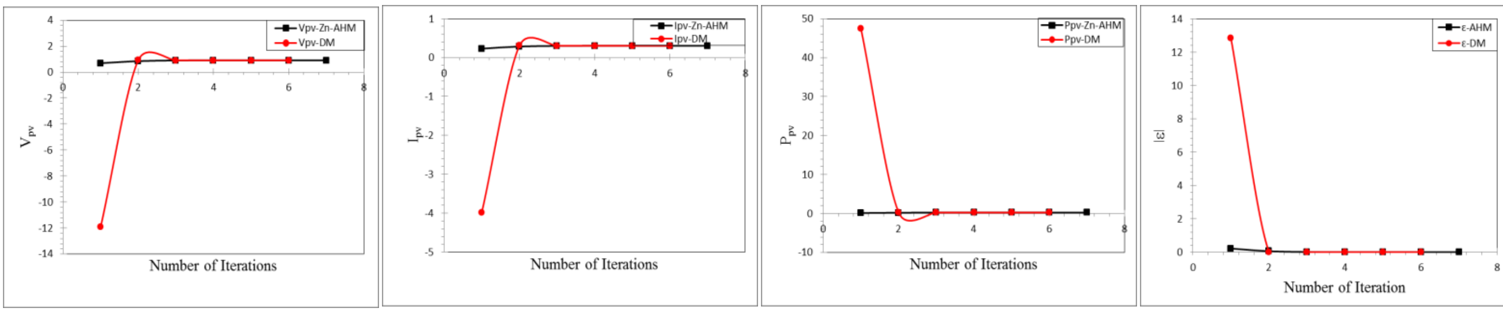

Fig. 3 – Implementation of numerical technique using nonlinear equation.

Table 4 - Mathematical modeling of nonlinear equation.

Iterations	V_{pv}-AHM	I_{pv}- AHM	P_{pv}-AHM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-AHM	ε-DM
1	0.970256795	0.242564199	0.235349562	0.928705817	0.232176454	0.215623624	0.068516193	0.026965215
2	0.942718592	0.235679648	0.222179586	0.910811274	0.227702819	0.207394294	0.04097799	0.009070672
3	0.920122669	0.230030667	0.211656431	0.902978772	0.225744693	0.203842666	0.018382067	0.00123817
4	0.906346232	0.226586558	0.205365873	0.901765896	0.225441474	0.203295433	0.00460563	2.52937e-05
5	0.902077679	0.22551942	0.203436035	0.901740613	0.225435153	0.203284033	0.000337077	1.07391e-08
6	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028	1.90073e-06	1.9984e-15
7	0.901740602	0.225435151	0.203284028	0.901740602	0.22543515	0.203284028	6.0686e-11	0
8	0.901740602	0.22543515	0.203284028				0	

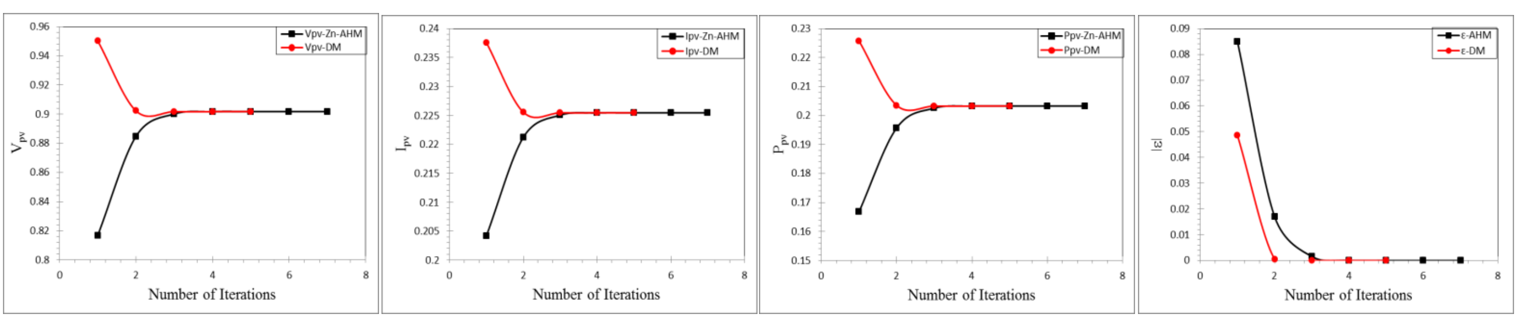

Fig. 4 – Implementation of numerical technique using nonlinear equation.

Table 5 - Mathematical modeling of nonlinear equation.

Iterations	V_{pv}-AHM	I_{pv}- AHM	P_{pv}-AHM	V_{pv}-DM	I_{pv}-DM	P_{pv}-DM	ε-AHM	ε-DM
1	0.969869532	0.193973906	0.188129382	0.926171150	0.185234230	0.171558600	0.080776817	0.037078435
2	0.941324576	0.188264915	0.177218391	0.904871623	0.180974325	0.163758531	0.052231861	0.015778908
3	0.916395271	0.183279054	0.167956059	0.892666909	0.178533382	0.159370842	0.027302556	0.003574194
4	0.898534787	0.179706957	0.161472953	0.889305949	0.177861190	0.158173014	0.009442072	0.000213234
5	0.890476758	0.178095352	0.158589771	0.889093511	0.177818702	0.158097454	0.001384043	7.96007e-07
6	0.889125756	0.177825151	0.158108922	0.889092715	0.177818543	0.158097171	3.30416e-05	1.11419e-11
7	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171	1.91868e-08	0
8	0.889092715	0.177818543	0.158097171				6.43929e-15	
9	0.889092715	0.177818543	0.158097171				0	

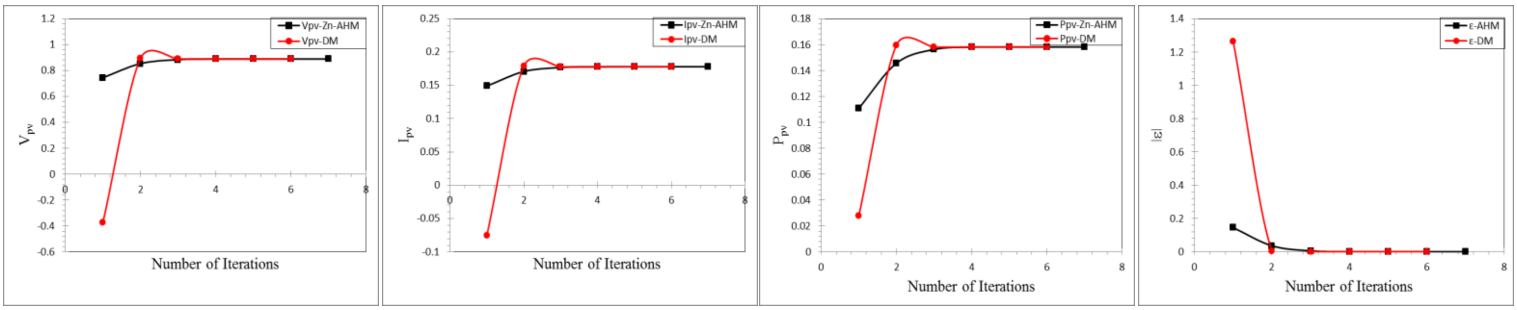

Fig. 5 – Implementation of numerical technique using nonlinear equation.

6. Conclusion

All numerical computations results are recorded in MATLAB program the stopping criterion has been taken as $|x_{n+1} - \alpha| + |f(x_{n+1})| < 10^{9}$. Several examples of nonlinear equation of PV cell have been analyzed and discussed. The new proposed method is free from second derivative of the function. Absolute error computations of the numerical methods are introduced too.

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