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The Single Diode Model for PV Characteristics Using Electrical Circuit

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ABSTRACT

A new algorithm of Two-Point Bracketing method based on Newton's algorithm has been developed. The order of convergence of the proposed algorithm is six. Starting with a suitably chosen x_0, this technique generates a sequence of iterations converging to the root. It requires evaluations of only one first order derivatives per iteration. The proposed method is comparable with NRM and does not need an evaluation derivative at the second order of the given function as required in other numerical methods. The efficiency of the technique is tested on a nonlinear equation of a model of a PV cell. It is observed that the proposed method needs lesser number of iterations than NRM.

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1. Introduction

The form of $f(x) = 0$ represent for several non-Linear equations, in Engineering and Science are complex. The exact solution using the common algebraic method, the numerical iterative algorithms for example iterative, regula falsi; Bisection and Newton techniques are used to realize the approximate numerical solution of these equations [1-18]. Several techniques are improved on the perfection of Newton's technique convergent, in order to obtain a superior convergence order than NRM [19-64].

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This paper is interest with the iterative algorithm to get a value of PV cell, voltage V_{pv} in the conditions $f(x) = 0$, and $\acute{f}(x) \neq 0$ where $f: R \rightarrow R$ be real function. The follows steps describe the procedure of this paper: section two depicting a model of a PV cell; section three characterize the zeros finding for Newton Raphson algorithm; whereas in section four Two-Point Bracketing technique has been portrayed; section five describe the results and discussion; finally section six contains the conclusions of the checked values obtained.

2. One-Diode Electrical Circuit : Non-Linear Equation

Consider Figure 1.

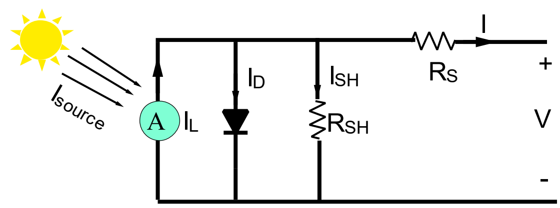

Fig. 1 – One diode of PV circuit.

The current and voltage characteristics of PV cell reported using the following Eqns. Kirchhoff's current law (KCL) is used

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

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

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

where:

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

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

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

Demage Eq. 4 in Eq. 5 yield

$$(I_{source}) - 10^{-12}\left(e^{(-V/1.2\times0.026)} - 1\right) = V/R \tag{6}$$

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

where: I_s reverse saturation current $= 10^{-12}$A.

Solving the first derivative of Eq. 6, V_{pv} has been determined numerically.

3. Newton's Algorithm Description

The following algorithm suggestion for solving Eq. 6 by using NRM

1. Let $x_0 = 1$ initial value.
2. Define $x = 0$
3. while $i \leq x_0$
4. Compute $x_{n+1} = x_n - \frac{f(x_n)}{\acute{f}(x_n)}$ for $n = 0, 1, 2, ...$ The approximate solution.
5. If $|x_i - x_{i-1}| < \varepsilon$ (tolerance); then determine x_{n+1} and stop.

6. Put $n = n + 1; i = i + 1$ and go to 2.
7. Output

4. Two – Point Bracketing Method (TPBM)

Two-Point Bracketing method is a root-finding algorithm, a numerical method for solving nonlinear equations in the form of $f(x) = 0$. This method starts with two x as initial values, initially found by trial-and error, at which the function $f(x)$ has opposite signs. Suppose the current bracketing interval is $[a_k, b_k]$, then the new solution consider c_k is obtained by

$$c_k = (a_k + b_k)/2 \tag{8}$$

Thus c_k is between a_k and b_k.

5. Results and Discussion

Pointing to Eq. 6, we start with $x_n = 1$ for all cases; in Table 1 we give the number of iterations and the number of function evaluations needed satisfying the stopping criterion where $R = 1$,

Table 1 - V_{pv} obtained by solving Eq. 6 using various methods.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- TPBM	I_{pv}- TPBM	P_{pv}- TPBM	ε-NRM	ε-TPBM
1	1	1	1	0.959074734	0.959074734	0.919824345	0.077576865	0.036651599
2	0.971416861	0.971416861	0.943650719	0.938299156	0.938299156	0.880405306	0.048993727	0.015876021
3	0.946732606	0.946732606	0.896302627	0.9265568	0.9265568	0.858507503	0.024309472	0.004133665
4	0.929865706	0.929865706	0.864650231	0.922840947	0.922840947	0.851635413	0.007442571	0.000417812
5	0.923247893	0.923247893	0.852386673	0.922428568	0.922428568	0.850874463	0.000824759	$5.43368E^{-06}$
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864441	$1.08655E^{-05}$	$9.5125E^{-10}$
7	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439	$1.9025E^{-09}$	0
8	0.922423135	0.922423135	0.850864439				$1.11022E^{-16}$	
9	0.922423135	0.922423135	0.850864439				0	

Figure 2 displays the iteration number of the voltage, current and power parameters of PV cell.

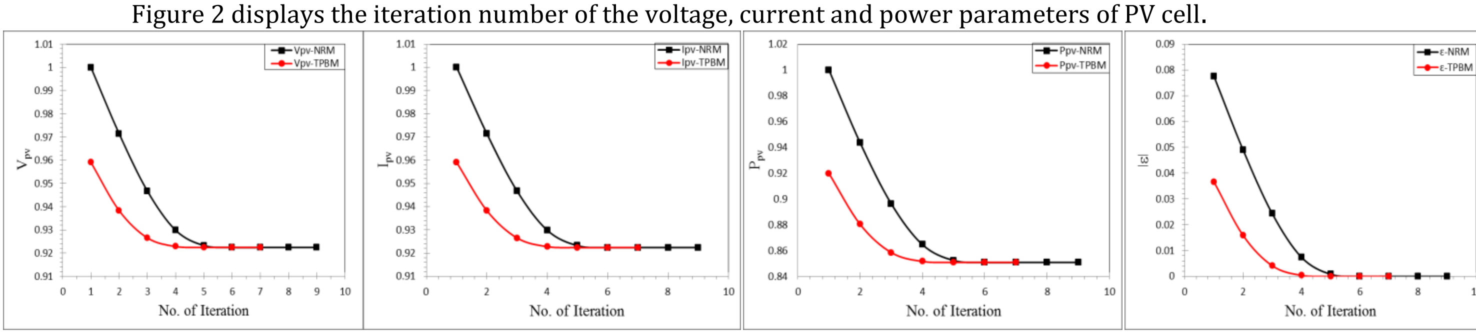

Fig. 2 – Estimated parameters from experimental data.

In Table 2 we give the number of iterations and the number of function evaluations needed satisfying the stopping criterion where $R = 2$.

Table 2 - V_{pv} obtained by solving Eq. 6 using various methods.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- TPBM	I_{pv}- TPBM	P_{pv}- TPBM	ε-NRM	ε-TPBM
1	1	0.5	0.5	0.958226219	0.47911311	0.459098744	0.082964618	0.041190837
2	0.971030472	0.485515236	0.471450089	0.936128222	0.468064111	0.438168024	0.05399509	0.019092839
3	0.945421967	0.472710983	0.446911348	0.922636611	0.461318306	0.425629158	0.028386584	0.005601229
4	0.926834477	0.463417238	0.429511073	0.917752815	0.458876408	0.421135115	0.009799094	0.000717433
5	0.918438746	0.459219373	0.421764865	0.917051142	0.458525571	0.420491398	0.001403363	1.57593E^{-05}
6	0.917066885	0.458533442	0.420505836	0.91703539	0.458517695	0.420476954	3.15024E^{-05}	8.0588E^{-09}
7	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946	1.61176E^{-08}	2.10942E^{-15}
8	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	4.21885E^{-15}	0
9	0.917035382	0.458517691	0.420476946				0	

Figure 3 shows the iteration number of the voltage, current and power parameters of PV cell.

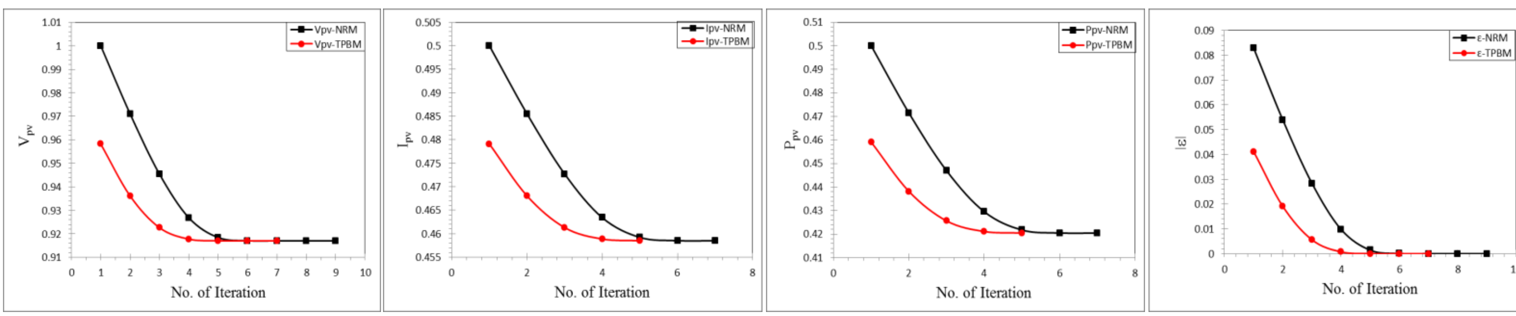

Fig. 3 - Estimated parameters from experimental data.

In Table 3 we give the number of iterations and the number of function evaluations needed satisfying the stopping criterion where R = 3.

Table 3 - V_{pv} obtained by solving Eq. 6 using various methods.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- TPBM	I_{pv}- TPBM	P_{pv}- TPBM	ε-NRM	ε-TPBM
1	1	0.333333333	0.333333333	0.957364012	0.319121337	0.305515284	0.089596626	0.046960638
2	0.970643792	0.323547931	0.31404979	0.933839237	0.311279746	0.29068524	0.060240418	0.023435863
3	0.944084232	0.314694744	0.297098346	0.918236042	0.306078681	0.281052476	0.033680858	0.007832668
4	0.923594243	0.307864748	0.284342109	0.911689551	0.303896517	0.277059279	0.013190869	0.001286177
5	0.91287784	0.304292613	0.277781984	0.910452397	0.303484132	0.276307856	0.002474466	4.90229E-05
6	0.910501262	0.303500421	0.276337516	0.910403453	0.303467818	0.276278149	9.78883E-05	7.87086E-08
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101	1.57417E-07	2.03837E-13
8	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	4.07563E-13	0
9	0.910403374	0.303467791	0.276278101				0	

Figure 4 displays the iteration number of the voltage, current and power parameters of PV cell.

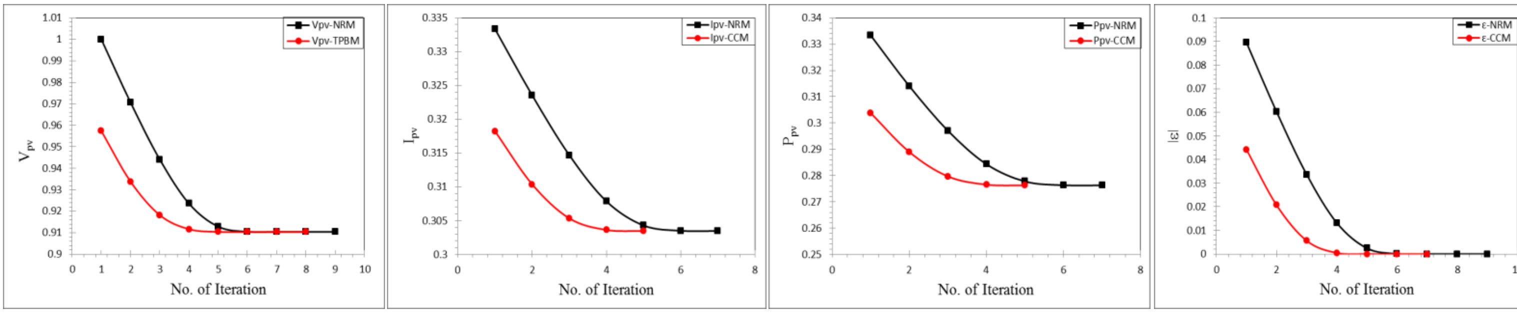

Fig. 4 - Estimated parameters from experimental data.

In Table 4 we give the number of iterations and the number of function evaluations needed satisfying the stopping criterion where R = 4.

Table 4 - V_{pv} obtained by solving Eq. 6 using various methods.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- TPBM	I_{pv}- TPBM	P_{pv}- TPBM	ε-NRM	ε-TPBM
1	1	0.25	0.25	0.956487771	0.239121943	0.228717214	0.098259398	0.054747169
2	0.970256822	0.242564205	0.235349575	0.931420865	0.232855216	0.216886207	0.06851622	0.029680263
3	0.94271872	0.23567968	0.222179646	0.913234752	0.228308688	0.208499428	0.040978118	0.01149415
4	0.920123009	0.230030752	0.211656588	0.9042121	0.226053025	0.204399881	0.018382407	0.002471498
5	0.906346494	0.226586624	0.205365992	0.901910105	0.225477526	0.203360459	0.004605892	0.000169503
6	0.902077706	0.225519427	0.203436047	0.901741552	0.225435388	0.203284457	0.000337104	9.50472E-07
7	0.901742503	0.225435626	0.203284885	0.901740602	0.225435151	0.203284028	1.90088E-06	3.03456E-11
8	0.901740602	0.225435151	0.203284028	0.901740602	0.22543515	0.203284028	6.06911E-11	0
9	0.901740602	0.22543515	0.203284028				0	

Figure 5 displays the iteration number of the voltage, current and power parameters of PV cell.

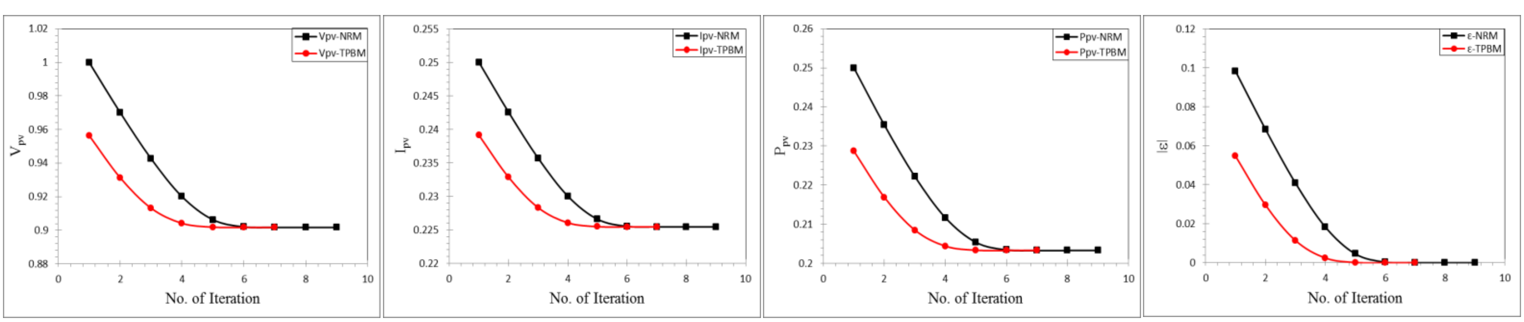

Fig. 5 - Estimated parameters from experimental data.

In Table 5 we give the number of iterations and the number of function evaluations needed satisfying the stopping criterion where R = 5.

Table 5 - V_{pv} obtained by solving Eq. 6 using various methods.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- TPBM	I_{pv}- TPBM	P_{pv}- TPBM	ε-NRM	ε-TPBM
1	1	0.2	0.2	0.955597145	0.191119429	0.182633181	0.110907285	0.066504431
2	0.96986956	0.193973912	0.188129393	0.928860287	0.185772057	0.172556287	0.080776845	0.039767572
3	0.941324731	0.188264946	0.17721845	0.907465744	0.181493149	0.164698815	0.052232016	0.018373029
4	0.916395843	0.183279169	0.167956268	0.894506327	0.178901265	0.160028314	0.027303128	0.005413612
5	0.898535645	0.179707129	0.161473261	0.889801386	0.177960277	0.158349301	0.00944293	0.000708671
6	0.890477009	0.178095402	0.158589861	0.889109249	0.17782185	0.158103051	0.001384294	1.65338E-05
7	0.889125763	0.177825153	0.158108925	0.889092724	0.177818545	0.158097174	3.30483E-05	9.59538E-09
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171	1.91907E-08	3.21965E-15
9	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171	6.43929E-15	0
10	0.889092715	0.177818543	0.158097171				0	

Figure 6 displays the iteration number of the voltage, current and power parameters of PV cell.

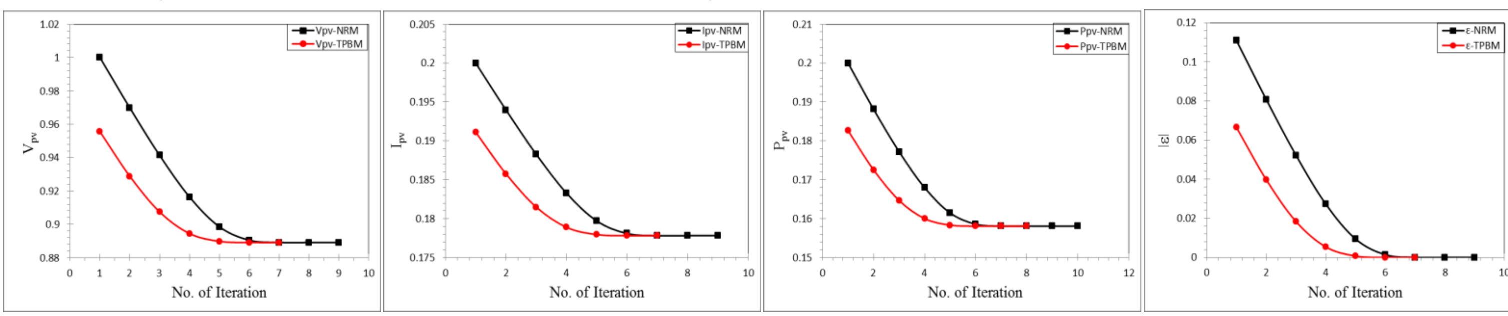

Fig. 6 - Estimated parameters from experimental data.

Tables and Figures (1, 2,3, 4 and 5), (2,3, 4, 5 and 6), respectively have been depicted that the suggested method for finding simple real zeros of non-linear equation with different values of R is free from second order derivative of the Eq. 6. Thus, this method is examined on several numbers of numerical experiments and on the comparison our results with those obtained by NRM, it is found that our method is most effective when it converges to the root must faster.

6. Conclusion

In this section, we present the results of single-diode nonlinear equation numerical tests to compare the efficiencies of the proposed technique. We used TPBM and Newton's algorithms in order to solve non-linear equation for PV cell. Numerical computational examples are examined with MATLAB and the criterion value achieved by the expression $|x_{n+1} - \alpha| + |f(x_{n+1})| < 10^{9}$.

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