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Determining the Voltage and Power of a Single Diode PV Cell in Matlab by Iteration

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ABSTRACT

In this paper, we proposed and analyzed a new two-step iterative method double false position method without derivatives in order to solve non-linear equation for a single-diode of a PV cell. We proved that the new proposed method with two-step iterative method could be regarded, as an alternative and modified method is accurate and efficient with a lesser number of iterations compared with the standard method NRM.

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1. Introduction

It is famous that a wide class of examples, which arise in different discipline of applied sciences, pure and engineering. Many problems require finding some or all roots of a nonlinear equation. In general, an equation containing one variable can be written as $f(x_n) = 0$. In modern years, many numerical algorithms have been approached and analyzed using various methods including Taylor series, quadrature and homotopy perturbation

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methods. The ideas and method can be utilized to acquire many iterative methods free from the second derivatives. There are a number of numerical algorithms to find an approximate value for a given root of the previous equation, the numerical iterative algorithms for example iterative, regula falsi; Bisection; secant and Newton techniques are used to achieve the approximate numerical solution of these equations [1-30]. All these numerical methods need a rough approximate value of a given equation root to enable it to generate sequential initial values of a given equation root to enable it to generate a sequential of better approximate values for that root. There are many techniques improved on the perfection of convergent Newton's method, in order to obtain a superior convergence order than NRM [31-66].

This paper is attention with the iterative algorithm for getting the value of the PV cell's voltage V_{pv} in the conditions $f(x) = 0$, and $\acute{f}(x) \neq 0$ where $f: R \rightarrow R$ be real function. The methodical of the paper achieves according to the following: in section two, the analytical model of a single-diode design of the solar cell has been depicted. In section three, the zeros finding of Newton Raphson algorithm is characterized. While in section four Double False Position method has been portrayed. In section five the discussion of the results is introduced. Finally, in section six the conclusion of an obtained results.

2. Solar Cell: One Diode: Non-Linear Equation

Suppose Figure 1.

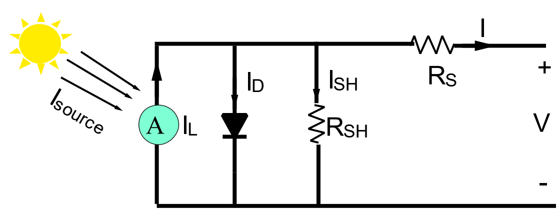

Fig. 1 – PV cell: single-diode equivalent circuit.

The current and voltage characteristics of the solar cell can be demonstrated using the following equations obey to Kirchhoff's current law (KCL)

$$I = I_{ph} - I_D \quad (1)$$

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

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

where:

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

$$I_{ph} = I_{source} \quad (4)$$

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

By integrate Eq. 4 in Eq. 5 yield

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

$$I_{pv} = V_{pv}/R;\ P_{pv} = I_{pv} \times V_{pv} \quad (7)$$

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

From Eq. 6 the voltage V_{pv} is calculated in numerical way using the first derivative of the function.

3. Newton's Numerical Technique

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 $n = 0, 1, 2, \ldots$. 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. Regula Falsi Method or Method of False Position or False Position Method (RFM)

Regula Falsi method is a root-finding algorithm, for solving nonlinear equations of the form $y = f(x) = 0$. It is old method for solving such equations but it is still in use. Two requisite types for false position technique is recognized historically, double false position and simple false position. The aim of double false position method (DFPM) is to solve complex problems which written algebraically in the form: calculate x so $f(x) = ax + b$, it is known that $f(x_1) = b_1$, $f(x_2) = b_2$.

It is mathematically equivalent to linear interpolation. Using a pair of test inputs x_0, x_1; the output results of this method is given by the recurrence relation

$$x = b_1x_2 - b_2x_1/(b_1 - b_2) \tag{8}$$

If we have a function (linear), for example $f(x) = ax + c$

Therefore, the exact solution of the function acquires using RFM, then, if f is a non-linear equation; it acquires an approximation which improves using iteration.

5. Results and Discussion

We start with $x_0 = 1$; for Eq. 6 the results acquired using Newton iteration and the present iteration method RFM is appeared in the Tables from 1 to 5.

The examine function in Eq. 6 after 1st derivative using two methods NRM and RFM and the approximation V_{pv} for the examine function including the initial estimate value v_0 are displayed in Table 1. In fact, V_{pv} is calculated by the same function in Eq. 6 for the two methods and the computational order of convergence (tolerance ε) for the two numerical techniques is displayed in this table with the use of $R = 1$.

Table 1 - Comparison of NRM and RFM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-RFM	I_{pv}-RFM	P_{pv}-RFM	ε-NRM	ε- RFM
1	1	1	1	0.935676402	0.935676402	0.875490329	0.077576865	0.013253267
2	0.971416861	0.971416861	0.943650719	0.924881651	0.924881651	0.855406068	0.048993727	0.002458516
3	0.946732606	0.946732606	0.896302627	0.922517679	0.922517679	0.851038869	0.024309472	$9.45447E^{-05}$
4	0.929865706	0.929865706	0.864650231	0.922423278	0.922423278	0.850864704	0.007442571	$1.43773E^{-07}$
5	0.923247893	0.923247893	0.852386673	0.922423135	0.922423135	0.850864439	0.000824759	$3.33178E^{-13}$
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439	$1.08655E^{-05}$	0
7	0.922423136	0.922423136	0.850864443				$1.9025E^{-09}$	
8	0.922423135	0.922423135	0.850864439				$1.11022E^{-16}$	
9	0.922423135	0.922423135	0.850864439				0	

From table 1, one can see that nine iterations are needed in order to reach to the convergence for NRM, while the convergence is reached in six iterations for the proposed method RFM. Figure 2 represents comparative study for determines the value of the root V_{pv} for Eq. 6 based on NRM and RFM techniques with the use of R = 1.

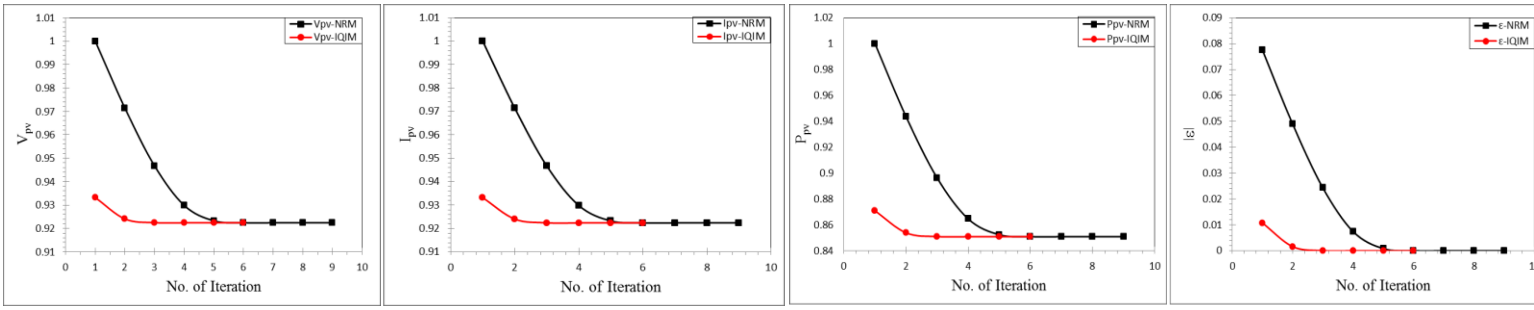

Fig. 2 – Solutions of Eq. 6 and ε value obtained using various techniques.

The examine function in Eq. 6 after 1st derivative using two methods NRM and RFM and the approximation V_{pv} for the examine function including the initial estimate value v_0 with the (tolerance ε) value are displayed in Table 2.

Table 2 - Comparison with NRM and RFM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-RFM	I_{pv}-RFM	P_{pv}-RFM	ε-NRM	ε- RFM
1	1	0.5	0.5	0.933452268	0.466726134	0.435666569	0.082964618	0.016416886
2	0.971030472	0.485515236	0.471450089	0.920708719	0.46035436	0.423852273	0.05399509	0.003673337
3	0.945421967	0.472710983	0.446911348	0.917245199	0.4586226	0.420669378	0.028386584	0.000209817
4	0.926834477	0.463417238	0.429511073	0.917036095	0.458518047	0.4204776	0.009799094	7.12519E-07
5	0.918438746	0.459219373	0.421764865	0.917035382	0.458517691	0.420476946	0.001403363	8.24774E-12
6	0.917066885	0.458533442	0.420505836	0.917035382	0.458517691	0.420476946	3.15024E-05	0
7	0.917035399	0.458517699	0.420476961				1.61176E-08	
8	0.917035382	0.458517691	0.420476946				4.21885E-15	
9	0.917035382	0.458517691	0.420476946				0	

From table 2, one can see that nine iterations are needed in order to reach to the convergence for NRM, while the convergence is reached in six iterations for the proposed method RFM. Figure 3 represents comparative study for determines the value of the root V_{pv} for Eq. 6 based on NRM and RFM techniques with the use of R = 2.

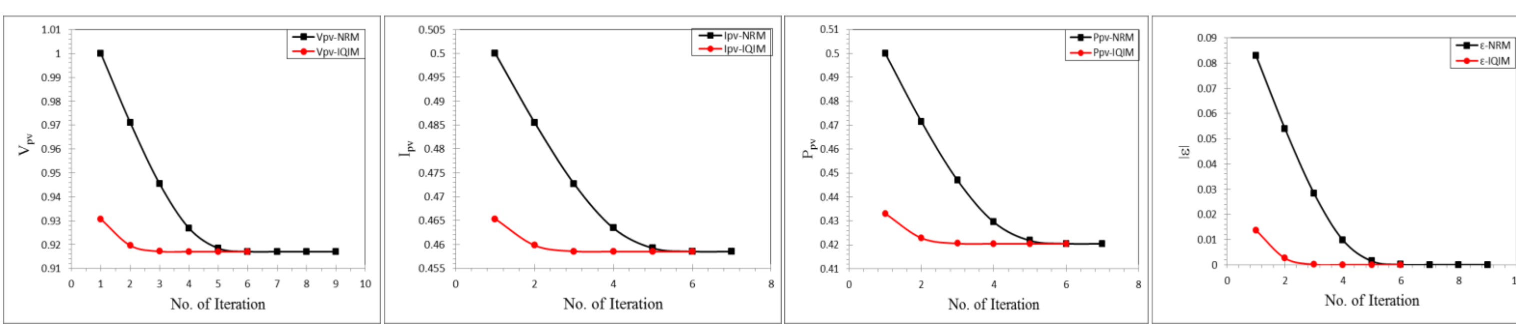

Fig. 3 - Solutions of Eq. 6 and ε value obtained using various techniques.

The examine function in Eq. 6 after 1st derivative using two methods NRM and RFM and the approximation V_{pv} for the examine function including the initial estimate value v_0 with the (tolerance ε) value are displayed in Table 3

Table 3 - Comparison with NRM and RFM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-RFM	I_{pv}-RFM	P_{pv}-RFM	ε-NRM	ε- RFM
1	1	0.333333333	0.333333333	0.931130761	0.31037692	0.289001498	0.089596626	0.020727387
2	0.970643792	0.323547931	0.31404979	0.916050375	0.305350125	0.279716096	0.060240418	0.005647001
3	0.944084232	0.314694744	0.297098346	0.91089377	0.303631257	0.27657582	0.033680858	0.000490396
4	0.923594243	0.307864748	0.284342109	0.910407299	0.3034691	0.276280483	0.013190869	$3.92473E^{-06}$
5	0.91287784	0.304292613	0.277781984	0.910403374	0.303467791	0.276278101	0.002474466	$2.53289E^{-10}$
6	0.910501262	0.303500421	0.276337516	0.910403374	0.303467791	0.276278101	$9.78883E^{-05}$	0
7	0.910403531	0.303467844	0.276278197				$1.57417E^{-07}$	
8	0.910403374	0.303467791	0.276278101				$4.07563E^{-13}$	
9	0.910403374	0.303467791	0.276278101				0	

From table 3, one can see that nine iterations are needed in order to reach to the convergence for NRM, while the convergence is reached in six iterations for the proposed method RFM. Figure 4 represents comparative study for determines the value of the root V_{pv} for Eq. 6 based on NRM and RFM techniques with the use of R = 3.

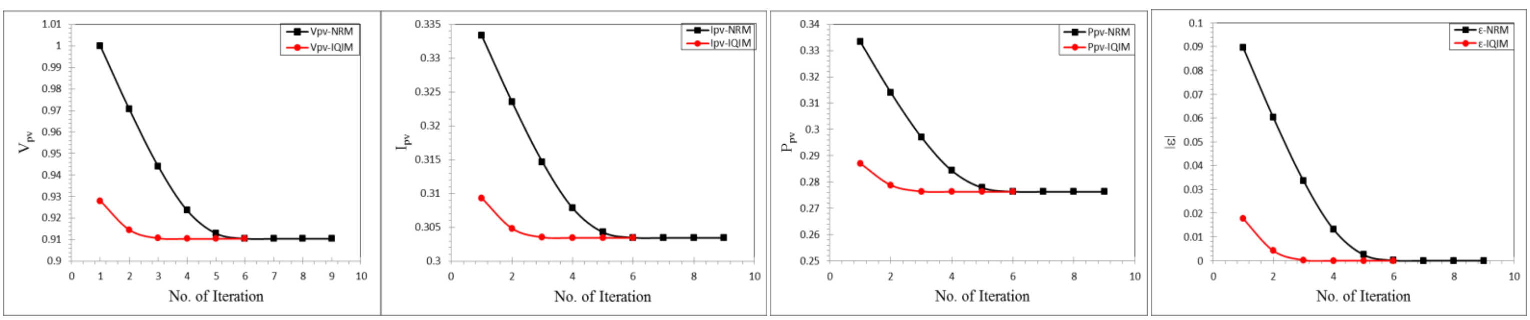

Fig. 4 - Solutions of Eq. 6 and ε value obtained using various techniques.

The examine function in Eq. 6 after 1st derivative using two methods NRM and RFM and the approximation V_{pv} for the examine function including the initial estimate value v_0 with the (tolerance ε) value are displayed in Table 4.

Table 4 - Comparison with NRM and RFM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-RFM	I_{pv}-RFM	P_{pv}-RFM	ε-NRM	ε- RFM
1	1	0.25	0.25	0.928705897	0.232176474	0.215623661	0.098259398	0.026965295
2	0.970256822	0.242564205	0.235349575	0.910811452	0.227702863	0.207394375	0.06851622	0.00907085
3	0.94271872	0.23567968	0.222179646	0.902978861	0.225744715	0.203842706	0.040978118	0.001238259
4	0.920123009	0.230030752	0.211656588	0.901765899	0.225441475	0.203295434	0.018382407	$2.52971E^{-05}$
5	0.906346494	0.226586624	0.205365992	0.901740613	0.225435153	0.203284033	0.004605892	$1.07408E^{-08}$
6	0.902077706	0.225519427	0.203436047	0.901740602	0.22543515	0.203284028	0.000337104	$1.88738E^{-15}$
7	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028	$1.90088E^{-06}$	0
8	0.901740602	0.225435151	0.203284028				$6.06911E^{-11}$	
9	0.901740602	0.22543515	0.203284028				0	

From table 4, one can see that nine iterations are needed in order to reach to the convergence for NRM, while the convergence is reached in six iterations for the proposed method RFM. Figure 5 represents comparative study for determines the value of the root V_{pv} for Eq. 6 based on NRM and RFM techniques with the use of R = 4.

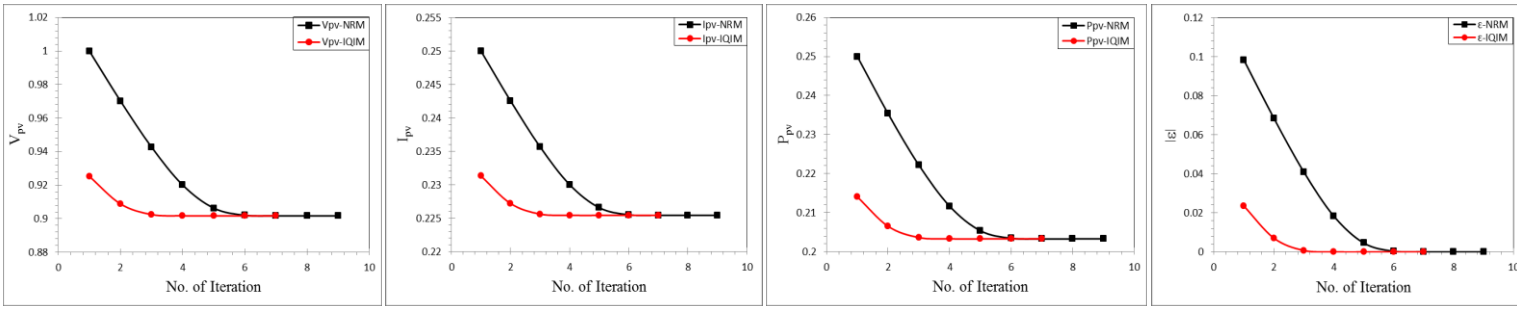

Fig. 5 - Solutions of Eq. 6 and ε value obtained using various techniques.

The examine function in Eq. 6 after 1st derivative using two methods NRM and RFM and the approximation V_{pv} for the examine function including the initial estimate value v_0 with the (tolerance ε) value are displayed in Table 5.

Table 5 - Comparison with NRM and RFM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-RFM	I_{pv}-RFM	P_{pv}-RFM	ε-NRM	ε- RFM
1	1	0.2	0.2	0.926171251	0.18523425	0.171558637	0.110907285	0.037078536
2	0.96986956	0.193973912	0.188129393	0.904871952	0.18097439	0.16375865	0.080776845	0.015779238
3	0.941324731	0.188264946	0.17721845	0.89266728	0.178533456	0.159370975	0.052232016	0.003574566
4	0.916395843	0.183279169	0.167956268	0.889306005	0.177861201	0.158173034	0.027303128	0.00021329
5	0.898535645	0.179707129	0.161473261	0.889093511	0.177818702	0.158097454	0.00944293	7.96313E-07
6	0.890477009	0.178095402	0.158589861	0.889092715	0.177818543	0.158097171	0.001384294	1.11465E-11
7	0.889125763	0.177825153	0.158108925	0.889092715	0.177818543	0.158097171	3.30483E-05	0
8	0.889092734	0.177818547	0.158097178				1.91907E-08	
9	0.889092715	0.177818543	0.158097171				6.43929E-15	
10	0.889092715	0.177818543	0.158097171				0	

From table 4, one can see that nine iterations are needed in order to reach to the convergence for NRM, while the convergence is reached in six iterations for the proposed method RFM. Figure 6 represents comparative study for determines the value of the root V_{pv} for Eq. 6 based on NRM and RFM techniques with the use of $R = 5$.

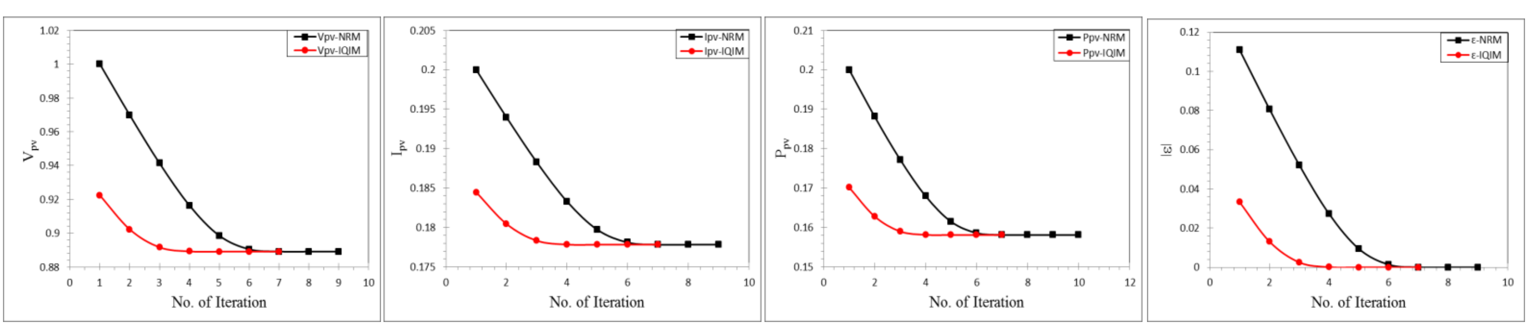

Fig. 6 - Solutions of Eq. 6 and ε value obtained using various techniques.

Based on Tables 1-5 and Figures 2-6, one can see that the proposed technique RFM is faster than NRM for determine the root of the Eq. 6 V_{pv}.

6. Conclusion

In this paper, we have acquired some new results of single-diode nonlinear equation using double false position method; a new approach to without using the second derivative. We have improved the order of convergence of this method. Numerical analysis proves that the suggested technique is more accurate and efficient comparable with the other famous method NRM and the other methods including the second order derivative of the function. We used RFM and Newton's algorithms in order to solve a nonlinear equation of a PV cell.

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