University Of AL-Qadisiyah
Available online at www.qu.edu.iq/journalcm
JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

Estimation of Single-Diode Model Parameters of PV Cell

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ARTICLE INFO

Article history:
Received: 03 /01/2021
Rrevised form: 23 /01/2021
Accepted : 25 /02/2021
Available online: 27 /02/2021

Keywords:

Predictor-Corrector [type 2] algorithm; Predictor-Corrector [type 1] algorithm; Newton's algorithm; comparison; physical parameters; load resistance.

ABSTRACT

The basic motivation of the present work is to apply the Predictor-Corrector [type 2] algorithm to perform the steps in Newton's and modified Newton's methods for approximating the solution of nonlinear equation of single diode model for a solar cell. A simple starting point for the iterative solutions is proposed. Some numerical applications are depicted and show that eight iterations are required to acquire approximate solutions, which are found to be sufficient, accurate, and efficient.

MSC. 41A25; 41A35; 41A36.

DOI : https://doi.org/10.29304/jqcm.2021.13.1.759

1. Introduction

Numerical analysis is deals with the mathematical derivation, description, and analysis of methods of acquiring numerical solutions of mathematical problems in various fields such as sciences; engineering; biology; chemistry and mathematics which consist of many subject as optimal control; integral and partial equations [1-17]. The study of direct and indirect thin-film technology has opened many areas of scientific research in solid-state physics based on unique phenomena of membranes such as thickness, shape, and composition of these films. Thin-film technology is the key to continuing technological advances in many fields such as photoelectric, optical and magnetic fields. The thin-film technology enables us to manufacture various electronic devices, as most of the materials differ in their

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Communicated by: Alaa Hussein Hamadi

physical, electrical, optical, and magnetic properties. When they are thin films, which helps to take advantage of these changes in the manufacture of new multi-use devices and applications that enter the manufacture of microelectronics and magnetic recording films optical sensors, solar cells, filters, remote sensors, etc [18-64].

In this paper both Newton's and improved Newton's method are applied for solving non-linear equation of a PV cell. It's describes according to the next steps: section two characterizing the model of a non-linear equation; section three establishing the zeros finding of Newton Raphson algorithm; whereas; in section four predictor-corrector [type 1] algorithm has been depicted; section 5 predictor-corrector [type 2] technique has been demonstrated; section six results and discussion; section seven the conclusion.

2. One-Diode Solar Cell Modelling Using Matlab

Suppose Figure 1.

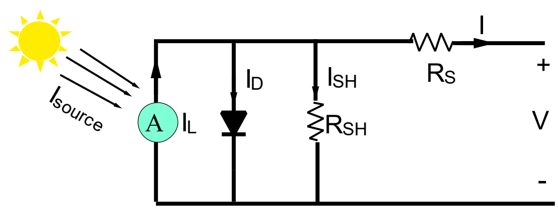

Fig. 1 – Solved Eq. 6 by means of various methods.

Junction rule and Kirchhoff's current law (KCL) gives

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

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

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

where:

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

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

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

Merge Eq. 4 in Eq. 5 we get

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

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

Eq. 6 is a non-linear equation of the model and the PV parameters have been extracted by take it's first derivative.

3. Newton's 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 $i \le x_0$
4. Compute $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$ 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. Predictor-Corrector Type 1 (Algorithm 1)

Using the predictor-corrector type technique, we suggest the following two-step method, which is acquired by combining the Newton's method to obtain algorithm 1.

Let H_0, calculate H_{n+1} which is the approximate solution

$$H_{n+1} = H_n - [f(H_n)/\acute{f}(H_n)]$$

$$H_{n+1} = H_n - [6 \times f(H_n)/[\acute{f}(H_n) + 4 \times \acute{f}(H_n + H^*_{n+1} / 2) + \acute{f}(H^*_{n+1})]] , n = 0, 1, 2, 3, \ldots$$

where x_0 is an initial value.

5. Predictor – Corrector Type (Algorithm 2)

To compare the different numerical methods of iterations, methods 1 NRM has been used against the proposed method 2 Predictor-Corrector [Type 2] (Algorithm 2). In addition; Eq. 6 has been solved to demonstrate the performance of the new method, the results are examined using some iteration.

Using the predictor-corrector type technique, we suggest the following two-step method, which is acquired by combining the Newton's method to obtain algorithm 2.

Let H_0, calculate H_{n+1} which is the approximate solution

$$H_{n+1} = H_n - [6 \times f(H_n) \times \acute{f}(H_n)/ 2 \times (\acute{f}(H_n))^2 - f(H_n) \times \acute{\acute{f}}(H_n)]$$

$$H_{n+1} = H_n - [6 \times f(H_n)/[\acute{f}(H_n) + 4 \times \acute{f}(H_n + H^*_{n+1} / 2) + \acute{f}(H^*_{n+1})]] , n = 0, 1, 2, 3, \ldots$$

An efficient starting iteration H_0 can be obtained by substitution for Eq. 6

where x_0 is an initial value.

6. Results and Discussion

Solving Eq. 6 numerically yields: In Table 1 shows NRM and Predictor-Corrector [type 1] and [type 2] of the solution results; voltage V_{pv}; current I_{pv}; power P_{pv} of the solar cell [R = 1] load resistance. This table indicates the number of iterations for different techniques, the approximation x_n for test function Eq. 6 with guess initial estimate value x_0 is displayed in this table too.

In order to calculate and compare the accuracy of the optimization proposed method, Eq. 6 has been used.

Table 1 - The obtained values using NRM, Algorithm 1 and Algorithm 2.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	1	1	0.956353318	0.956353318	0.914611669	0.909061968	0.909061968	0.826393662
2	0.971416861	0.971416861	0.943650719	0.935681181	0.935681181	0.875499273	0.912675411	0.912675411	0.832976406
3	0.946732606	0.946732606	0.896302627	0.924882295	0.924882295	0.85540726	0.920491417	0.920491417	0.847304449
4	0.929865706	0.929865706	0.864650231	0.922517684	0.922517684	0.851038878	0.922359246	0.922359246	0.850746579
5	0.923247893	0.923247893	0.852386673	0.922423278	0.922423278	0.850864704	0.922423038	0.922423038	0.850864262
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439
7	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439
8	0.922423135	0.922423135	0.850864439						
9	0.922423135	0.922423135	0.850864439						

Figure 2 illustrates solutions of Eq. 6.

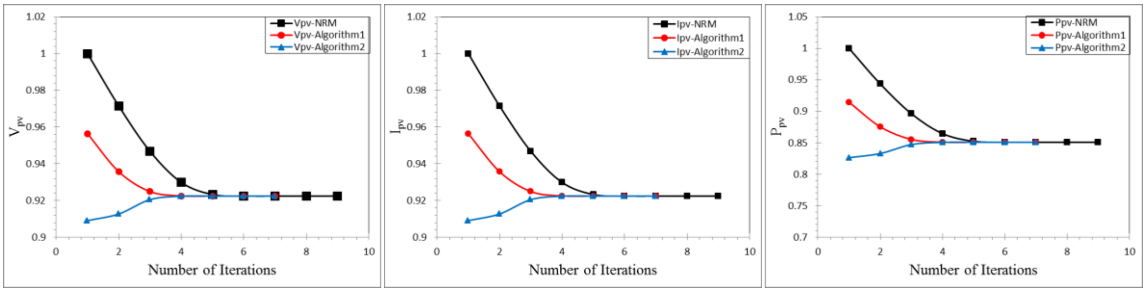

Fig. 2 – Number of iterations versus the parameters of PV cell.

The approximation x_n for test function Eq. 6 with guess initial estimate value x_0 is displayed in Table 2 at a value of R = 2.

Table 2 - The obtained values using NRM, Algorithm 1 and Algorithm 2.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.5	0.5	0.955521013	0.477760507	0.456510203	0.904579258	0.452289629	0.409131817
2	0.971030472	0.485515236	0.471450089	0.93345809	0.466729045	0.435672003	0.905657295	0.452828647	0.410107568
3	0.945421967	0.472710983	0.446911348	0.920709796	0.460354898	0.423853264	0.914052791	0.457026396	0.417746253
4	0.926834477	0.463417238	0.429511073	0.917245217	0.458622609	0.420669394	0.916889024	0.458444512	0.420342741
5	0.918438746	0.459219373	0.421764865	0.917036095	0.458518047	0.4204776	0.917034902	0.458517451	0.420476505
6	0.917066885	0.458533442	0.420505836	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946
7	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946
8	0.917035382	0.458517691	0.420476946						
9	0.917035382	0.458517691	0.420476946						

Figure 3 illustrates solutions of Eq. 6.

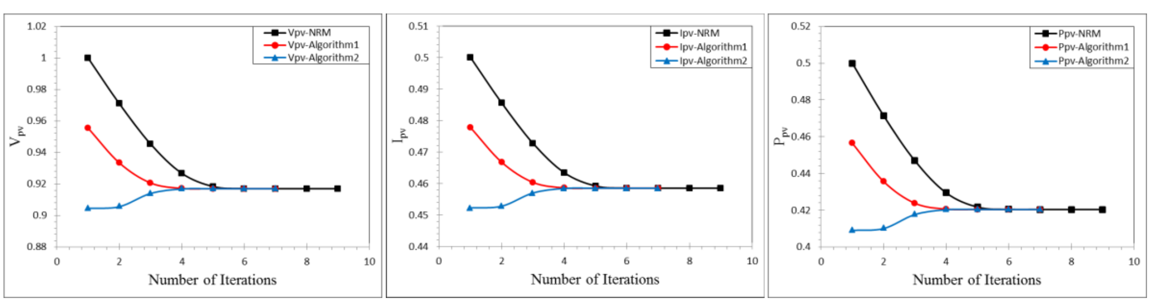

Fig. 3 - Number of iterations versus the parameters of PV cell.

The approximation x_n for test function Eq. 6 with guess initial estimate value x_0 is displayed in Table 3 at a value of R = 3.

Table 3 - The obtained values using NRM, Algorithm 1 and Algorithm 2.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.333333333	0.333333333	0.954680538	0.318226846	0.303804977	0.899816691	0.299938897	0.269890026
2	0.970643792	0.323547931	0.31404979	0.931137845	0.310379282	0.289005896	0.897407275	0.299135758	0.268446606
3	0.944084232	0.314694744	0.297098346	0.916052182	0.305350727	0.2797172	0.905697121	0.30189904	0.273429092
4	0.923594243	0.307864748	0.284342109	0.910893833	0.303631278	0.276575858	0.910042334	0.303347445	0.276059017
5	0.91287784	0.304292613	0.277781984	0.910407299	0.3034691	0.276280483	0.910400684	0.303466895	0.276276468
6	0.910501262	0.303500421	0.276337516	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101
8	0.910403374	0.303467791	0.276278101						
9	0.910403374	0.303467791	0.276278101						

Figure 4 illustrates solutions of Eq. 6.

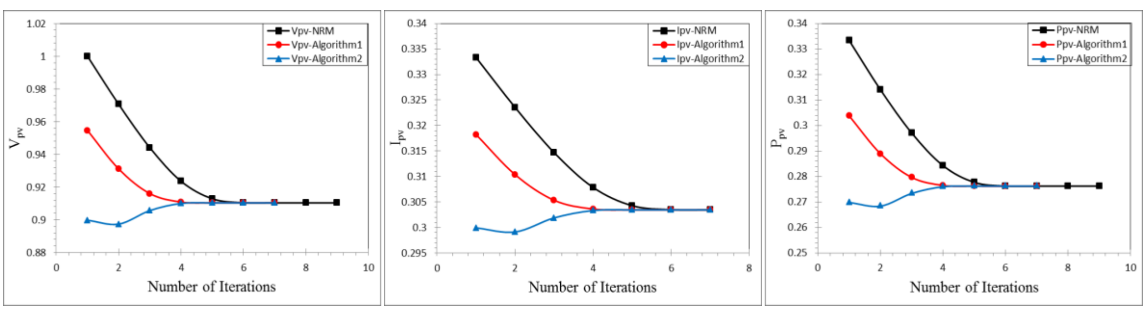

Fig. 4 - Number of iterations versus the parameters of PV cell.

The approximation x_n for test function Eq. 6 with guess initial estimate value x_0 is displayed in Table 4 at a value of $R = 4$.

Table 4 - The obtained values using NRM, Algorithm 1 and Algorithm 2.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.25	0.25	0.953831829	0.238457957	0.227448789	0.894754474	0.223688618	0.200146392
2	0.970256822	0.242564205	0.235349575	0.928714508	0.232178627	0.215627659	0.88761038	0.221902595	0.196963047
3	0.94271872	0.23567968	0.222179646	0.910814499	0.227703625	0.207395763	0.894168824	0.223542206	0.199884471
4	0.920123009	0.230030752	0.211656588	0.902979093	0.225744773	0.20384281	0.900742902	0.225185726	0.202834444
5	0.906346494	0.226586624	0.205365992	0.9017659	0.225441475	0.203295434	0.901722644	0.225430661	0.203275931
6	0.902077706	0.225519427	0.203436047	0.901740613	0.225435153	0.203284033	0.901740594	0.225435149	0.203284025
7	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028	0.901740602	0.22543515	0.203284028
8	0.901740602	0.225435151	0.203284028	0.901740602	0.22543515	0.203284028	0.901740602	0.22543515	0.203284028
9	0.901740602	0.22543515	0.203284028						

Figure 5 illustrates solutions of Eq. 6.

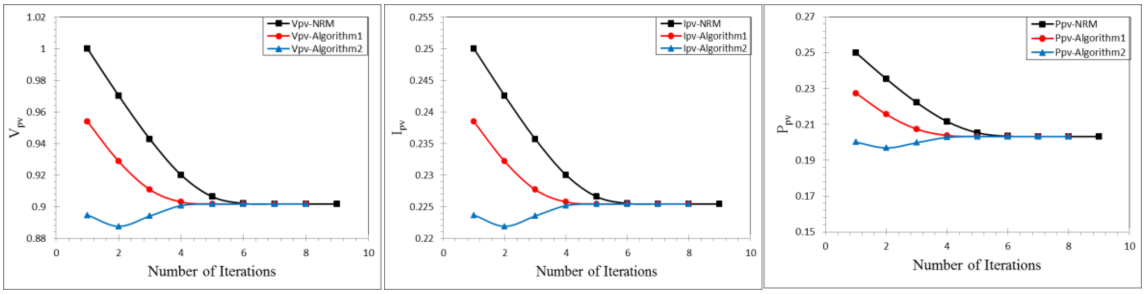

Fig. 5 - Number of iterations versus the parameters of PV cell.

The approximation x_n for test function Eq. 6 with guess initial estimate value x_0 is displayed in Table 5 at a value of R = 5.

Table 5 - The obtained values using NRM, Algorithm 1 and Algorithm 2.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.2	0.2	0.952974818	0.190594964	0.181632201	0.889371467	0.177874293	0.158196321
2	0.96986956	0.193973912	0.188129393	0.926181706	0.185236341	0.171562511	0.875855338	0.175171068	0.153424515
3	0.941324731	0.188264946	0.17721845	0.904877121	0.180975424	0.163760521	0.876941816	0.175388363	0.15380539
4	0.916395843	0.183279169	0.167956268	0.892668197	0.178533639	0.159371302	0.885772918	0.177154584	0.156918733
5	0.898535645	0.179707129	0.161473261	0.88930602	0.177861204	0.15817304	0.888923198	0.17778464	0.158036891
6	0.890477009	0.178095402	0.158589861	0.889093511	0.177818702	0.158097454	0.889092102	0.17781842	0.158096953
7	0.889125763	0.177825153	0.158108925	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171
9	0.889092715	0.177818543	0.158097171						
10	0.889092715	0.177818543	0.158097171						

Figure 6 illustrates solutions of Eq. 6.

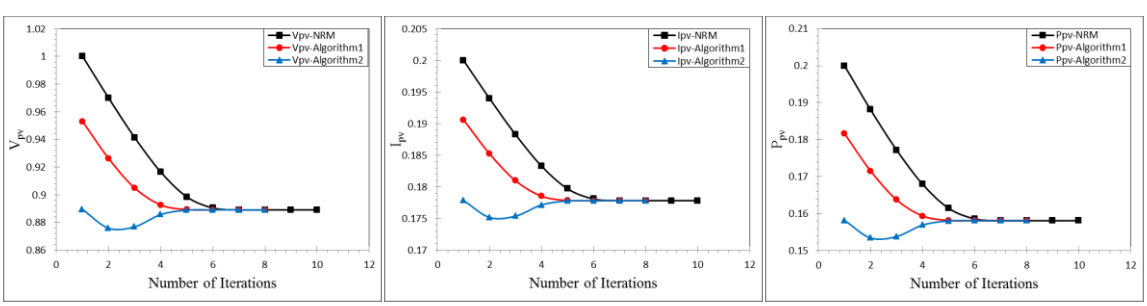

Fig. 6 - S Number of iterations versus the parameters of PV cell.

The obtained solution plot in the (no. of iteration)-V, I and P-plane and the initial-output values proves that the proposed method Predictor-Corrector [type 2] have an eight iterations indicated a fast behavior

7. Conclusion

Predictor-Corrector [type 1], [type 2] and Newton's techniques were implemented to acquire the numerical solution of a non-linear equation for a solar cell. The three methods are compassed using various values of the load resistance R and good results were developed. The proposed method achieved a very convenient and useful algorithm for this nonlinear equation. The results for the NRM were modified utilizing Predictor-Corrector [type 2] to perform the roots of the single-diode equation within this algorithm by taking the initial value of x_0.

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