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)

Extraction of a Photovoltaic Cell's Single-Diode Model Parameters from Equivalent Circuit

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ARTICLE INFO

Article history:
Received: 25 /12/2020
Rrevised form: 25 /01/2021
Accepted : 26 /02/2021
Available online: 26 /02/2021

Keywords:

Classic Chord algorithm; Newton's algorithm; MATLAB; load resistance; absolute errors.

ABSTRACT

The algorithms are plays an important and significant rule in the evaluation of nonlinear equations. In this paper, two methods for solving a nonlinear equation of a solar cell including single diode model are presented. The solution is examined with different values of load resistance 1 to 5 Ω at room temperature. The nonlinear equation of a photovoltaic cell is calculated from the equivalent circuit of this cell. The obtained results reveal that the propose algorithm is appropriate one for solving such equations.

MSC. 41A25; 41A35; 41A36.

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

1. Introduction

In nature many of the nonlinear equations of the form f(x) = 0, in Engineering and Science are complex. So it is not possible to acquire it is exact solution using the usual algebraic method, the numerical iterative algorithms for example Bisection, secant and Newton techniques are utilized to acquire the approximate solution of these equations [1-19]. There are several methods developed on the refinement of convergent Newton's method, in order to obtain a superior convergence order than NRM [20-64].

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Communicated by: Alaa Hussein Hamadi

This paper is concerned with the iterative methods to find values of the PV cell, such as voltage V_{pv} in the conditions $f(x) = 0$, and $\acute{f}(x) \neq 0$ where $f: R \rightarrow R$ be real function. It is ordinal as the follows: in section two describing a model for PV cell; in section three establishment the zero finding of Newton Raphson algorithm; then, in section four Classic Chord algorithm has been reported; in section five results and discussion; finally in section six, conclusions of the fulfilled data.

2. PV Cell: Non-Linear Equation: Single-Diode Model

Figure 1 shows the PV single-diode equivalent electrical circuit.

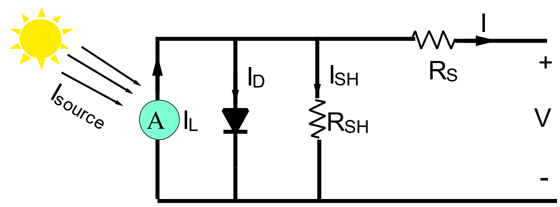

Fig. 1 – Single-diode electrical equivalent circuit of a solar cell.

From Figure 1, the current and voltage characteristics of the PV cell indicated using following expressions depending (KCL) Kirchhoff's current law, yield

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

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

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

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$= 1.38 \times 10^{-23}$J/K rescpectivelly.

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

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

Damage Eq. 4 into Eq. 5 yield

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

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

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

The voltage of PV cell is determined by solving Eq. 6 numerically using two methods in our case.

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 $i \leq x_0$
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. Classical Chord Algorithm (CCM)

Classic Chord Method is a root-finding algorithm, a numerical method for solving nonlinear equations in the form of $f(x) = 0$; which is first described by David E. Muller in the year of 1956. To compare the different numerical methods of iterations, methods 1 NRM has been used against the proposed method 2 Classic Chord Algorithm (CCM). In addition; Eq. 6. In the section 2 has been solved to characterize the performance of the proposed method, the results are examined using some iteration by aide of Matlab program.

Using the Classic Chord Algorithm technique, we present the following steps method, which is obtained by combining the Newton's method.

For a given x_0, compute the approximate solution x_{n+1} by the iterative scheme

$$x_{n+1} = x_n - mf(x_n) \tag{8}$$

where: $0 < m\acute{f}(x_n) < 2$; the chord method is therefore clearly a first-order method; and if we take m variable (change with every iteration), the we can do the improvement of the order of convergence.

$$x_{n+1} = x_n - m_n f(x_n) \tag{9}$$

It takes as the value for the inverse of the slope for the straight line m_n denoted by the points $(x_{n-1}, f(x_{n-1}))$ and $(x_n, f(x_n))$

$$x_{n+1} = x_n - [x_n - x_{n-1}/f(x_n) - f(x_{n-1})]f(x_n) \tag{10}$$

If $\acute{f}(a) \neq 0$ and $\acute{\acute{f}}(x)$is continuous in the neighbourhood of a, this means that the proposed method will converge.

where x_0 is an initial value.

5. Results and Discussion

Initial value of Eq. 6 is $x_0 = 1$; yields:

In Table 1 solving Eq. 6 using CCM gives the solution of for V_{pv}= 0.922423135 after N=7 iterates and NRM gives the solution after N=9 iterates at a condition of the load resistance $R = 1$. The tolerance of the proposed method reach to zero after 9 iterations while using NRM was 7 iterations.

Table 1 - Comparison with NRM and CCM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-CCM	I_{pv}-CCM	P_{pv}-CCM	ε-NRM	ε-CCM
1	1	1	1	0.956342897	0.956342897	0.914591738	0.077576865	0.033919763
2	0.971416861	0.971416861	0.943650719	0.935676402	0.935676402	0.875490329	0.048993727	0.013253267
3	0.946732606	0.946732606	0.896302627	0.924881651	0.924881651	0.855406068	0.024309472	0.002458516
4	0.929865706	0.929865706	0.864650231	0.922517679	0.922517679	0.851038869	0.007442571	$9.45447E^{-05}$
5	0.923247893	0.923247893	0.852386673	0.922423278	0.922423278	0.850864704	0.000824759	$1.43773E^{-07}$
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439	$1.08655E^{-05}$	$3.33178E^{-13}$
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 indicates the tolerance and iterations for two methods.

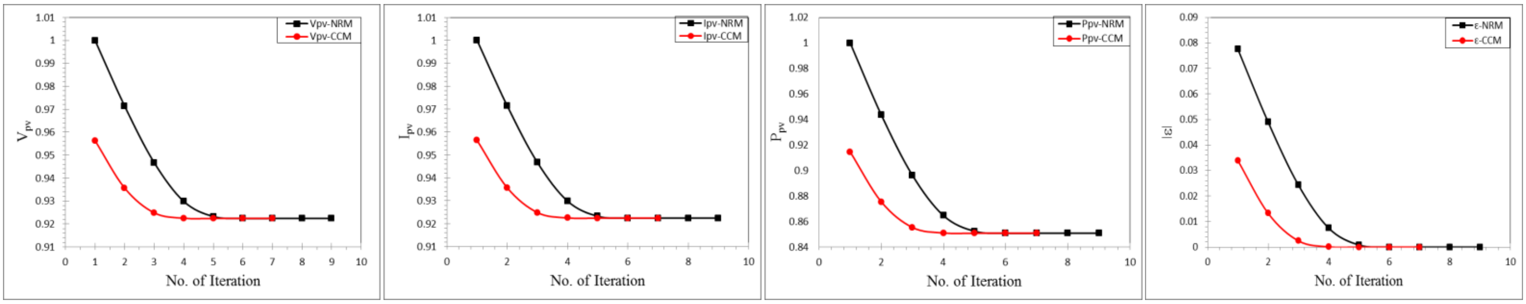

Fig. 2 – Number of iterations versus the parameters of PV cell and the tolerance.

In Table 2 solving Eq. 6 using CCM gives the solution of for V_{pv}= 0.917035382 after N=7 iterates and NRM gives the solution after N=9 iterates at a condition of R = 2. The tolerance for a proposed method reach to zero after 9 iterations while using NRM was 7 iterations.

Table 2 - Comparison with NRM and CCM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-CCM	I_{pv}-CCM	P_{pv}-CCM	ε-NRM	ε-CCM
1	1	0.5	0.5	0.955509809	0.477754904	0.456499497	0.082964618	0.038474426
2	0.971030472	0.485515236	0.471450089	0.933452268	0.466726134	0.435666569	0.05399509	0.016416886
3	0.945421967	0.472710983	0.446911348	0.920708719	0.46035436	0.423852273	0.028386584	0.003673337
4	0.926834477	0.463417238	0.429511073	0.917245199	0.4586226	0.420669378	0.009799094	0.000209817
5	0.918438746	0.459219373	0.421764865	0.917036095	0.458518047	0.4204776	0.001403363	7.12519E^{-07}
6	0.917066885	0.458533442	0.420505836	0.917035382	0.458517691	0.420476946	3.15024E^{-05}	8.24774E^{-12}
7	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946	1.61176E^{-08}	0
8	0.917035382	0.458517691	0.420476946				4.21885E^{-15}	
9	0.917035382	0.458517691	0.420476946				0	

Figure 3 indicates the tolerance and iterations for two methods.

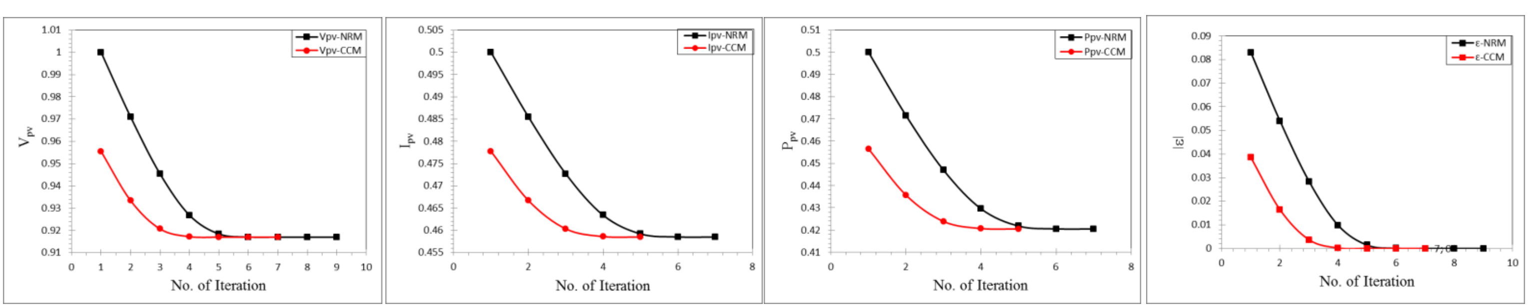

Fig. 3 - Number of iterations versus the parameters of PV cell and the tolerance.

In Table 3 solving Eq. 6 using CCM gives the solution of for V_{pv}= 0.910403374 after N=7 iterates and NRM gives the solution after N=9 iterates at a condition for R = 3. The tolerance for a proposed method reach to zero after 9 iterations while using NRM was 7 iterations.

Table 3 - Comparison with NRM and CCM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-CCM	I_{pv}-CCM	P_{pv}-CCM	*ε*-NRM	*ε*-CCM
1	1	0.333333333	0.333333333	0.954668501	0.318222834	0.303797316	0.089596626	0.044265127
2	0.970643792	0.323547931	0.31404979	0.931130761	0.31037692	0.289001498	0.060240418	0.020727387
3	0.944084232	0.314694744	0.297098346	0.916050375	0.305350125	0.279716096	0.033680858	0.005647001
4	0.923594243	0.307864748	0.284342109	0.91089377	0.303631257	0.27657582	0.013190869	0.000490396
5	0.91287784	0.304292613	0.277781984	0.910407299	0.3034691	0.276280483	0.002474466	$3.92473E^{-06}$
6	0.910501262	0.303500421	0.276337516	0.910403374	0.303467791	0.276278101	$9.78883E^{-05}$	$2.53289E^{-10}$
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101	$1.57417E^{-07}$	0
8	0.910403374	0.303467791	0.276278101				$4.07563E^{-13}$	
9	0.910403374	0.303467791	0.276278101				0	

Figure 4 indicates the tolerance and iterations for two methods.

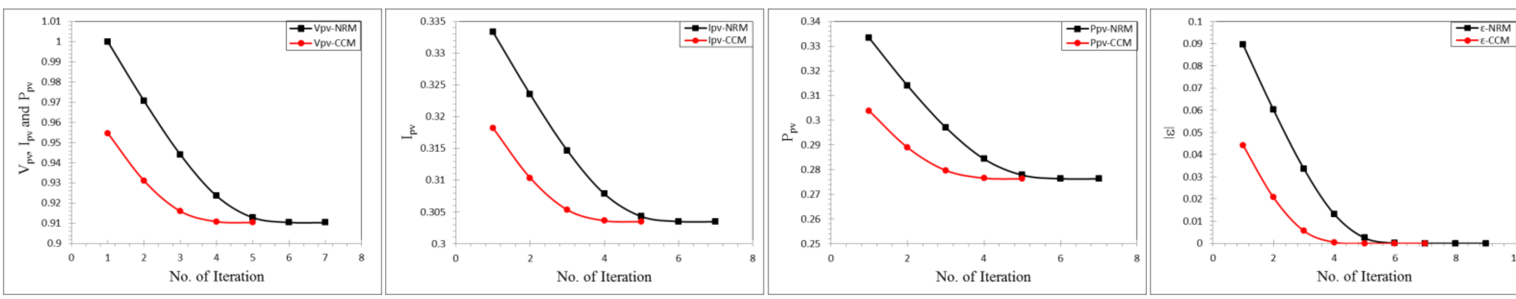

Fig. 4 - Number of iterations versus the parameters of PV cell and the tolerance.

In Table 4 solving Eq. 6 using CCM gives the solution of for V_{pv}= 0.901740602 after N=7 iterates and NRM gives the solution after N=9 iterates at a condition for R = 4. The tolerance for a proposed method reach to zero after 9 iterations while using NRM was 7 iterations.

Table 4 - Comparison with NRM and CCM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-CCM	I_{pv}-CCM	P_{pv}-CCM	*ε*-NRM	*ε*-CCM
1	1	0.25	0.25	0.953818908	0.238454727	0.227442627	0.098259398	0.052078306
2	0.970256822	0.242564205	0.235349575	0.928705897	0.232176474	0.215623661	0.06851622	0.026965295
3	0.94271872	0.23567968	0.222179646	0.910811452	0.227702863	0.207394375	0.040978118	0.00907085
4	0.920123009	0.230030752	0.211656588	0.902978861	0.225744715	0.203842706	0.018382407	0.001238259
5	0.906346494	0.226586624	0.205365992	0.901765899	0.225441475	0.203295434	0.004605892	$2.52971E^{-05}$
6	0.902077706	0.225519427	0.203436047	0.901740613	0.225435153	0.203284033	0.000337104	$1.07408E^{-08}$
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	

Figure 5 indicates the tolerance and iterations for two methods.

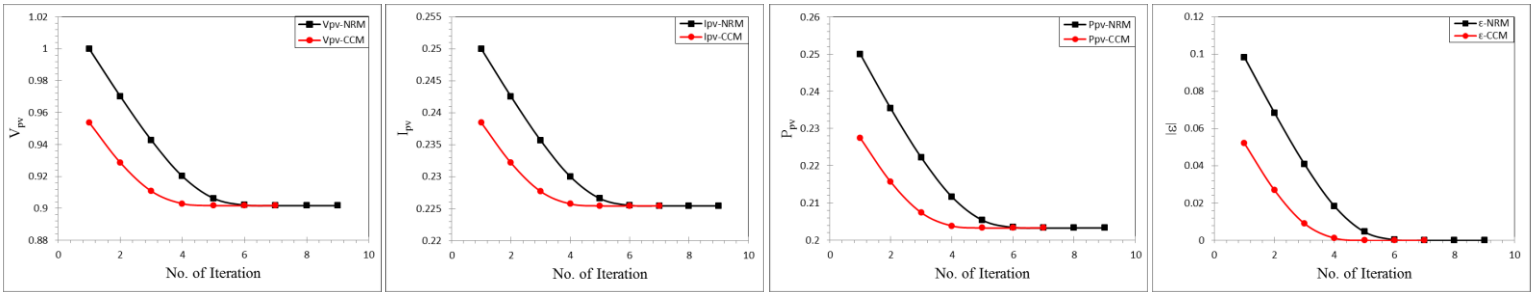

Fig. 5 - Number of iterations versus the parameters of PV cell and the tolerance.

In Table 5 solving Eq. 6 using CCM gives the solution of for V_{pv}= 0.889092715 after N=8 iterates and NRM gives the solution after N=10 iterates at a condition for R = 5. The tolerance for a proposed method reach to zero after 10 iterations while using NRM was 8 iterations.

Table 5 - Comparison with NRM and CCM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-CCM	I_{pv}-CCM	P_{pv}-CCM	ε-NRM	ε-CCM
1	1	0.2	0.2	0.952960959	0.190592192	0.181626918	0.110907285	0.063868245
2	0.96986956	0.193973912	0.188129393	0.926171251	0.18523425	0.171558637	0.080776845	0.037078536
3	0.941324731	0.188264946	0.17721845	0.904871952	0.18097439	0.16375865	0.052232016	0.015779238
4	0.916395843	0.183279169	0.167956268	0.89266728	0.178533456	0.159370975	0.027303128	0.003574566
5	0.898535645	0.179707129	0.161473261	0.889306005	0.177861201	0.158173034	0.00944293	0.00021329
6	0.890477009	0.178095402	0.158589861	0.889093511	0.177818702	0.158097454	0.001384294	7.96312E-07
7	0.889125763	0.177825153	0.158108925	0.889092715	0.177818543	0.158097171	3.30483E-05	1.11464E-11
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171	1.91907E-08	0
9	0.889092715	0.177818543	0.158097171				6.43929E-15	
10	0.889092715	0.177818543	0.158097171				0	

Figure 6 indicates the tolerance and iterations for two methods.

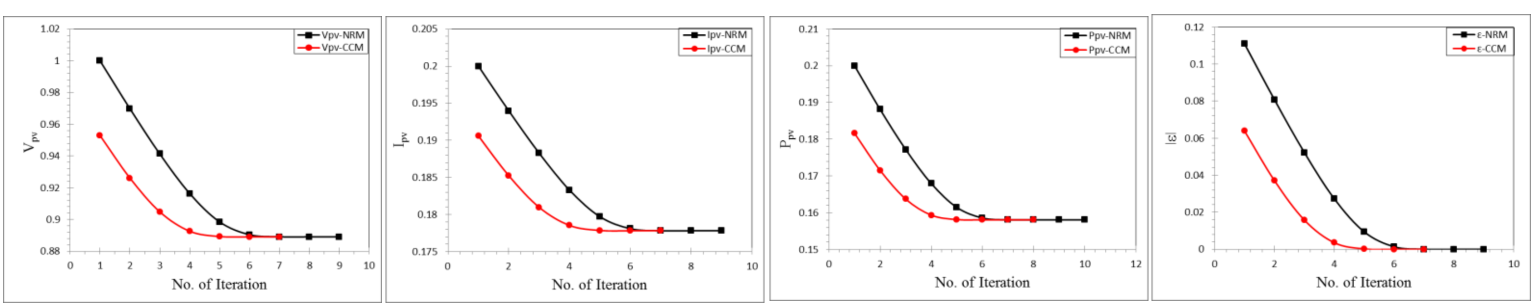

Fig. 6 - Number of iterations versus the parameters of PV cell and the tolerance.

According to the Figures 2 to 6, we can derive that using different methods NRM and CCM and use the procedure reported in this paper in order to obtain methods for solving non-linear equation based on different values of the load resistance of the circuit. It is also observe that the proposed method gives better results than the existing method such as NRM. Several analytical and numerical experiments have showed that the tolerance of the data is better for the proposed method too.

7. Conclusion

In this study, we have utilized CCM and Newton's algorithms for solving non-linear equation. This equation is solved easily by classical numerical methods. The given numerical example supports the claim that only a small number of iterations are needed to accomplish satisfactory results. The obtained numerical determination MATLAB software is used. The proposed method CCM is a reliable method to handle this type of problems and it concluded that this technique is quite suitable, accurate and efficient in comparison to the other classical method NRM.

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