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)

Comparison Study Between Classic Chord and Inverse Quadratic Interpolation Methods

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ARTICLE INFO

Article history:
Received: 21 /01/2020
Rrevised form: 21 /02/2021
Accepted : 23 /03/2021
Available online: 24 /03/2021

Keywords:

Classic chord method; inverse quadratic interpolation method; Newton's method; root-finding method; zeroes; root estimate

ABSTRACT

Many numerical approaches have been proposed for solving a non-linear equation (PV cell model). In this paper, Inverse Quadratic Interpolation method using initial value x_0 is implemented in MATLAB for solving the problem of this design. Comparisons the results obtained in terms of number of iterations and absolute error show promising application of the proposed method for solving nonlinear examples.

MSC. 41A25; 41A35; 41A36

DOI : https://doi.org/10.29304/jqcm.2021.13.1.781

1. Introduction

A zero finding technique called inverse quadratic interpolation method; which means in mathematical analysis it is mean an algorithm for finding zeroes called roots of continuous functions. Several papers concern with a non-linear equation in the field of Sciences and Engineering has been attained. There are many root-finding algorithms can be employed to perform approximations to such a root. One of the most popular analyses is Newton's method (NRM), it didn't require second derivatives functions. Only iterative numerical algorithms can solve many nonlinear

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Communicated by: ***Dr. Rana Jumaa Surayh aljanabi***

equations, involving most of the more complicated ones [1-18]. All the 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. Several techniques improved on the perfection of convergence of NRM, for obtaining a lesser iterations than NRM [19-96].

In this research, some new techniques Inverse Quadratic Interpolation and Classic chord method are introduced and analyzed for solving zeroes of nonlinear equation of a photovoltaic cell. The following steps indicate the procedure of this paper: section two and three depicting the PV model design and demonstrate the zero finding of Newton Raphson algorithm. In section four, five and six Classic chord method has been termed, Inverse Quadratic Interpolation method has been characterized, results, discussion and conclusions.

2. Non-Linear Equation Based on An Electrical Circuit Model

Figure 1 indicates PV cell an equivalent circuit (single diode scheme)

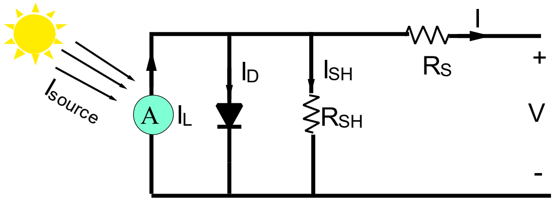

Fig. 1 – PV cell electrical single diode design.

KCL-Kirchhoff's current law have been applied on Figure 1; a final equation of the PV cell current is extracted according to this equivalent as follows

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

$$I_D = I_0\left(e^{-V_{pv}/\,nV_T} - 1\right) \tag{2}$$

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

where:

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

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

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

Subst. Eq. 4 in Eq. 5 yield

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

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

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

Based on the first derivative of Eq. 6; V can be determined numerically.

3. Classic Chord Algorithm (CCM)

A zero finding technique is called Classic Chord Method, an iterative algorithm in order to solve nonlinear equations which takes the expression $f(x) = 0$; this 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.

An iterative technique is based on defining the function $\mathrm{b(t)}$ of the nonlinear equation $\mathrm{t = g(t) \equiv t - b(t).f(t)}$ which represents the degree of the method. By considering the constant function $\mathrm{b(t) = m}$ (m is constant $\neq 0$), Chord method can be defined as follows

- Determine the approximate solution t_{n+1} , for a given initial t_0

$$\mathrm{t_{n+1} = t_n - mf(t_n),\ 0 < m\acute{f}(t_n) < 2}$$

- Using the following equation to increase the order of convergence

$$\mathrm{t_{n+1} = t_n - m_n f(t_n)}$$

Here $\mathrm{m_n = \frac{t_n - t_{n-1}}{f(t_n) - f(t_{n-1})}}$

Note that this method converges when

(i) $\acute{f}(a) \neq 0,$
(ii) $\acute{\acute{f}}\mathrm{(t)}$ is continuous in the neighborhood of a.

The tolerance $\varepsilon = 10^{-9}$ is used in order to predicting the zero $\sigma = |\mathrm{x_{n+1} - x_n}| < \varepsilon$, $|\mathrm{f(x_n)}| < \varepsilon$

4. Inverse Quadratic Interpolation Method (IQIM)

A root finding method is called Inverse quadratic interpolation in order to solve equations of the form $\mathrm{y = d(t) = 0}$. This method use a quadratic interpolation in order to find the approximate of the inverse f. The IQIM required three initial values $\mathrm{t_0, t_1, t_2}$ and realized by the recurrence relation

$$\mathrm{t_{n+1} = \frac{d_{n-1}d_n}{(d_{n-2} - d_{n-1})(d_{n-2} - d_n)} t_{n-2} + \frac{d_{n-2}d_n}{(d_{n-1} - d_{n-2})(d_{n-1} - d_n)} t_{n-1} + \frac{d_{n-2}d_{n-1}}{(d_n - d_{n-2})(d_n - d_{n-1})} t_n}$$

This method can be proved using Secant method and the order of convergence is 1.8.

5. Results and Discussion

Zeros of equation 6 (non-linear equation) are obtained by means of two techniques CCM and IQIM extracted by Eqns. 7 and 9 with predict guess x_0. The approximate solutions produced by the two methods. Five various numerical experiments are used based on equation 6 which are depending on the resistance values (load resistance) which have the values of 1 to 5 ohm as indicated in the Tables 1-5 and Figs 2-6. The results show that IQIM algorithm need 4 iterations while CCM need 7 iterations respectively in order to reach to the convergence which proves that IQIM is faster than CCM.

Table 1 - CCM and IQIM iterations for solving Eq. 6.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε-CCM	ε-IQIM
1	0.956342897	0.956342897	0.914591738	0.922680482	0.922680482	0.851339272	0.033919763	0.000257348
2	0.935676402	0.935676402	0.875490329	0.922424074	0.922424074	0.850866172	0.013253267	9.39432E-07
3	0.924881651	0.924881651	0.855406068	0.922423135	0.922423135	0.850864439	0.002458516	1.13682E-11
4	0.922517679	0.922517679	0.851038869	0.922423135	0.922423135	0.850864439	9.45447E-05	0

5	0.922423278	0.922423278	0.850864704				1.43773E-07	
6	0.922423135	0.922423135	0.850864439				3.33178E-13	
7	0.922423135	0.922423135	0.850864439				0	

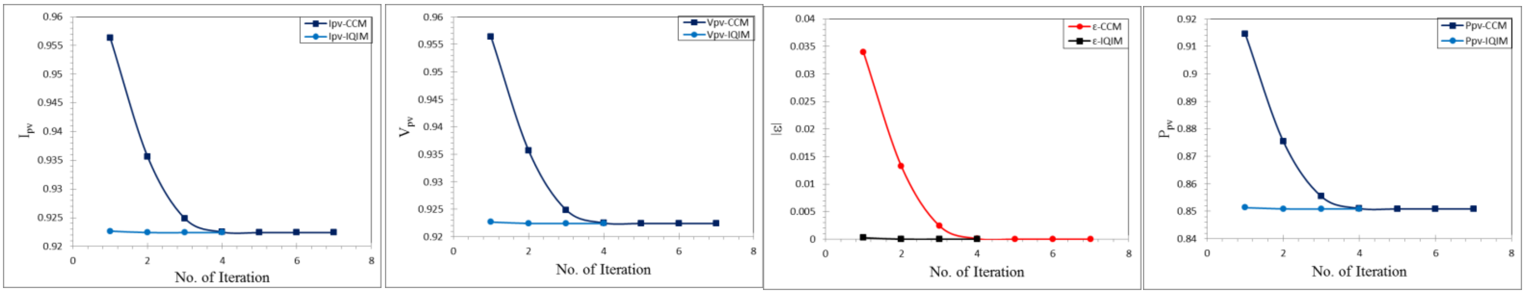

Fig. 2 – The v_{pv} values and ε values based on CCM and IQIM techniques.

Table 2 - CCM and IQIM iterations for solving Eq. 6.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε-CCM	ε-IQIM
1	0.955509809	0.477754904	0.456499497	0.917545403	0.458772702	0.420944784	0.038474426	0.000510021
2	0.933452268	0.466726134	0.435666569	0.917039162	0.458519581	0.420480412	0.016416886	3.77918E-06
3	0.920708719	0.46035436	0.423852273	0.917035383	0.458517691	0.420476946	0.003673337	1.88389E-10
4	0.917245199	0.4586226	0.420669378	0.917035382	0.458517691	0.420476946	0.000209817	2.22045E-16
5	0.917036095	0.458518047	0.4204776	0.917035382	0.458517691	0.420476946	7.12519E-07	0
6	0.917035382	0.458517691	0.420476946				8.24774E-12	
7	0.917035382	0.458517691	0.420476946				0	

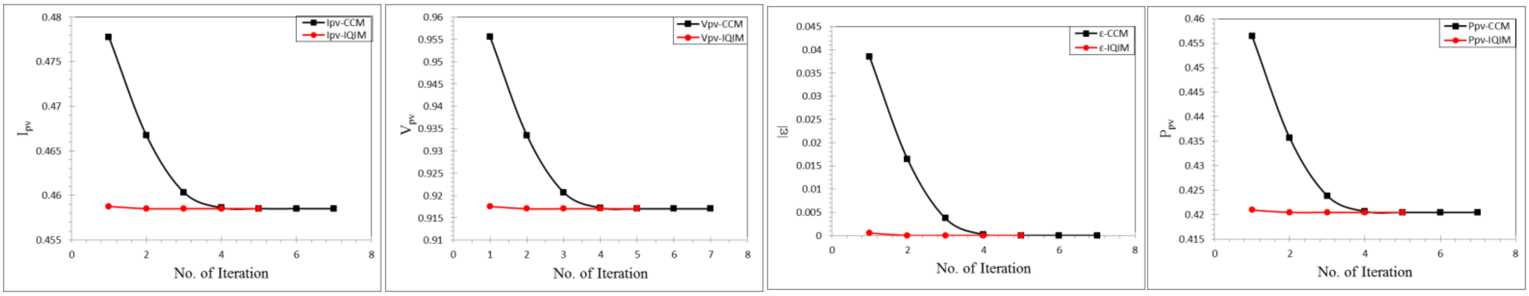

Fig. 3 – The v_{pv} values and ε values based on CCM and IQIM techniques.

Table 3 - CCM and IQIM iterations for solving Eq. 6.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε-CCM	ε-IQIM
1	0.954668501	0.318222834	0.303797316	0.911457718	0.303819239	0.276918391	0.044265127	0.001054344
2	0.931130761	0.31037692	0.289001498	0.91041998	0.303473327	0.27628818	0.020727387	1.66056E-05
3	0.916050375	0.305350125	0.279716096	0.910403378	0.303467793	0.276278103	0.005647001	3.76416E-09
4	0.91089377	0.303631257	0.27657582	0.910403374	0.303467791	0.276278101	0.000490396	0
5	0.910407299	0.3034691	0.276280483	0.910403374	0.303467791	0.276278101	3.92473E-06	
6	0.910403374	0.303467791	0.276278101				2.53289E-10	
7	0.910403374	0.303467791	0.276278101				0	

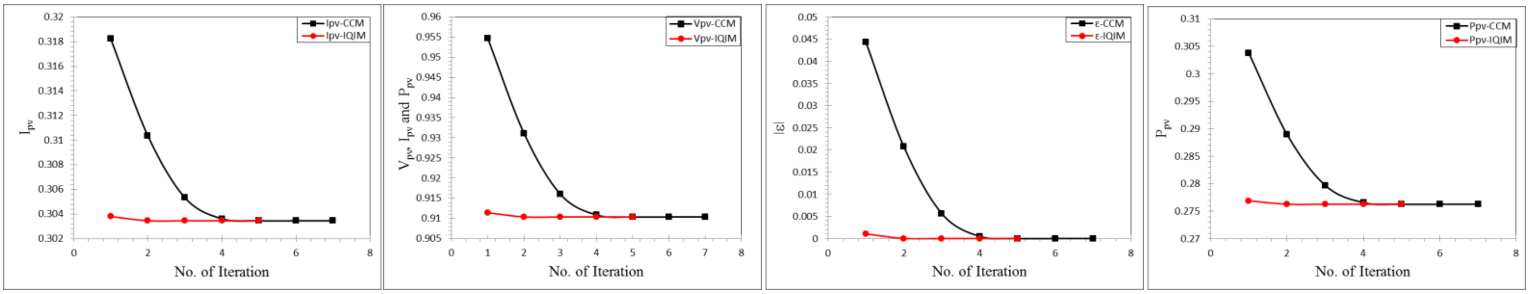

Fig. 4 – The v_{pv} values and ε values based on CCM and IQIM techniques.

Table 4 - CCM and IQIM iterations for solving Eq. 6.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε-CCM	*ε*-IQIM
1	0.953818908	0.238454727	0.227442627	0.904063004	0.226015751	0.204332479	0.052078306	0.002322402
2	0.928705897	0.232176474	0.215623661	0.901823681	0.22545592	0.203321488	0.026965295	8.30785E-05
3	0.910811452	0.227702863	0.207394375	0.901740701	0.225435175	0.203284073	0.00907085	9.93676E-08
4	0.902978861	0.225744715	0.203842706	0.901740602	0.22543515	0.203284028	0.001238259	1.28009E-13
5	0.901765899	0.225441475	0.203295434	0.901740602	0.22543515	0.203284028	2.52971E-05	0
6	0.901740613	0.225435153	0.203284033				1.07408E-08	
7	0.901740602	0.22543515	0.203284028				0	

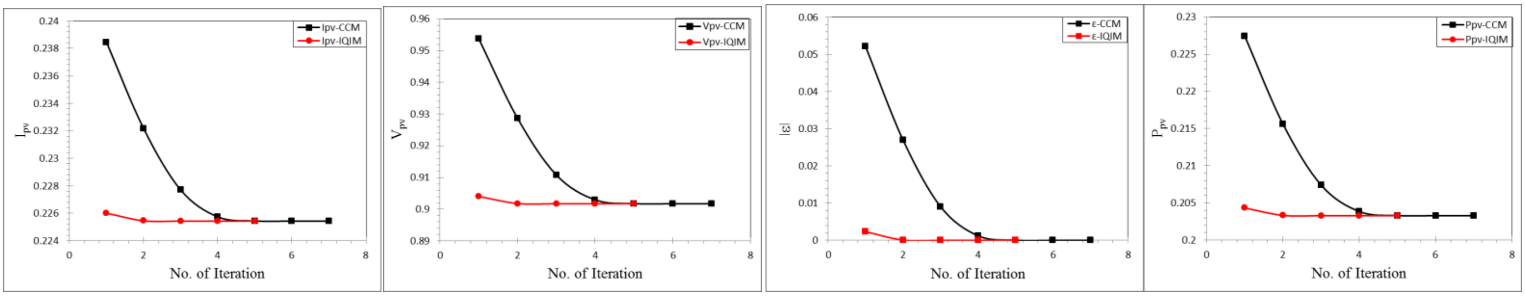

Fig. 5 – The v_{pv} values and ε values based on CCM and IQIM techniques.

Table 5 - CCM and IQIM iterations for solving Eq. 6.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IQIM	I_{pv}-IQIM	P_{pv}-IQIM	ε-CCM	*ε*-IQIM
1	0.952960959	0.190592192	0.181626918	0.89481333	0.178962666	0.160138179	0.063868245	0.005720615
2	0.926171251	0.18523425	0.171558637	0.889610077	0.177922015	0.158281218	0.037078536	0.000517362
3	0.904871952	0.18097439	0.16375865	0.889096938	0.177819388	0.158098673	0.015779238	4.22358E-06
4	0.89266728	0.178533456	0.159370975	0.889092715	0.177818543	0.158097171	0.003574566	2.51441E-10
5	0.889306005	0.177861201	0.158173034	0.889092715	0.177818543	0.158097171	0.00021329	0
6	0.889093511	0.177818702	0.158097454				7.96312E-07	
7	0.889092715	0.177818543	0.158097171				1.11464E-11	
8	0.889092715	0.177818543	0.158097171				0	

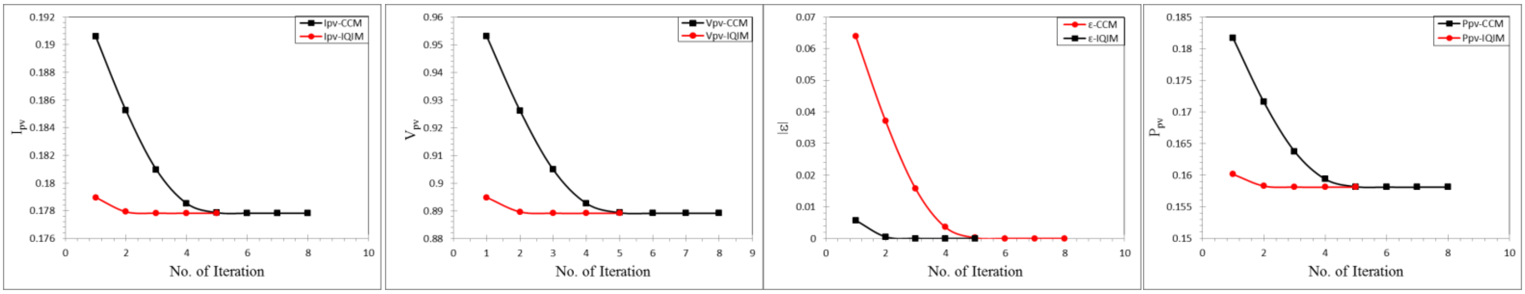

Fig. 6 – The v_{pv} values and ε values based on CCM and IQIM techniques.

6. Conclusion

Inverse Quadratic Interpolation technique is applied to numerical solution for solving a real zeroes of nonlinear equation corresponding to PV model design in ambient temperature. We employed IQI and CCM algorithm in order to solve a nonlinear equation. Comparison of the results acquired by the proposed method with existing method (CCM) reveal that the presented method are very effective, accurate, convenient and easy to use.

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