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In The Solution of Nonlinear Equation

Mohammed RASHEED [a,*], ***Suha SHIHAB*** [b], ***Ahmed Rashid*** [c], ***Taha Rashid*** [d], ***Saad Hussin Abed Hamad*** [e], ***Ola Abdulelah Abed Al-Farttoosi*** [f]

[a] *Applied Science Department, University of Technology, Baghdad, Iraq, email: rasheed.mohammed40@yahoo.com, mohammed.s.rasheed@uotechnology.edu.iq.*

[b] *Applied Science Department, University of Technology, Baghdad, Iraq, e-mail: alrawy1978@yahoo.com, suha.n.shihab@uotechnology.edu.iq.*

[c] *Al Iraqia University, College of Arts, Baghdad, Iraq, e-mail: dr.ahm.8215@gmail.com, ahmed_rashed@aliraqia.edu.iq.*

[d] *Computer and Microelectronics System, Faculty of Engineering, University of Malaysia,Skudai 81310, Johor Bahru, Malaysia, and Al Iraqia University, College of Arts, Baghdad, Iraq, e-mail: tsiham95@gmail.com, taha1988@graduate.utm.my.*

[e] *College of Computer Science & Information Technology, Al Qadysiah University, Al-Diwaniyah, Iraq, e-mail: shsaadsh2014@gmail.com, saad.hussain@qu.edu.iq.*

[f] *Mechanical Engineering, Faculty of Engineering, University of Malaysia,Skudai 81310, Johor Bahru, Malaysia, e-mail: abed.ola@graduate.utm.my.*

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ABSTRACT

In this work, we present numerical method in order to solve non-linear equation of solar cell based on single diode model using two suitable approximations; Illinois Algorithm and Classic Chord techniques. Algorithms have discussed the tolerances of the values. It is founded that the new proposed method has the lesser number of evaluations than the other ones. Numerical examples are presented in order to test the efficiency, accuracy and the performance of this method. Numerical calculations observe that the proposed method is compatible with the famous existing methods and in this case gives the better results. The results obtained explain that the new suggested technique is more easy, accurate to use and efficient than other numerical methods are introduced.

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∗Corresponding author: Mohammed RASHEED

Email addresses: rasheed.mohammed40@yahoo.com , 10606@uotechnology.edu.iq

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1. Introduction

In present years, researchers have sophisticated several iterative algorithms due to solving non-linear equation of PV cell based. These algorithms categorized like one-step; two-steps and three-step algorithms. Newton's and other methods are used with these techniques. Now a days, several authors has been exhibited these algorithms can be harness to perfection some iterative algorithms for solving non-linear examples in different field such as pure and applied science and engineering [1-40]. Some iterative techniques second derivative is free having been proposed and analyzed. The convergence of Newton's method has been improved by many ways on the advancement for attaining lesser iterations than it [41-115].

The proposed algorithm IRFM requires 6 evaluations of the function while the other technique (CCM) needs 7 evaluation of the function. The following steps are investigate the procedure of this work: section two, three and four investigating the modelling and the root finding of IRFM and CCM algorithms respectively while; section five and six indicate the numerical problems, discussion and conclusion results respectively.

2. Modeling of a Non-Linear Equation

KCL Kirchhoff's law is employed in order to depict the electrical parameters of PV cell scheme [30-50]

$$I = I_{ph} - I_{Diode}, I_{Diode} = I_0 \left[\exp\left(\frac{-V_{pv}}{nV_T}\right) - 1\right] \quad (1)$$

where:

I_0 is diode reverse saturation current measured in (A), I_{ph} is light current, n is diode ideality factor (unitless), $k = (1.38 \times 10^{-23} J/K)$ is Boltzmann constant, $q = (1.602 \times 10^{-19}\ C)$ is elementary charge, V_T is thermal voltage given by $V_T = kT/q$, I_{ph} is the light generated current in the cell, T is temperature (p-n junction), I_D is the voltage dependent current lost to recombination.

The current I_{pv} and power P_{pv} of the cell is given by $I_{pv} = \frac{V_{pv}}{R}$; $P_{pv} = I_{pv} \times V_{pv}$

The final equation from the circuit is given by

$$(I_{source}) - 10^{-12}\left(e^{\frac{-V}{1.2*0.026}} - 1\right) = V / R \quad (2)$$

3. Classic Chord Algorithm (CCM)

An iterative technique is based on defining the function b(t) of the nonlinear equation $t = g(t) \equiv t - b(t).f(t)$, which represents the degree of the method. By considering the constant function $b(t) = m$ (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

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

Using the following equation to increase the order of convergence

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

$$\text{Here } m_n = \frac{t_n - t_{n-1}}{f(t_n) - f(t_{n-1})} \quad (3)$$

Note that this method converges when

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

4. Illinois Algorithm (IRFM)

Double false position method (DFPM) is used to solve difficult examples define by the following expression: calculate t then

$f(x) = at + b$, then $f(t_1) = b_1, f(t_2) = b_2$

Using a pair of initial test values t_0, t_1; the output results of this method is given by the recurrence relation

$$t = \frac{b_1 t_2 - b_2 t_1}{(b_1 - b_2)} \tag{4}$$

If the function is linear yield, $f(t) = at + c$

DFOM gives the exact solution, but the nonlinear function f gives an approximation improve using iteration.

$$e_k = \frac{\frac{1}{2}f(d_k)a_k - f(c_k)b_k}{\frac{1}{2}f(c_k) - f(c_k)} \text{ or } e_k = \frac{f(d_k)c_k - \frac{1}{2}f(c_k)d_k}{f(d_k) - \frac{1}{2}f(c_k)} \tag{5}$$

The tolerance $= 10^{-9}$; the following expression is utilized in order to estimate zero value

$$\varepsilon > \sigma = |t_{n+1} - t_n|, \varepsilon > |f(t_n)| \tag{6}$$

5. Results and Discussion

Two numerical experiments is suggested to demonstrate the performance of the Classic Chord Method (CCM) represented in Eq. 3 acquired in the present paper in order to solve non-linear equation with the initial value $x_0 = 1$ and we compare it with Illinois Algorithm (IRFM) represented in Eq. 5 with two initial values x_0 and x_1. For convergence criteria, the distance between two consecutive iterates is based on Eq. 8, less than 10^{-9}. Five examples in Eq. 2 are used for numerical testing with the R values from 1-5 ohm, represents (load resistance) of the circuit. All determinations are carried out with the algorithm precision introduced in Tables and Figures 1 to 5 and the number of function evaluations needed are extracted from the Eq. 2. The numerical examples and the approximate solutions produced by two techniques for solving Eq. 2.

Tables and Figs. indicate that IRFM algorithm needs 6 iterations while CCM technique need 7 iterations to reach to the convergence which proves that IRFM is faster than CCM.

Table 1 - Comparison of iteration strategies CCM and IRFM.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IFRM	I_{pv}-IRFM	P_{pv}-IRFM	ε-CCM	ε-IRFM
1	0.956342897	0.956342897	0.914591738	0.932466800	0.932466800	0.869494332	0.033919763	0.010043665
2	0.935676402	0.935676402	0.875490329	0.923976237	0.923976237	0.853732086	0.013253267	0.001553102
3	0.924881651	0.924881651	0.855406068	0.922473110	0.922473110	0.850956640	0.002458516	4.99759E-05
4	0.922517679	0.922517679	0.851038869	0.922423207	0.922423207	0.850864572	9.45447E-05	7.20506E-08
5	0.922423278	0.922423278	0.850864704	0.922423135	0.922423135	0.850864439	1.43773E-07	1.66644E-13
6	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439	3.33178E-13	0
7	0.922423135	0.922423135	0.850864439				0	

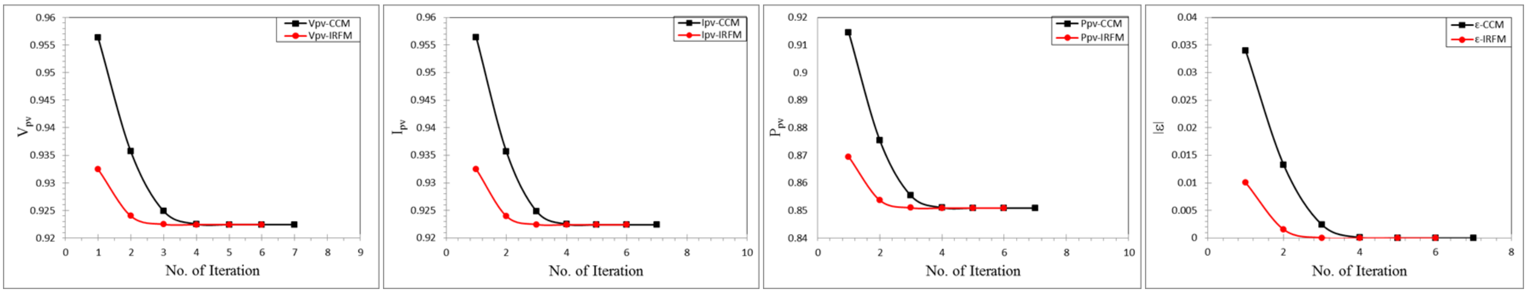

Fig. 1 – Two iterative methods CCM and IRFM with their tolerance.

Table 2 - Comparison of iteration strategies CCM and IRFM.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IFRM	I_{pv}-IRFM	P_{pv}-IRFM	ε-CCM	ε-IRFM
1	0.955509809	0.477754904	0.456499497	0.929805105	0.464902553	0.432268767	0.038474426	0.012769723
2	0.933452268	0.466726134	0.435666569	0.919448427	0.459724213	0.422692705	0.016416886	0.002413044
3	0.920708719	0.460354360	0.423852273	0.917149156	0.458574578	0.420581287	0.003673337	0.000113774
4	0.917245199	0.458622600	0.420669378	0.917035740	0.458517870	0.420477275	0.000209817	3.58074E-07
5	0.917036095	0.458518047	0.420477600	0.917035382	0.458517691	0.420476946	7.12519E-07	4.12392E-12
6	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946	8.24774E-12	0
7	0.917035382	0.458517691	0.420476946				0	

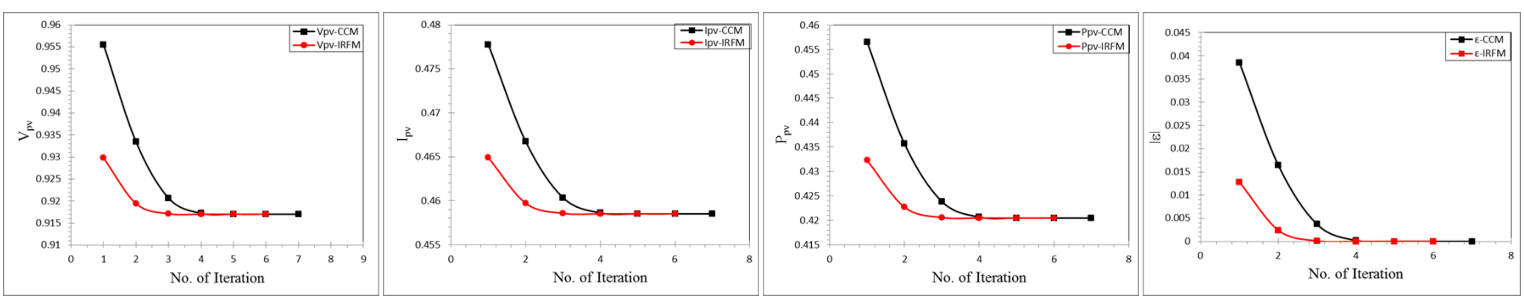

Fig. 2 – Two iterative methods CCM and IRFM with their tolerance.

Table 3 - Comparison of iteration strategies CCM and IRFM.

Iterations	V_{pv}-CCM	I_{pv}- CCM	P_{pv}-CCM	V_{pv}-IFRM	I_{pv}-IRFM	P_{pv}-IRFM	ε-CCM	ε-IRFM
1	0.954668501	0.318222834	0.303797316	0.926988773	0.308996258	0.286436062	0.044265127	0.016585399
2	0.931130761	0.310376920	0.289001498	0.914288362	0.304762787	0.278641070	0.020727387	0.003884988
3	0.916050375	0.305350125	0.279716096	0.910679809	0.303559936	0.276445905	0.005647001	0.000276435
4	0.910893770	0.303631257	0.276575820	0.910405360	0.303468453	0.276279306	0.000490396	1.98591E-06
5	0.910407299	0.303469100	0.276280483	0.910403374	0.303467791	0.276278101	3.92473E-06	1.26657E-10
6	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101	2.53289E-10	0
7	0.910403374	0.303467791	0.276278101				0	

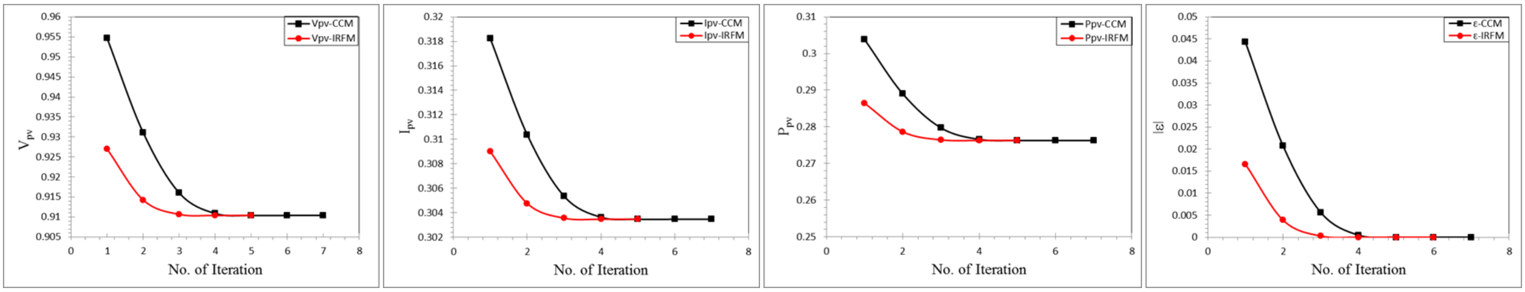

Fig. 4 – Two iterative methods CCM and IRFM with their tolerance.

Table 4 - Comparison of iteration strategies CCM and IRFM.

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	0.924004538	0.231001134	0.213446097	0.052078306	0.022263936
2	0.928705897	0.232176474	0.215623661	0.908335831	0.227083958	0.206268496	0.026965295	0.006595229
3	0.910811452	0.227702863	0.207394375	0.902481938	0.225620484	0.203618412	0.009070850	0.000741336
4	0.902978861	0.225744715	0.203842706	0.901753637	0.225438409	0.203289905	0.001238259	1.30348E-05
5	0.901765899	0.225441475	0.203295434	0.901740607	0.225435152	0.203284031	2.52971E-05	5.37384E-09
6	0.901740613	0.225435153	0.203284033	0.901740602	0.225435150	0.203284028	1.07408E-08	8.88178E-16
7	0.901740602	0.225435150	0.203284028	0.901740602	0.225435150	0.203284028	1.9984E-15	0
8	0.901740602	0.225435150	0.203284028				0	

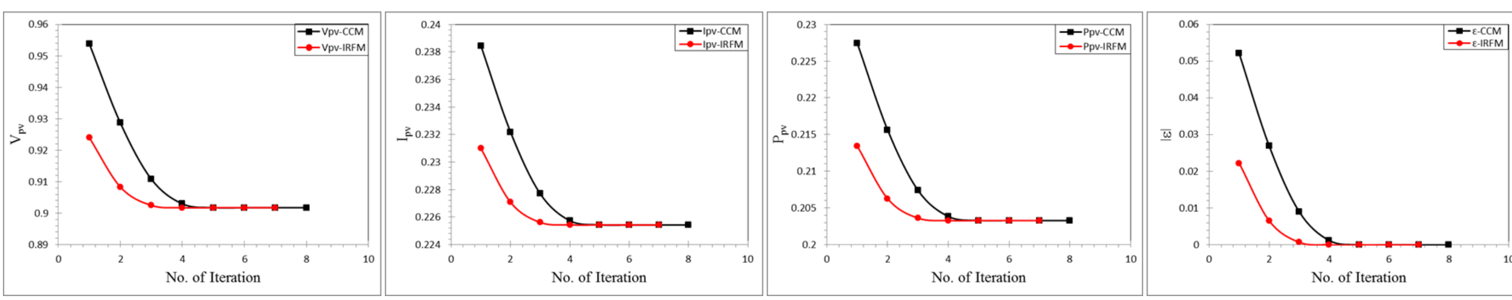

Fig. 4 – Two iterative methods CCM and IRFM with their tolerance.

Table 5 - Comparison of iteration strategies CCM and IRFM.

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	0.920837784	0.184167557	0.169588445	0.063868245	0.031745069
2	0.926171251	0.185234250	0.171558637	0.901374600	0.180274920	0.162495234	0.037078536	0.012281885
3	0.904871952	0.180974390	0.163758650	0.891449914	0.178289983	0.158936590	0.015779238	0.0023572
4	0.892667280	0.178533456	0.159370975	0.889208783	0.177841757	0.158138452	0.003574566	0.000116068
5	0.889306005	0.177861201	0.158173034	0.889093115	0.177818623	0.158097313	0.00021329	4.00386E-07
6	0.889093511	0.177818702	0.158097454	0.889092715	0.177818543	0.158097171	7.96312E-07	5.57343E-12
7	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171	1.11464E-11	0
8	0.889092715	0.177818543	0.158097171				0	

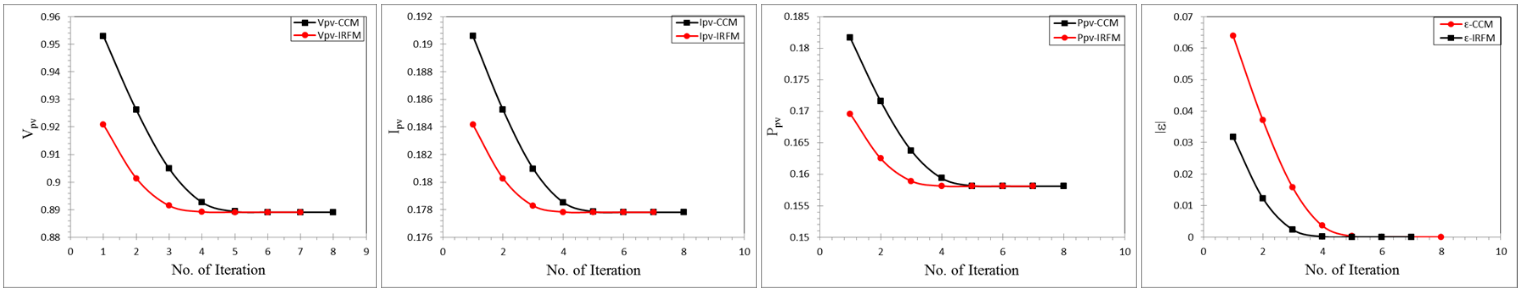

Fig. 5 – Two iterative methods CCM and IRFM with their tolerance.

6. Conclusion

In this paper, we noticed obtained results from the suggested technique IRFM are comparable with other methods CCM and NRM algorithms in all cases. Many experiments reveal that the new suggested technique is more efficient to use with lesser evaluations as compared with other techniques and realizes better than common and classical Newton's algorithm.

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