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)

Parameters Determination of PV Cell Using Computation Methods

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ARTICLE INFO

Article history:
Received: 15 /11/2020
Rrevised form: 15 /12/2020
Accepted : 17 /01/2020
Available online: 22 /01/2021

Keywords:

Comparison, equivalent circuit, Improved Newton-Horner algorithm, Newton's algorithm, roots of the equation.

ABSTRACT

This paper describes two algorithms Newton's algorithm and Improved Newton-Horner algorithm for solving non-linear equation of an electrical circuit of a PV cell. In these algorithms, an approximated solution is assumed; then the assumed solution is used to construct the electrical parameters of a solar cell. The proposed method consists for solving the solar cell's equation using the initial value $x_0 = 1$. Moreover, the Newton's and Improved Newton-Horner algorithms are used to determine the required voltage, current, and power of the PV cell according to different values of R_L have introduced with the aid of Matlab language. The obtained results appeared that the suggested technique is the most effective compare with NRM.

MSC. 41A25; 41A35; 41A36.

DOI : https://doi.org/10.29304/jqcm.2021.13.1.739

1. Introduction

The interest of applied mathematics and the world in numerical methods has grown considerably in recent decades for many reasons that made it possible to make calculations that were not easy to make a few years ago. Numerical analysis deals with solutions of different equations for a variety of topics, including algebraic equations of high order, differentiation, integration and partial and differential equations [1-9]. Silicon is the second most abundant element in the earth's crust, making it the cheapest and least expensive semiconductor element. Solar cells (PV) are considered one of the most important sources of alternative energy because they generate energy without

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Communicated by: Alaa Hussein Hamadi

any noise and do not need any kind of fuels [10-17]. On the other hand, solar power generation suffers from many problems such as high cost; limited generation in daylight hours, unstable energy generated due to the constant change in the acquired temperature as well as; the need for other complementary systems such as the conversion of continuous voltage (DC) generated from the panels to Alternating voltage (AC) and control system to connect to the network, which reduces its efficiency. Improving the performance of solar cells in recent decades has contributed significantly to reducing the cost of these cells and development has become one of the most important areas of research in renewable energies. There is a lot of research looking into the development of these cells from the development of solar cell manufacturing, while other research goes into the development of complementary technologies [18-35]. For other applications [36-63].

The aim of this article is to investigate a new iterative algorithm; Improved Newton-Horner algorithm (IHOM) for soling non-linear equation, the obtained resells are analyzed and compared.

2. Mathematical Model of Non-Linear Equation

The mathematical model of the present study has been extracted from Figure 1.

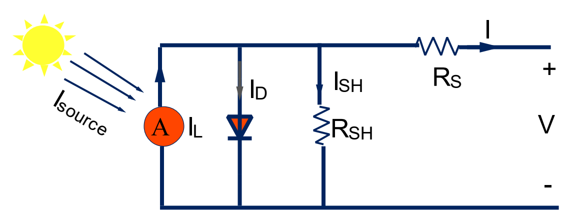

Fig. 1 - The electrical circuit of the present study.

The current and voltage characteristics of the solar cell can be analyzed by Kirchhoff's current law (KCL) [11-12].

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

$$\mathrm{I_D} = \mathrm{I_0} \times (e^{(-V_D/nV_T)} - 1) \quad (2)$$

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

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

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

Put Eq. 4 in Eq. 5, we get

$$\mathrm{I_{source}} - 10^{-12}\left(e^{(-V\times q/m\times k\times T)} - 1\right) = \mathrm{V/R} \quad (6)$$

where the constants are indicated as below

$\mathrm{V_T} = \frac{\mathrm{kT}}{\mathrm{q}} = 0.0259\ \mathrm{V} = 26\ \mathrm{mV}$= Thermal voltage

m: Diode quality factor $1 < \mathrm{m} < 2$

k: Boltzmann constant= $1.38 \times 10^{-23}\mathrm{J/K}$

q: The electron charge= 1.6×10^{-19} C

T: Temperature of p-n junction

Air-Mass= 1.5, $\mathrm{T} = 25\ ^{o}\mathrm{C}$

$\mathrm{V_{pv}}$, $\mathrm{I_{pv}}$ and $\mathrm{P_{pv}}$: The voltage, current and power of the cell.

I_{ph}: Light Induced current (photocurrent)

I_0: Saturation current of diode dark

First derivative of Eq. 6 yield V calculated numerically.

3. Newton's Method

Step 1: Put $v = 0$, $v_0 = 1$(initial approximation) and N: maximum number of iterations, ε: is the tolerance.

Step 2: $i \leq v_0$

Step 3: Compute v_{n+1} using the following equation$v_{n+1} = v_n - \frac{f(v_n)}{\acute{f}(v_n)}$ for $n = 0, 1, 2, \ldots$. where v_{n+1} is the output

Step 4: if $|v_i - v_{i-1}| < \varepsilon$ (tolerance); then v_{n+1} and stop.

Step 5: Put $n = n + 1$; $i = i + 1$ and go to Step 2.

Step 6: Find v_{n+1} (OUTPUT)

4. Improved Hornor-Newton Method (IHOM)

To compare the different numerical methods of iterations, methods 1 NRM has been used against the proposed method 2 IHOM. In addition, Eq. 6. has been solved to demonstrate the performance of the new method, the results are examined using some iteration.

Suppose that $f(x)$ is a polynomial of degree $n \geq 2$ and there exists a number of $x \in [a, b]$, where $f(x) = 0$.

If $\acute{f}(x) \neq 0$, then there exists a $d > 0$ such that the sequence $\{x_x\}_{k=0}^{\infty}$ describe by the newton's iteration method

$x_{k+1} = x_k - f(x_k)/\acute{f}(x_k)\,, \qquad k = 0, 1, 2, 3, \ldots$

will converge to x for any initial approximation $x_0 \in \{x - d, x + d\}$

Now; the recursive method of Newton-Horner iteration can be adapted to compute $f(x_k)$ and $\acute{f}(x_k)$ such that $f(x_k) = b_{k,0}$ and $\acute{f}(x_k) = c_{k,1}$ and the resulting Newton-Horner iteration method will be

$x_{k+1} = x_k - b_{k,0}/c_{k,1}\,, \qquad k = 0, 1, 2, 3, \ldots$

where x_0 is an initial value.

In order to improved Newton's method can be developed by keeping the second order terms in Taylor series expansion and the following result will be as follows

$x_{k+1} = x_k - f(x_k)/\acute{f}(x_k)\left[1 + \left(f(x_k) \times \acute{\acute{f}}(x_k)/2 \times (\acute{f}(x_k)^2)\right)\right]$

Now, the recursive formula of improved Newton-Horner iteration can be adopted to compute $\acute{f}(r_k)$ and $\acute{f}(x_k)$ as the following expressions

$f(x_k) = b_{k,0}\,, \acute{f}(x_k) = c_{k,1}\,,$ and $\acute{f}(x_k) = 2! \times d_{k,2}$

Thus, the resulting improved Newton-Horner iteration method will be

$x_{k+1} = x_k - (b_{k,0}/c_{k,1})\left[1 + 2 \times b_{k,0} \times d_{k,2}/2 \times (c_{k,1})^2)\right]$ or

$x_{k+1} = x_k - (b_{k,0}/c_{k,1})\left[1 + (b_{k,0} \times d_{k,2}/(c_{k,1})^2)\right]$, $k = 0, 1, 2, 3, \ldots$

where x_0 is an initial value

5. Results and Discussion

By applying NRM and IHOM on Eq. 6 yield the results in Tables 1 to 5.

Table 1 - Comparison results of the present study based on load resistance value R = 1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-IHOM	I_{pv}-IHOM	P_{pv}-IHOM
1	1	1	1	0.427494232	0.427494232	0.182751318
2	0.971416861	0.971416861	0.943650719	0.798058028	0.798058028	0.636896615
3	0.946732606	0.946732606	0.896302627	0.900774416	0.900774416	0.811394548
4	0.929865706	0.929865706	0.864650231	0.920781097	0.920781097	0.847837829
5	0.923247893	0.923247893	0.852386673	0.922404491	0.922404491	0.850830044
6	0.922434	0.922434	0.850884484	0.922423131	0.922423131	0.850864433
7	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439
8	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439
9	0.922423135	0.922423135	0.850864439	0.427494232	0.427494232	0.182751318

The best approximation to the zero of the Eq. 6 is always nearer to the initial value and from Table 1 it is clear that the suggested method better than the first method NRM which gives approximation of the equation's root 0.922423135 with the minimum number of iterations 8 when the value of the load resistance of the circuit is R = 1.

Figure 2 from the Table 1, the values obtained for the parameters of PV cell V_{pv} , I_{pv} and P_{pv} the voltage, current and power respectively.

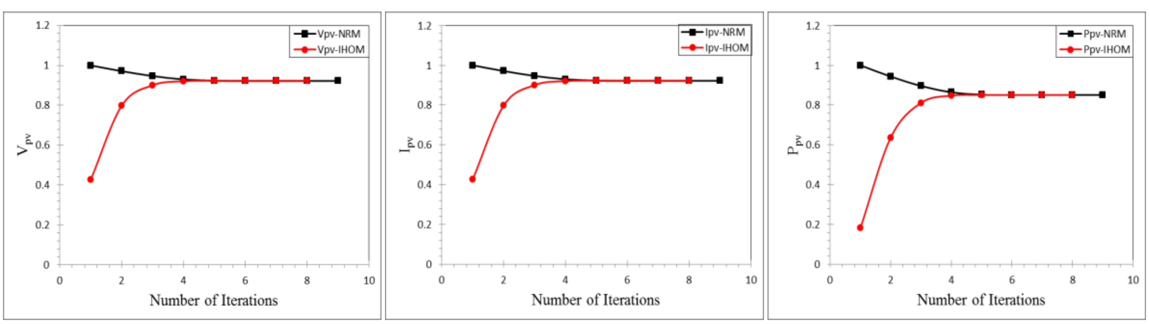

Fig. 2 – The acquired results of the present study solutions.

Table 2 - The obtained values using NRM and IHOM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-IHOM	I_{pv}-IHOM	P_{pv}-IHOM
1	1	0.5	0.5	0.691771569	0.345885784	0.239273952
2	0.971030472	0.485515236	0.471450089	0.866573289	0.433286645	0.375474633
3	0.945421967	0.472710983	0.446911348	0.910009416	0.455004708	0.414058569
4	0.926834477	0.463417238	0.429511073	0.916663928	0.458331964	0.420136378
5	0.918438746	0.459219373	0.421764865	0.917031761	0.45851588	0.420473625
6	0.917066885	0.458533442	0.420505836	0.917035381	0.45851769	0.420476945
7	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946
8	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946
9	0.917035382	0.458517691	0.420476946			

In Table 2 one can see that the suggested method better than the first method obtains an approximation of the equation's root 0.917035382 with the minimum number of iterations 8 when the value of the load resistance of the circuit is R = 2.

Figure 3 from the Table 2, the values obtained for the parameters of PV cell V_{pv} , I_{pv} and P_{pv} the voltage, current and power respectively

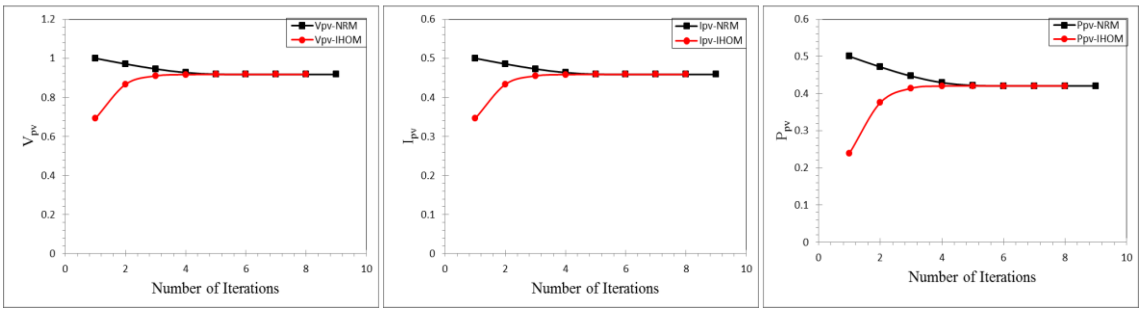

Fig. 3 - The acquired results of the present study solutions

From Table 3 we noticed the suggested method better than the first method obtains an approximation of the equation's root 0.917035382 with the minimum number of iterations 8 when the value of the load resistance of the circuit is R = 3

Table 3 - The obtained values using NRM and IHOM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HOM	I_{pv}-HOM	P_{pv}-HOM
1	1	0.333333333	0.333333333	0.779539843	0.259846614	0.202560789
2	0.970643792	0.323547931	0.31404979	0.888363228	0.296121076	0.263063075
3	0.944084232	0.314694744	0.297098346	0.910627284	0.303542428	0.276414017
4	0.923594243	0.307864748	0.284342109	0.911169131	0.303723044	0.276743062
5	0.91287784	0.304292613	0.277781984	0.910444101	0.303481367	0.27630282
6	0.910501262	0.303500421	0.276337516	0.910403443	0.303467814	0.276278143
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101
8	0.910403374	0.303467791	0.276278101	0.910403374	0.303467791	0.276278101
9	0.910403374	0.303467791	0.276278101			

Figure 4 from the Table 3, the values obtained for the parameters of PV cell V_{pv} , I_{pv} and P_{pv} the voltage, current and power respectively

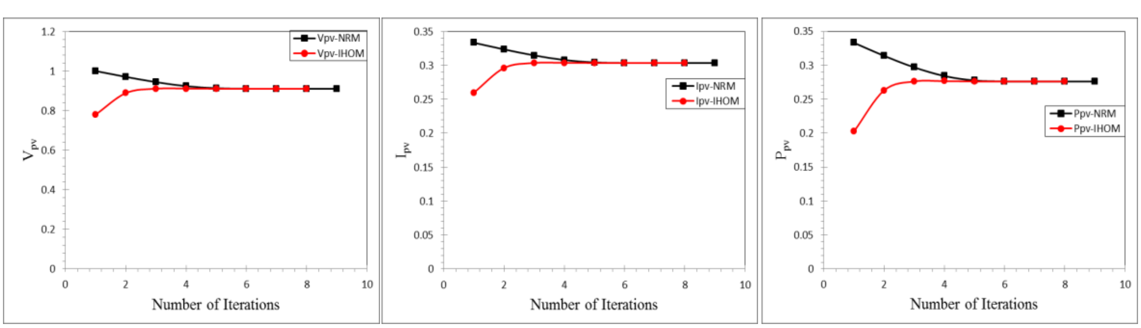

Fig. 4 - The acquired results of the present study solutions.

Table 4 - The obtained values using NRM and IHOM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-IHOM	I_{pv}-IHOM	P_{pv}-IHOM
1	1	0.25	0.25	0.823180576	0.205795144	0.169406565
2	0.970256822	0.242564205	0.235349575	0.898446452	0.224611613	0.201801507
3	0.94271872	0.23567968	0.222179646	0.90888589	0.227221472	0.20651839
4	0.920123009	0.230030752	0.211656588	0.904487439	0.22612186	0.204524382
5	0.906346494	0.226586624	0.205365992	0.90196956	0.22549239	0.203387272
6	0.902077706	0.225519427	0.203436047	0.901741933	0.225435483	0.203284628
7	0.901742503	0.225435626	0.203284885	0.901740602	0.225435151	0.203284028
8	0.901740602	0.225435151	0.203284028	0.901740602	0.22543515	0.203284028
9	0.901740602	0.22543515	0.203284028			

Pointing to Table 4 it is cleared that the proposed method better than the first method obtains an approximation of the equation's root 0.901740602 with the minimum number of iterations 8 when the value of the load resistance of the circuit is R = 4.

Figure 5 from the Table 4, the values obtained for the parameters of PV cell V_{pv} , I_{pv} and P_{pv} the voltage, current and power respectively.

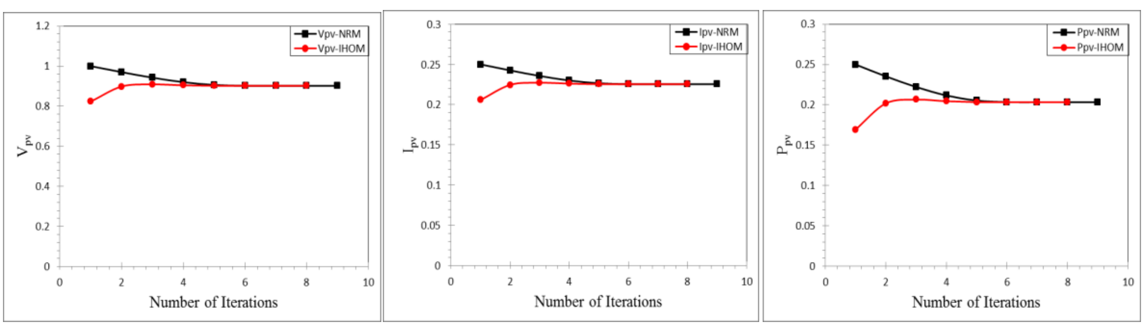

Fig. 5 - The acquired results of the present study solutions.

Table 5 - The obtained values using NRM and IHOM.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-IHOM	I_{pv}-IHOM	P_{pv}-IHOM
1	1	0.2	0.2	0.849170074	0.169834015	0.144217963
2	0.96986956	0.193973912	0.188129393	0.903825999	0.1807652	0.163380287
3	0.941324731	0.188264946	0.17721845	0.906012953	0.181202591	0.164171894
4	0.916395843	0.183279169	0.167956268	0.896365939	0.179273188	0.160694379
5	0.898535645	0.179707129	0.161473261	0.890248776	0.178049755	0.158508577
6	0.890477009	0.178095402	0.158589861	0.889121037	0.177824207	0.158107244
7	0.889125763	0.177825153	0.158108925	0.889092731	0.177818546	0.158097177
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171
9	0.889092715	0.177818543	0.158097171	0.889092715	0.177818543	0.158097171
10	0.889092715	0.177818543	0.158097171			

Indicating to Table 5 the proposed method better than the first method clearly obtains an approximation of the equation's root 0.889092715 with the minimum number of iterations 8 when the value of the load resistance of the circuit is R = 5.

Figure 6 from the Table 5, the values obtained for the parameters of PV cell V_{pv} , I_{pv} and P_{pv} the voltage, current and power respectively.

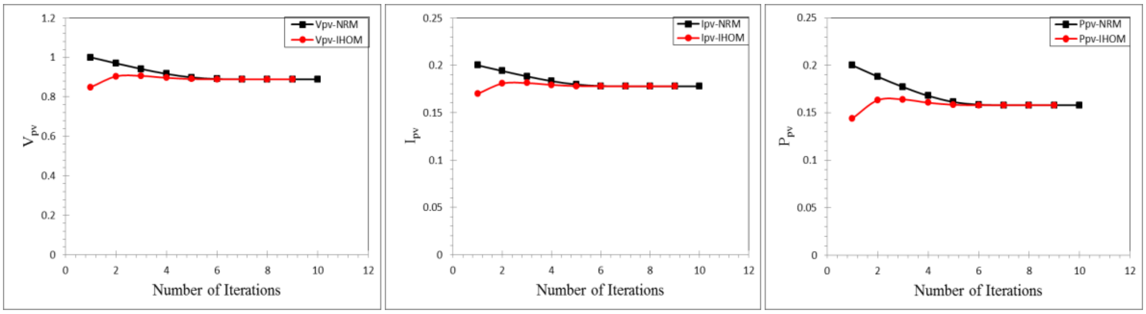

Fig. 6 - The acquired results of the present study solutions.

The numerical examples as mentioned above from Figures 2 to 6 shows also that the proposed method IHOM works better than NRM indicated a fast behavior.

7. Conclusion

Improved Newton's-Horner and Newton's methods were satisfied to find the numerical solution of the non-linear equation of a solar cell. The two methods are examined by taking various values of the load resistance R and good results were realized. The proposed method provided a very convenient and useful algorithm for the nonlinear equation. The results for the NRM were improved using IHOM to extract the roots of the single-diode equation within this algorithm by taking the initial value of x_0.

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