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Two Step and Newton-Raphson Algorithms in the Extraction for the Parameters of Solar Cell

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Two Step and Newton- Raphson Algorithms in the Extraction for the Parameters of Solar Cell

<p>Authors Names a. Mohammed RASHEED b. Suha SHIHAB, c. Taha RASHID</p> <p>Article History Received on: 3/01/2021 Revised on: 14/01/2021 Accepted on: 18/01/2021</p> <p>Keywords: <i>Two step algorithm; Newton's method; numerical solution; iterations; Matlab language</i></p> <p>DOI:https://doi.org/10.29350/jops.2021.26.1.1260</p>	<p>ABSTRACT</p> <p>The goal of this work is to find a numerical solution of nonlinear solar cell equation. This equation has been instructed using a single-diode model. The proposed method consists of solving the equation using two iterative methods with the initial value $x_0=1$. Moreover, the Newton's and Two-step methods are used to determine the required the current, the voltage, and the power of the PV cell in the procedure of the present research. Different values of load resistance have introduced with these methods. The obtained results appeared that the proposed method is the most efficient compare with NRM and all the calculations are achieved using Matlab program.</p>
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1. Introduction

Scientists began to investigate natural phenomena, whether chemical, physical, engineering, or biological, as various sciences were complicated by the interferences between them and developed terribly. Numerical analysis of all kinds played an important role for explaining these phenomena's in order to obtaining various solutions whether numerical or analytical. Numerical analysis plays a prominent role in solving many physical problems, called communication issues in the science of elasticity, mathematical engineering and mathematics. There have been many ways to

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solve these equations, whether analytical or numerical [1, 12, 14, 15, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 40, 41, 42, 49, 50, 52 and 53]. Solar cells play an important role in providing clean electricity. Photovoltaic cells, made from semiconductor materials such as silicon, are devices that directly convert solar photons into direct current. Due to the manufacturing techniques and types of materials used in the production of photovoltaic cells, these cells can be classified into three groups [2, 3, 4, 5, 6, 7, 8, 9, 13, 16, 17, 18, 19, 30, 26, 35, 36, 39, 51, 54 and 55]. First group Cells made of silicon crystals. Second group It is divided into four sub-types according to the crystalline structure of the materials involved in its manufacture, as well as the identity and type of materials that include the cells manufactured from the following materials; Amorphous silicon; Polycrystalline silicon; Cadmium Telluride; Indium Copper Alloy. Third group they are the most modern cells, which the world is reliable in obtaining units of highly efficient Solar cells. The cells of this generation are divided into several families: They are the most modern cells, which the world is reliable in obtaining units of highly efficient Solar cells. The cells of this generation are divided into several families, Solar cell nanocrystals; Electrochemical photocells; Polymer solar cells manufactured from polymers; Dye Sensitized solar cells; Solar cells manufactured from molds polymers grafted with inorganic crystals, scientists believe that this type of cells to be manufactured within the fourth generation of solar cells [10, 11, 21, 22, 23, 24 and 25]. For more applications, see [43, 44, 45, 46, 47 and 48]

The aim of this article is to introduce a new iterative algorithm two-step method (2SM) for solving PV cell equation. Two various algorithms are discussed and applied with the comparison between them.

2. Non-Linear Equation Derived from an Electrical Circuit

Figure 1 presents the simple equivalent electronic circuit of a solar cell (neglecting R_s and R_{sh}).

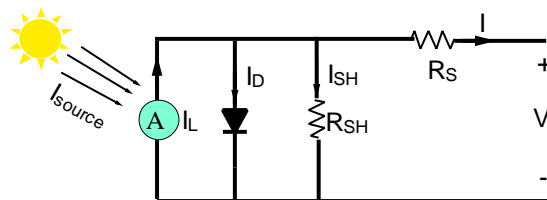


Fig. 1 - Single-diode electrical equivalent circuit of a solar cell.

The final equation of the solar cell current can be extracted according to this equivalent by applying (KCL) Kirchhoff's current law as follows [28 and 50].

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

$$I_D = I_0 \left(e^{\frac{-V_{pv}}{nV_T}} - 1 \right) \quad (2)$$

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

where: I_0 , I_{ph} , I measured in Ampere: reverse saturation current, photocurrent and is reverse saturation current and cell's current respectively. In addition, V_T and V_{pv} the thermic voltage= 26 mV and voltage's cell respectively. The value of the recombination factor of about ($1 < m < 2$), q and k : the electron charge= 1.6×10^{-19} C and Boltzmann constant= 1.38×10^{-23} J/K respectively. Temperature junction is T [29].

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

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

Put Eq. 4 in Eq. 5 yield

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

where: I_s reverse saturation current= 10^{-12} A. In parallel, $V_D = V_{pv} = V$

The derivative of the Eq. 6 is necessary to find the roots of the V_{pv} numerically.

3. Newton's Technique (NRM)

The following algorithm suggestion for solving Eq. 6 by using NRM

- INPUT initial approximate solution $x_0 = 1$, $\varepsilon =$ tolerance, $N =$ maximum number of iterations.

- Output $x_{n+1} =$ approximate solution

1. Set $x = 0$

2. Step 2: while $i \leq x_0$
3. Step 3: Calculate $x_{n+1} = x_n - \frac{f(x_n)}{\hat{f}(x_n)}$ for $n = 0, 1, 2, \dots$
4. Step 4: If $|x_i - x_{i-1}| < \varepsilon$; so $x_{n+1} =$ approximate solution output and stop.
5. Step 5: put $i = i + 1, n = n + 1$; go to Step 2.
6. Step 6: Output

4. Two Step Iterative Method (2SM)

To compare the different numerical methods of iterations, methods 1 (NRM) has been used against the proposed method 2 (2SM). In addition, Eq. 6. has been solved to demonstrate the performance of the new method, and determine the consistency and stability of results. The results are examined using some iteration.

$$y_n = d_n - \frac{2 \times f(d_n)}{3 \times \hat{f}(d_n)}, n = 0, 1, 2, 3, \dots$$

$$d_{n+1} = d_n - \frac{2 \times f(d_n)}{\hat{f}(d_n) + \hat{f}(d_n)}, n = 0, 1, 2, 3, \dots$$

The tolerance and criteria used in the following equations $\varepsilon = 10^{-9}$ and

$$\sigma = |d_{n+1} - d_n| < \varepsilon, |f(d_n)| < \varepsilon$$

5. Results and Discussion

The two numerical methods NRM and 2SM are applied in nonlinear Equation Eq. 6 for PV single diode model and the results obtained are presented in the following Tables for various data of load resistance of the proposed circuit.

Iterations	V_{pv} -NRM	I_{pv} -NRM	P_{pv} -NRM	V_{pv} -2SM	I_{pv} -2SM	P_{pv} -2SM
1	1	1	1	0.962945371	0.962945371	0.927263787
2	0.971416861	0.971416861	0.943650719	0.940361045	0.940361045	0.884278896
3	0.946732606	0.946732606	0.896302627	0.926849876	0.926849876	0.859050692
4	0.929865706	0.929865706	0.864650231	0.922778557	0.922778557	0.851520266
5	0.923247893	0.923247893	0.852386673	0.922426883	0.922426883	0.850871355
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.85086444
7	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439
8	0.922423135	0.922423135	0.850864439			
9	0.922423135	0.922423135	0.850864439			

Table 1 - Comparison of different methods for solving Eq. 6 using NRM and 2SM.

Referring to Table 1 for an initial value $x_0 = 1$, in it very interesting to note the following: at 9th iterations convergence to the root 0.922423135 using NRM while; the proposed method in the Eq. 6 converges to the same approximate root 0.922423135 at 7th iterations. Figure 2 shows the results of the PV parameters obtained by NRM and 2SM.

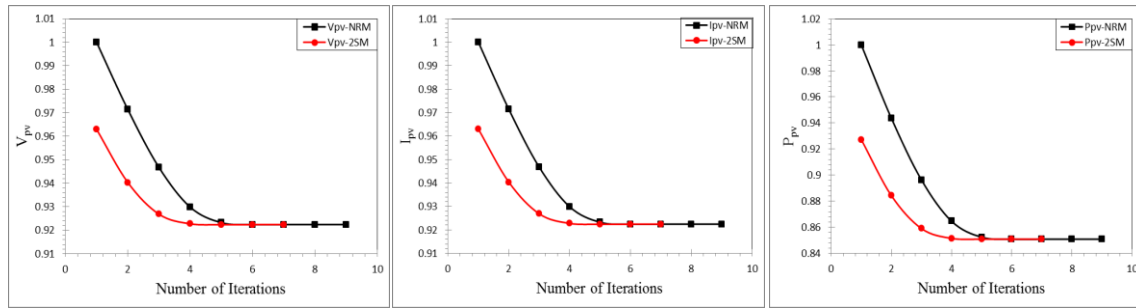


Fig. 2 – Comparison of PV cell parameters obtained by NRM and 2SM at R = 1.

Iterations	V_{pv} -NRM	I_{pv} -NRM	P_{pv} -NRM	V_{pv} -2SM	I_{pv} -2SM	P_{pv} -2SM
1	1	0.5	0.5	0.970250663	0.485125332	0.470693175
2	0.971030472	0.485515236	0.471450089	0.944854325	0.472427163	0.446374848
3	0.945421967	0.472710983	0.446911348	0.926576837	0.463288418	0.429272317
4	0.926834477	0.463417238	0.429511073	0.918396494	0.459198247	0.42172606
5	0.918438746	0.459219373	0.421764865	0.917065915	0.458532958	0.420504947
6	0.917066885	0.458533442	0.420505836	0.917035398	0.458517699	0.420476961
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			

Table 2 - Comparison of different methods for solving Eq. 6 using NRM and 2SM.

According to Table 2 for an initial value $x_0 = 1$, in it very interesting to note the following: at 9th iterations convergence to the root 0.917035382 using NRM while; the proposed method in the Eq. 6 converges to the same approximate root 0.917035382 at 7th iterations. Figure 3 shows the results of the PV parameters obtained by NRM and 2SM.

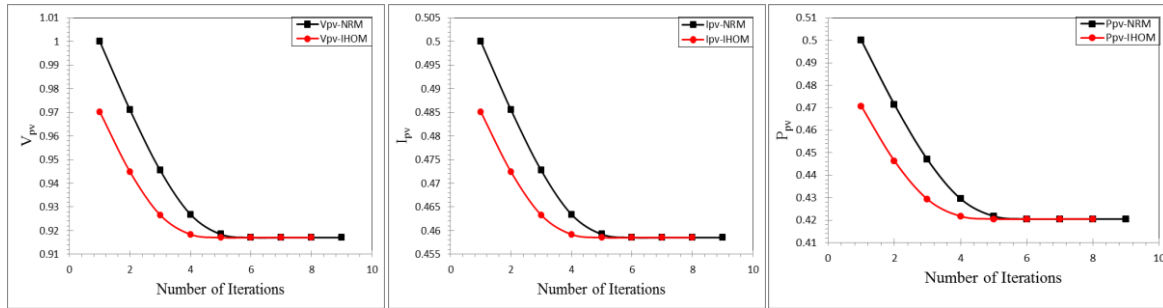


Fig. 3 – Comparison of PV cell parameters obtained by NRM and 2SM at R = 2.

Iterations	V_{pv} -NRM	I_{pv} -NRM	P_{pv} -NRM	V_{pv} -2SM	I_{pv} -2SM	P_{pv} -2SM
1	1	0.3333333333	0.3333333333	0.969836085	0.323278695	0.313527344
2	0.970643792	0.323547931	0.31404979	0.943460514	0.314486838	0.296705914
3	0.944084232	0.314694744	0.297098346	0.923267523	0.307755841	0.284140973
4	0.923594243	0.307864748	0.284342109	0.912805332	0.304268444	0.277737858
5	0.91287784	0.304292613	0.277781984	0.910498287	0.303499429	0.27633571
6	0.910501262	0.303500421	0.276337516	0.910403527	0.303467842	0.276278194
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			

Table 3 - Comparison of different methods for solving Eq. 6 using NRM and 2SM.

Based on Table 3 for an initial value $x_0 = 1$, in it very interesting to note the following: at 9th iterations convergence to the root 0.910403374 using NRM while; the proposed method in the Eq. 6 converges to the same approximate root 0.910403374 at 7th iterations. Figure 4 shows the results of the PV parameters obtained by NRM and 2SM.

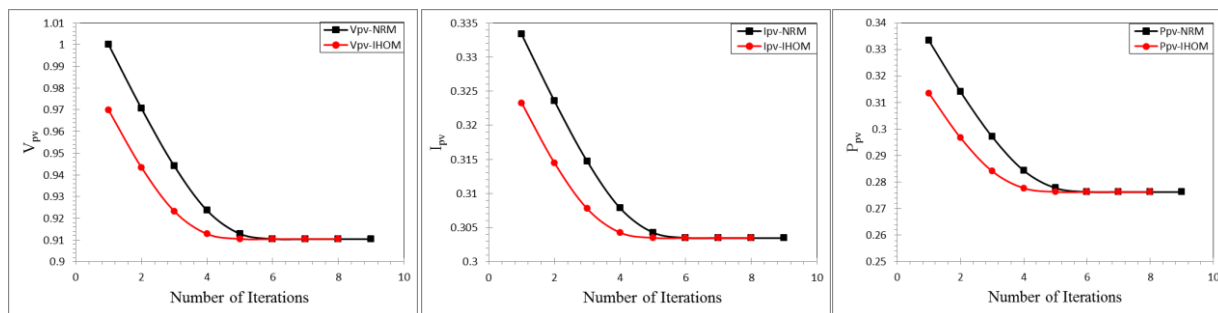


Fig. 4 – Comparison of PV cell parameters obtained by NRM and 2SM at R = 3.

Iterations	V_{pv} -NRM	I_{pv} -NRM	P_{pv} -NRM	V_{pv} -2SM	I_{pv} -2SM	P_{pv} -2SM
1	1	0.25	0.25	0.598809171	0.149702293	0.089643106
2	0.970256822	0.242564205	0.235349575	0.816819533	0.204204883	0.166798538
3	0.94271872	0.23567968	0.222179646	0.884826124	0.221206531	0.195729317
4	0.920123009	0.230030752	0.211656588	0.900161102	0.225040276	0.202572502
5	0.906346494	0.226586624	0.205365992	0.901713938	0.225428485	0.203272007
6	0.902077706	0.225519427	0.203436047	0.901740591	0.225435148	0.203284023
7	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028
8	0.901740602	0.225435151	0.203284028			
9	0.901740602	0.22543515	0.203284028			

Table 4 - Comparison of different methods for solving Eq. 6 using NRM and 2SM.

As a results on Table 4 for an initial value $x_0 = 1$, in it very interesting to note the following: at 9th iterations convergence to the root 0.901740602 using NRM while; the proposed method in the Eq. 6 converges to the same approximate root 0.901740602 at 7th iterations. Figure 5 shows the results of the PV parameters obtained by NRM and 2SM.

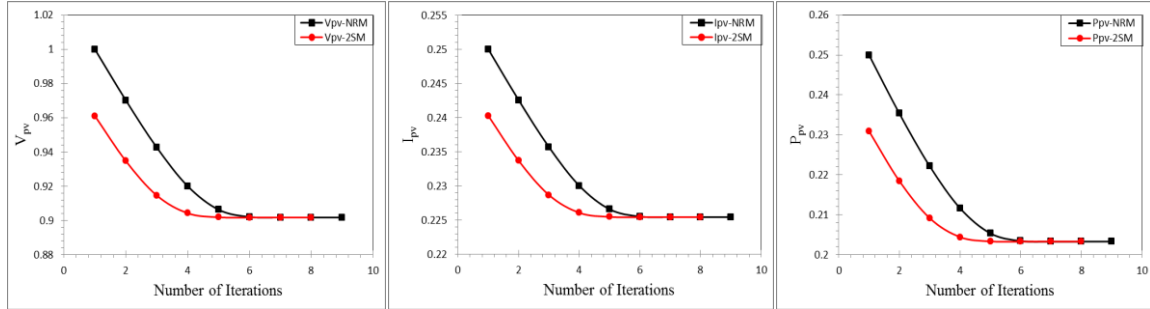


Fig. 5 – Comparison of PV cell parameters obtained by NRM and 2SM at R = 4.

Iterations	V_{pv} -NRM	I_{pv} -NRM	P_{pv} -NRM	V_{pv} -2SM	I_{pv} -2SM	P_{pv} -2SM
1	1	0.2	0.2	0.960466918	0.192093384	0.18449934
2	0.96986956	0.193973912	0.188129393	0.932816856	0.186563371	0.174029457
3	0.941324731	0.188264946	0.17721845	0.909783325	0.181956665	0.16554114
4	0.916395843	0.183279169	0.167956268	0.895021368	0.179004274	0.16021265
5	0.898535645	0.179707129	0.161473261	0.889732889	0.177946578	0.158324923
6	0.890477009	0.178095402	0.158589861	0.889104432	0.177820886	0.158101338
7	0.889125763	0.177825153	0.158108925	0.889092721	0.177818544	0.158097173
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			

Table 4 - Comparison of different methods for solving Eq. 6 using NRM and 2SM.

For an initial value $x_0 = 1$, in it very interesting to note the following: at 10th iterations convergence to the root 0.901740602 using NRM while; the proposed method in the Eq. 6 converges to the same approximate root 0.901740602 at 9th iterations as shown in Table 5. Figure 6 shows the results of the PV parameters obtained by NRM and 2SM.

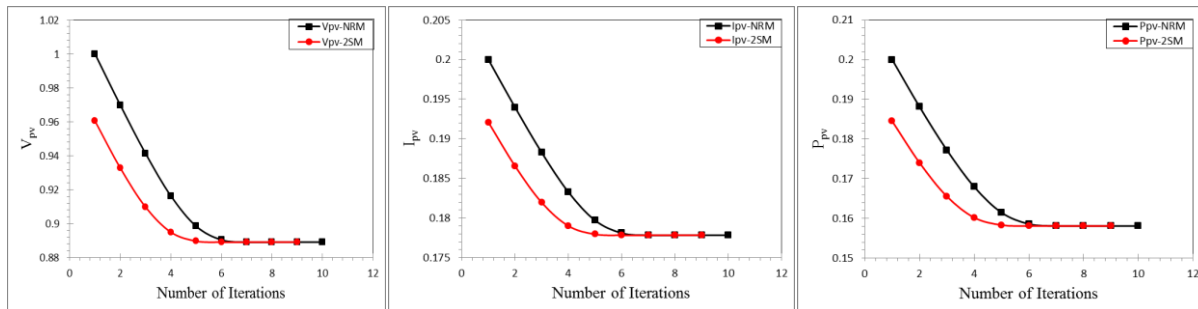


Fig. 6 – Comparison of PV cell parameters obtained by NRM and 2SM at $R = 5$.

According to the Tables 1, 2, 3, 4 and 5, it is famous that the best approximation to the exact root is often nearer to the initial value, so the results acquired by the proposed method are nearer to the initial approximation $x_0 = 1$, therefore these two methods works better with this type of model (PV – single diode model – nonlinear equation). In addition, the minimum numbers of iterations are appeared by the proposed method 2SM.

6. CONCLUSION

Two-step and Newton's methods were applied to find the numerical solution of the non-linear equation of a solar cell. The methods are tested by taking different values of the load resistance and good results were achieved. The process of computation in these methods is simple because the approximate results were obtained easily by a few computations with the aid of Matlab. Therefore, this approach is considerably powerful. In the proposed method the good results depend on the selecting of the initial value of x_0 are obtained.

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