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Experimental Results for a Nonlinear Equation Using Improved Newton-Raphson Estimation Method

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ABSTRACT

In this paper, two algorithms for solving the nonlinear equation of the solar cell within single diode model are proposed. These algorithms are plays an important and significant rule in the evaluation of this equation. The solution is examined with a various values of load resistance (1, 5) Ω at room temperature. The nonlinear equation of a solar cell is derived from the equivalent circuit of this cell. The obtained results reveal that the propose algorithm is appropriate one for solving such equations with the aid of Matlab language.

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1. Introduction

Most of the numerical methods used to solve nonlinear equations are a kind of iterative methods. Therefore, we need the initial value of the root from which we can generate a sequential of approximate values that are another value of the root of the equation and approach it as the values of the approach speed of the root increase, which depends mainly on correct choice of starting point. There are many ways to solve nonlinear equations that are available in all other sciences such as engineering, science, medicine and mathematics [1-20]. The cheapest and least expensive semiconductor element is silicon, which is the second element in the earth's crust. The monopoly of

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nanomaterials for the unusual optical, electrical, and chemical properties of conventional granular materials has greatly increased their chances of being employed in the production of an advanced and distinctive generation of solar cells known as the third generation [21-96].

The aim of this article is to investigate a new iterative algorithm; predictor-corrector type technique (A1) in order to solve nonlinear equation of a PV cell. The following steps describe the next sections: section two and three characterizing the model of a PV cell and establishing the zeros finding of Newton Raphson algorithm respectively; while in section four predictor-corrector type algorithm has been depicted; section five and six; results, discussion and conclusions respectively.

2. PV Model Design (An Electrical Circuit)

Figure 1 illustrates PV cell an equivalent circuit (single diode model)

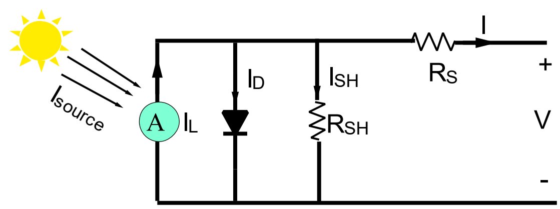

Fig. 1 – PV cell electrical equivalent circuit.

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

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

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

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

where:

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

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

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

Subs. 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, $V_D = V = V_{pv}$

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

3. Newton's Method

[1] The following algorithm suggestion for solving Eq. 6 by using NRM
[2] $x_0 = 1$, input initial approximate solution.
[3] x_{n+1} the output solution
[4] Step 1- Set $x = 0$
[5] Step 2- while $i \le x_0$

[6] Step 3- Determine $x_{n+1} = x_n - \frac{f(x_n)}{\acute{f}(x_n)}$ for $n = 0, 1, 2, ...$ (7)

[7] Step 4- if $|x_i - x_{i-1}| < \varepsilon$; then x_{n+1} and stop.

[8] Step 5- Set $n = n + 1$; $i = i + 1$ and return to step 2.

[9] Step 6- OUTPUT

4. Predictor – Corrector Type (A1)

To compare the different numerical methods of iterations, methods 1 NRM has been used against the proposed method 2 Predictor-Corrector Type (A1). In addition; Eq. 6. has been solved to demonstrate the performance of the new method, the results are examined using some iteration.

Using the predictor-corrector type technique, we suggest the following two-step method, which is acquired by combining the Newton's method to obtain algorithm 1.

For a given H_0, compute the approximate solution H_{n+1} by the iterative scheme

$$H_{n+1} = H_n - \frac{f(H_n)}{\acute{f}(H_n)} \quad (8)$$

$$H_{n+1} = H_n - \frac{6 \times f(H_n)}{\acute{f}(H_n) + 4 \times \acute{f}\left(\frac{H_n + H_{n+1}^*}{2}\right) + \acute{f}(H_{n+1}^*)}, \ n = 0, 1, 2, 3, \dots \quad (9)$$

where x_0 is an initial value.

By assuming that $\varepsilon = 10^{-9}$ as a tolerance; the following criteria is used for estimating the zero $\sigma = |H_{n+1} - H_n| < \varepsilon$, $|f(H_n)| < \varepsilon$ (10)

5. Results and Discussion

The roots of Eq. 6 (non-linear equation) are obtained by means of two techniques NRM and AHM extracted by Eqns. 7 and 9 with predict guess v_0. The approximate solutions produced by the two methods. Five various numerical experiments are used using equation 6 which are based on the Resistance values (load resistance) which is varies between 1 to 5 ohm as illustrated in the Tables 1-5 and Figs 2-6. The results show that A1 technique need 7 iterations while NRM need 9 iterations respectively in order to reach to the convergence which proves that A1 is faster than the other method.

Table 1 - Total number of iterations for PV cell test case-two iteration methods NRM and A1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1
1	1	1	1	0.956353318	0.956353318	0.914611669
2	0.971416861	0.971416861	0.943650719	0.935681181	0.935681181	0.875499273
3	0.946732606	0.946732606	0.896302627	0.924882295	0.924882295	0.85540726
4	0.929865706	0.929865706	0.864650231	0.922517684	0.922517684	0.851038878
5	0.923247893	0.923247893	0.852386673	0.922423278	0.922423278	0.850864704
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439
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			

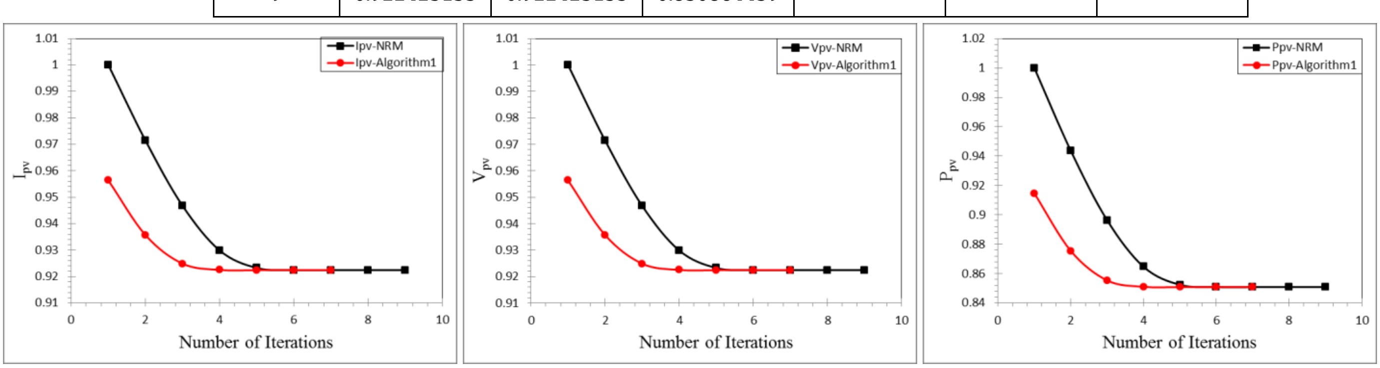

Fig. 2 – Measured PV parameters for the NRM and A1 algorithms.

Table 2 - Total number of iterations for PV cell test case-two iteration methods NRM and A1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1
1	1	0.5	0.5	0.955521013	0.477760507	0.456510203
2	0.971030472	0.485515236	0.471450089	0.93345809	0.466729045	0.435672003
3	0.945421967	0.472710983	0.446911348	0.920709796	0.460354898	0.423853264
4	0.926834477	0.463417238	0.429511073	0.917245217	0.458622609	0.420669394
5	0.918438746	0.459219373	0.421764865	0.917036095	0.458518047	0.4204776
6	0.917066885	0.458533442	0.420505836	0.917035382	0.458517691	0.420476946
7	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946
8	0.917035382	0.458517691	0.420476946			
9	0.917035382	0.458517691	0.420476946			

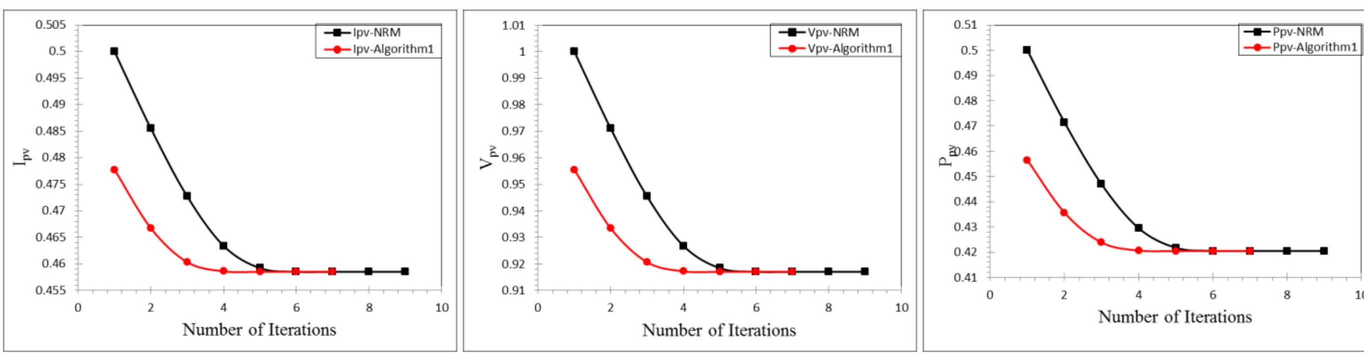

Fig. 3 – Measured PV parameters for the NRM and A1 algorithms.

Table 3 - Total number of iterations for PV cell test case-two iteration methods NRM and A1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1
1	1	0.333333333	0.333333333	0.954680538	0.318226846	0.303804977
2	0.970643792	0.323547931	0.31404979	0.931137845	0.310379282	0.289005896
3	0.944084232	0.314694744	0.297098346	0.916052182	0.305350727	0.2797172
4	0.923594243	0.307864748	0.284342109	0.910893833	0.303631278	0.276575858
5	0.91287784	0.304292613	0.277781984	0.910407299	0.3034691	0.276280483
6	0.910501262	0.303500421	0.276337516	0.910403374	0.303467791	0.276278101
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101
8	0.910403374	0.303467791	0.276278101			
9	0.910403374	0.303467791	0.276278101			

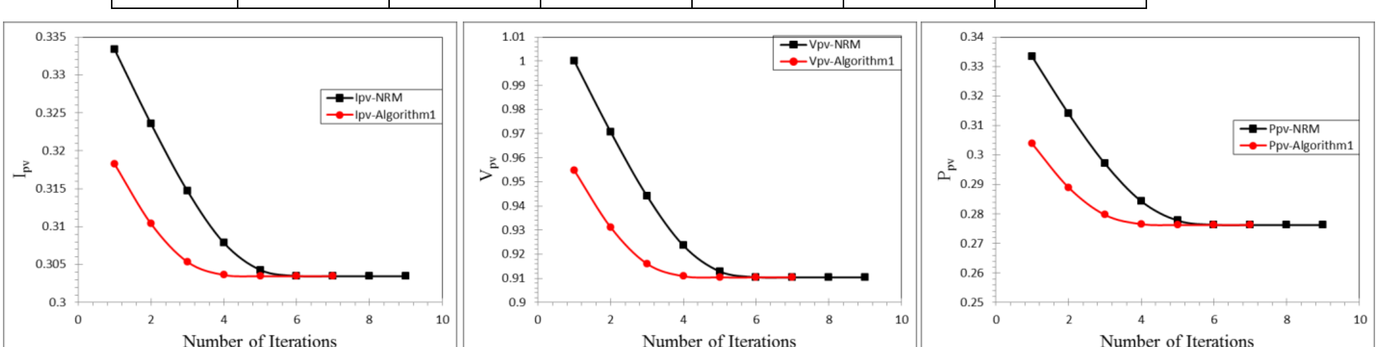

Fig. 4 – Measured PV parameters for the NRM and A1 algorithms.

Table 4 - Total number of iterations for PV cell test case-two iteration methods NRM and A1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1
1	1	0.25	0.25	0.953831829	0.238457957	0.227448789
2	0.970256822	0.242564205	0.235349575	0.928714508	0.232178627	0.215627659
3	0.94271872	0.23567968	0.222179646	0.910814499	0.227703625	0.207395763
4	0.920123009	0.230030752	0.211656588	0.902979093	0.225744773	0.20384281
5	0.906346494	0.226586624	0.205365992	0.9017659	0.225441475	0.203295434
6	0.902077706	0.225519427	0.203436047	0.901740613	0.225435153	0.203284033
7	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028
8	0.901740602	0.225435151	0.203284028	0.901740602	0.22543515	0.203284028
9	0.901740602	0.22543515	0.203284028			

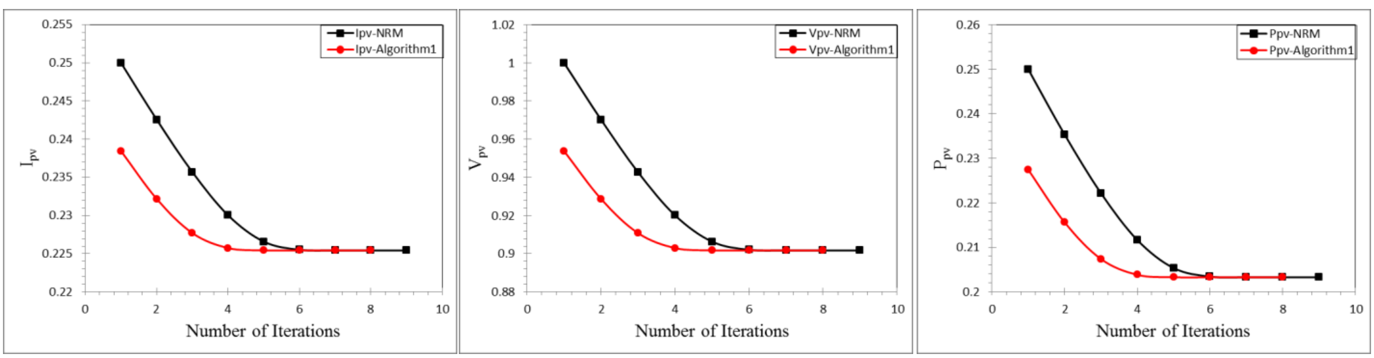

Fig. 5 – Measured PV parameters for the NRM and A1 algorithms.

Table 5 - Total number of iterations for PV cell test case-two iteration methods NRM and A1.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A1	I_{pv}-A1	P_{pv}-A1
1	1	0.2	0.2	0.952974818	0.190594964	0.181632201
2	0.96986956	0.193973912	0.188129393	0.926181706	0.185236341	0.171562511
3	0.941324731	0.188264946	0.17721845	0.904877121	0.180975424	0.163760521
4	0.916395843	0.183279169	0.167956268	0.892668197	0.178533639	0.159371302
5	0.898535645	0.179707129	0.161473261	0.88930602	0.177861204	0.15817304
6	0.890477009	0.178095402	0.158589861	0.889093511	0.177818702	0.158097454
7	0.889125763	0.177825153	0.158108925	0.889092715	0.177818543	0.158097171
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171
9	0.889092715	0.177818543	0.158097171			
10	0.889092715	0.177818543	0.158097171			

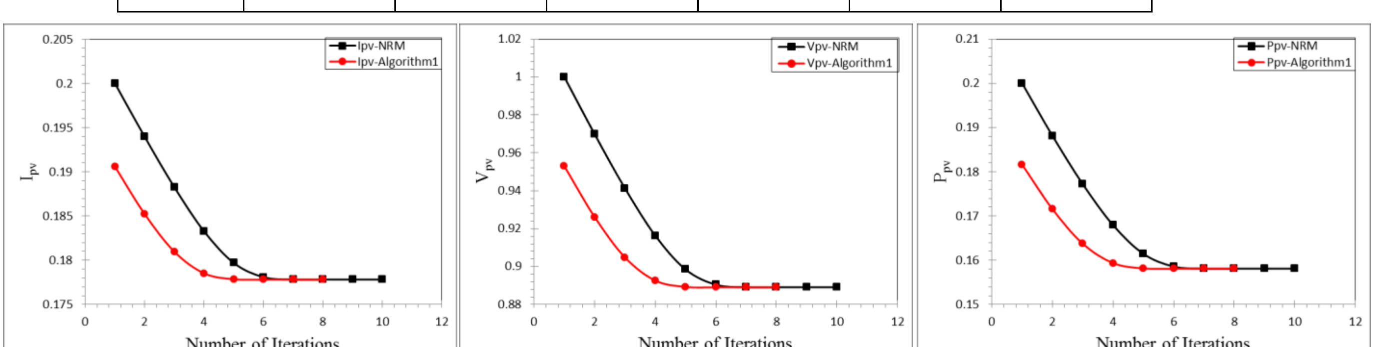

Fig. 6 – Measured PV parameters for the NRM and A1 algorithms.

6. Conclusion

Predictor-Corrector type and Newton's techniques were realized to obtain 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 achieved. The proposed method provided a very convenient and useful algorithm for the nonlinear equation. The results for the NRM were improved using Predictor-Corrector type to extract the roots of the single-diode equation within this algorithm by taking the initial value of x_0.

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