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Predictor-Corrector Solutions for Nonlinear Equations

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ABSTRACT

Two algorithms Predictor-Corrector [type 2] and Newton's algorithms are developed and applied to evaluate the approximate solution for nonlinear equation of a single diode model. All programs associated with the above algorithms are written in Matlab language. We have been that Predictor-Corrector [type 2] algorithm values are sufficiently accurate besides that going from NRM. Examples of a PV cell design are presented to illustrate this feature.

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1. Introduction

Numerical analysis studies numerical methods (using computer) to find root values. There are many ways to solve nonlinear equations that are available in all other sciences such as engineering, science, medicine and mathematic. In the computer science and mathematics many researchers used numerical iterations in order to implements, creates and analyzes algorithms for developing numerical solutions to problems including continuous variables [1-18]. The field of materials science and engineering society is capable of creating new materials from the unusual blending of chemical, physical and mechanical properties that will change modern society. Technological advances require thin films for different application. Thin-film technology is the foundation in the development of

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solid-state electronics and the optical properties of metallic films and scientific curiosity about the behavior of two-dimensional solids are responsible for the tremendous progress in the study of thin-film technology [19-96].

This paper investigates a new iterative algorithm; predictor-corrector [type 2] (A2) for solving a nonlinear model design. The following steps indicate the procedure of this paper: section two and three characterizing the model of a PV single diode (SD) design of a PV cell and establishing the zeros finding of Newton Raphson algorithm; while; in section four predictor-corrector [type 2] algorithm is depicted; section five and six results, discussion and conclusions have been presented.

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

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

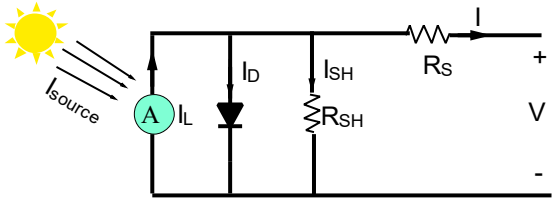

Fig. 1 – PV cell electrical equivalent circuit.

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

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

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

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

where:

$V_T = kT/q = 26$ 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

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

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

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 $i \leq x_0$

[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 (A2)

To compare the different numerical methods of iterations, methods 1 NRM has been used against the proposed method 2 Predictor-Corrector [Type 2] (A2). 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 2.

Compute the approximate solution H_{n+1} corresponding to H_0

$$H_{n+1} = H_n - \frac{6\times f(H_n)\times \hat{f}(H_n)}{2\times(\acute{f}(H_n))^2 - f(H_n)\times \acute{\hat{f}}(H_n)} \quad (8)$$

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

An efficient starting iteration H_0 can be obtained by substitution for Eq. 6

where x_0 is an initial value and the tolerance $\varepsilon = 10^{-9}$; $\sigma = |H_{n+1} - H_n| < \varepsilon, |f(H_n)| < \varepsilon$ (predicting the roots of the function)

5. Results and Discussion

Zeros of equation 6 (non-linear equation) are obtained by means of two techniques NRM and A2 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 A2 algorithm need 7 iterations while NRM need 9 iterations respectively in order to reach to the convergence which proves that A2 is faster than NRM.

Table 1 - Newton's and A2 iterations for solving Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	1	1	0.909061968	0.909061968	0.826393662
2	0.971416861	0.971416861	0.943650719	0.912675411	0.912675411	0.832976406
3	0.946732606	0.946732606	0.896302627	0.920491417	0.920491417	0.847304449
4	0.929865706	0.929865706	0.864650231	0.922359246	0.922359246	0.850746579
5	0.923247893	0.923247893	0.852386673	0.922423038	0.922423038	0.850864262
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			

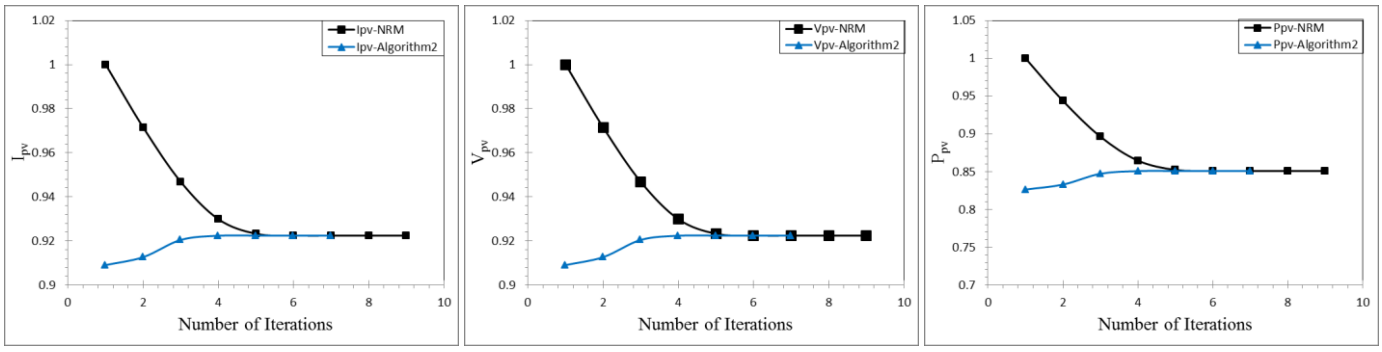

Fig. 2 – Solving a non-linear equation by means of two numerical techniques.

Table 2 - Newton's and A2 iterations for solving Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.5	0.5	0.904579258	0.452289629	0.409131817
2	0.971030472	0.485515236	0.471450089	0.905657295	0.452828647	0.410107568
3	0.945421967	0.472710983	0.446911348	0.914052791	0.457026396	0.417746253
4	0.926834477	0.463417238	0.429511073	0.916889024	0.458444512	0.420342741
5	0.918438746	0.459219373	0.421764865	0.917034902	0.458517451	0.420476505
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			

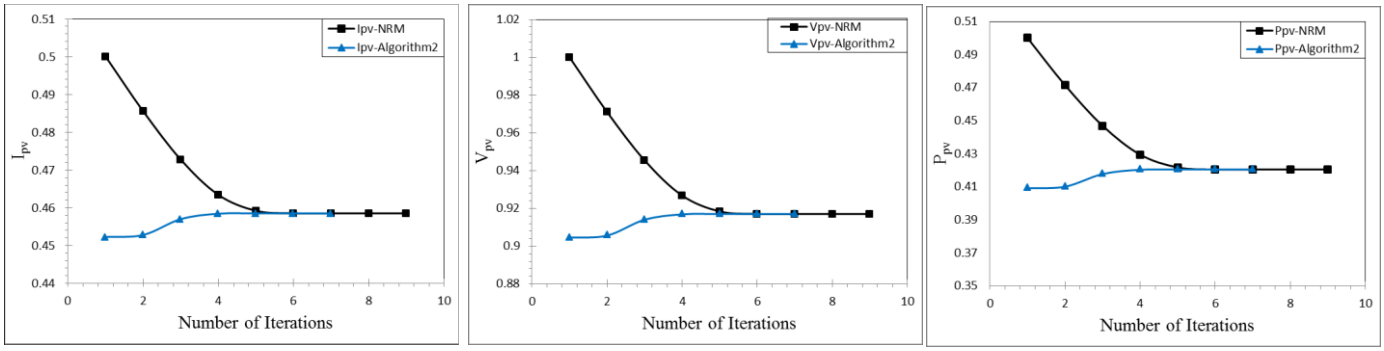

Fig. 3 – Solving a non-linear equation by means of two numerical techniques.

Table 3 - Newton's and A2 iterations for solving Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.333333333	0.333333333	0.899816691	0.299938897	0.269890026
2	0.970643792	0.323547931	0.31404979	0.897407275	0.299135758	0.268446606
3	0.944084232	0.314694744	0.297098346	0.905697121	0.30189904	0.273429092
4	0.923594243	0.307864748	0.284342109	0.910042334	0.303347445	0.276059017
5	0.91287784	0.304292613	0.277781984	0.910400684	0.303466895	0.276276468
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			

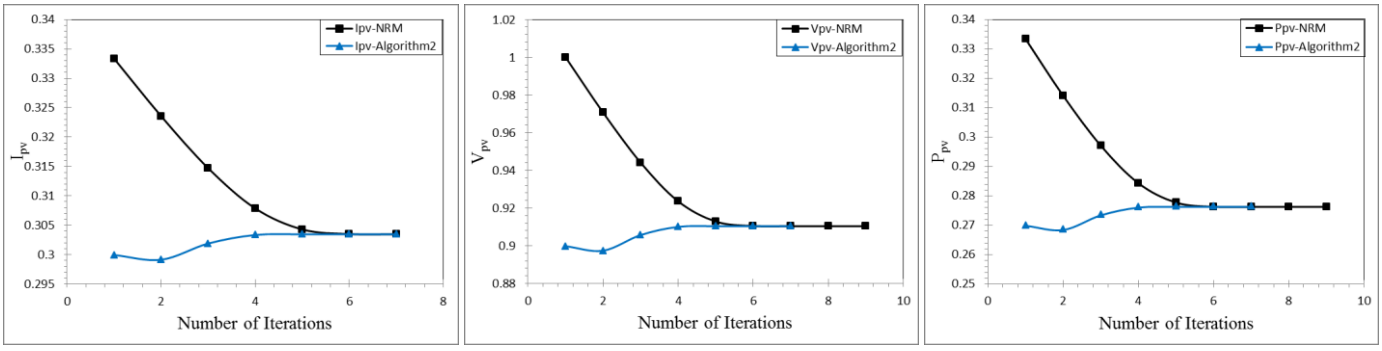

Fig. 4 – Solving a non-linear equation by means of two numerical techniques.

Table 4 - Newton's and A2 iterations for solving Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.25	0.25	0.894754474	0.223688618	0.200146392
2	0.970256822	0.242564205	0.235349575	0.88761038	0.221902595	0.19696305
3	0.94271872	0.23567968	0.222179646	0.894168824	0.223542206	0.199884471
4	0.920123009	0.230030752	0.211656588	0.900742902	0.225185726	0.202834444
5	0.906346494	0.226586624	0.205365992	0.901722644	0.225430661	0.203275931
6	0.902077706	0.225519427	0.203436047	0.901740594	0.225435149	0.203284025
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			

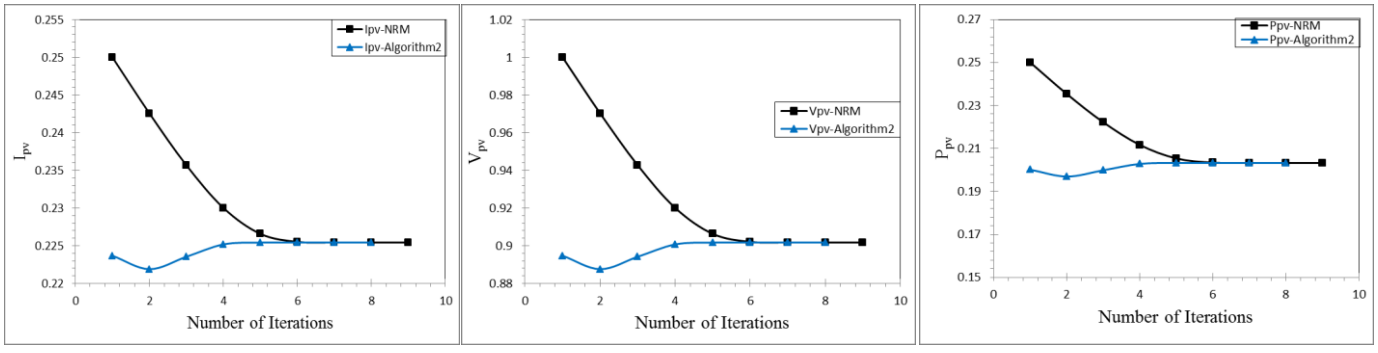

Fig. 5 – Solving a non-linear equation by means of two numerical techniques.

Table 5 - Newton's and A2 iterations for solving Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-A2	I_{pv}-A2	P_{pv}-A2
1	1	0.2	0.2	0.889371467	0.177874293	0.158196321
2	0.96986956	0.193973912	0.188129393	0.875855338	0.175171068	0.153424515
3	0.941324731	0.188264946	0.17721845	0.876941816	0.175388363	0.15380539
4	0.916395843	0.183279169	0.167956268	0.885772918	0.177154584	0.156918733
5	0.898535645	0.179707129	0.161473261	0.888923198	0.17778464	0.158036891
6	0.890477009	0.178095402	0.158589861	0.889092102	0.17781842	0.158096953

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			

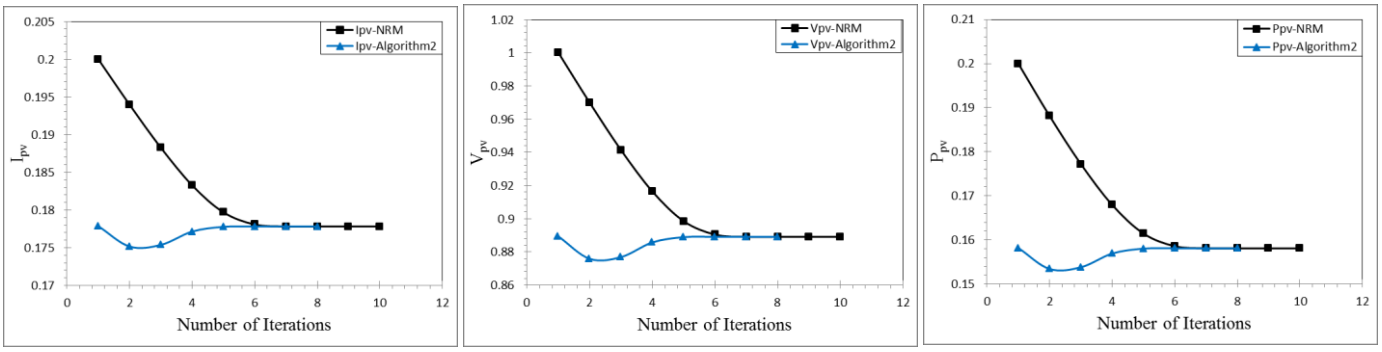

Fig. 6 – Solving a non-linear equation by means of two numerical techniques.

6. Conclusion

Predictor-Corrector [type 2] and Newton's techniques were employed to accomplish the numerical solution of the non-linear equation of a solar cell. The two methods are checked using various values of the load resistance R and good results were negotiated. The proposed method supplied a very convenient and useful algorithm for this nonlinear equation. The results for the NRM were improved using Predictor-Corrector [type 2] to obtain the roots of the single-diode equation within this algorithm by taking the initial value of x_0.

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