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Numerical Solving for Nonlinear Problems Using Iterative Techniques

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ABSTRACT

Three numerically algorithms are described and compared; newton's; Predictor-Corrector Hally and Accelerated Predictor-Corrector Hally methods have been applied in the present work. Algorithm development for solving the voltage of a solar cell based on it's a single diode equation; programmed using Matlab language. This example is given for induced the idea of this algorithm with the various values of load resistance. The results indicated the suggested algorithm is more efficient with the comparison with other two algorithms.

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1. Introduction

Numerical analysis occupies a prominent position in engineering and physical sciences, because of the relationships and laws governing the variables of a matter of physical or geometry appear in the form of a cocktail non-linear equations or differential equations or partial equations, etc. To understand this issue must be solved. Methods for the solutions of numerical nonlinear equations of the single diode equation of a PV cell depend on the equivalent circuit of a solar cells have been proposed by many applications. The researchers were able to solve many physical, engineering, or even medical problems using many different methods of numerical analysis [1-96].

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In this paper, describes a new algorithm Accelerated Predictor-Corrector Hally method (AHM); so that the nonlinear equation of a solar cell can be solved. It is systematic points: section two characterizing a design of a PV cell (single diode). Section three foundations the zeros finding of Newton Raphson technique. In section four Predictor-Corrector Hally methods has been described. Thus, in section 5 Accelerated Predictor-Corrector Hally method has been demonstrated here; in section six results and discussion are reported while in section seven the conclusions is presented.

2. Design of a Non-Linear Equation

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

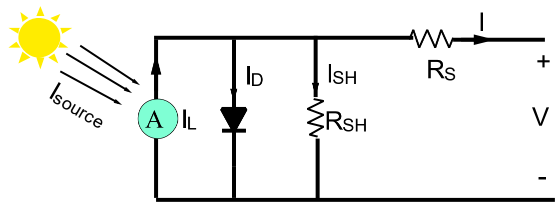

Fig. 1 – PV cell electrical equivalent circuit.

By applying KCL-Kirchhoff's current law 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:

I_{ph}, k, $V_T = kT/q = 26$ mV, q, T, I_0 and$1 < m < 2$: the photocurrent (A), 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 and the recombination factor, respectively.

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

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

Subs. Eq. 4 in Eq. 5 yield

$$(I_{source}) - 10^{-12}(\exp(-V/1.2 * 0.026) - 1) = V/R \quad (6)$$

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

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

INPUT initial approximate solution $x_0 = 1$,

OUTPUT x_{n+1}

Step 1- Set $x = 0$

Step 2- while $i \leq x_0$

Step 3- Calculate

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \text{ for } n = 0, 1, 2, \ldots. \quad (7)$$

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

Step 5- $i = i + 1$, $n = n + 1$, and retune to step 2.

Step 6- OUTPUT

4. Predictor – Corrector Halley's Method (HM)

Method 2: Predictor- Corrector Halley's Method (HM)

$$y_n = x_n - (f(x_n)/f'(x_n)) \quad (8)$$

$$x_{n+1} = y_n - \left(2 \times f(y_n)f'(y_n)/2 \times f'(y_n)^2 - f(y_n) \times f''(y_n)\right) \quad (9)$$

5. Accelerated Predictor-Corrector Halley's Method (AHM)

To compare the different numerical methods of iterations, algorithm 1 and algorithm 2 has been used against the proposed algorithm 3. In addition; Eq. 6. has been solved to demonstrate the performance of the new proposed algorithm and determine the consistency and stability of results. The results are examined using three iterative algorithms

Algorithm 1: Newton Raphson Method (NRM)

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}, n = 0, 1, 2, 3, \ldots \quad (10)$$

Algorithm 2: Predictor- Corrector Hally Method (HM)

$$y_n = x_n - \frac{f(x_n)}{f'(x_n)} \quad (11)$$

$$x_{n+1} = y_n - \frac{2 \times f(y_n)f'(y_n)}{2 \times f'(y_n)^2 - f(y_n) \times f''(y_n)} \quad (12)$$

Algorithm 3: Accelerated Predictor- Corrector Hally Method (AHM)

$$y_n = x_n - \frac{f(x_n)}{f'(x_n)} \quad (13)$$

$$x_{n+1} = y_n - \frac{2 \times f(y_n)f'(y_n)}{2 \times f'(y_n)^2 - f(y_n) \times f''(y_n)}, n = 0, 1, 2, 3, \ldots \quad (14)$$

$$z_n = x_n - \frac{(x_{n+1} - x_n)^2}{x_{n+2} - 2 \times x_{n+1} + x_n}, \ n = 0, 1, 2, 3, \ldots \quad (15)$$

Tolerance $\varepsilon = 10^{-9}$ and $\sigma = |z_{n+1} - z_n| < \varepsilon$, $|f(z_n)| < \varepsilon$ (16)

6. Results and Discussion

Three techniques are given by Eqns. 10, 12 and 15 is implemented in order to solve the roots of Eq. 6 which is a non-linear equation with predict guess x_0. To demonstrate the performance of the three algorithms is used. The approximate solutions produced by the techniques regarded and list the errors acquired by the three techniques. Five different cases are used with the use of Eq. 6 which are based on the R_L values from (1-5) ohm (load resistance)

Tables 1-5 and Figures 2-6. The results indicate AHM need 6 iterations whereas NRM and HM need 9 and 8 iterations respectively for reaching the convergence, this prove that AHM is better than NRM and HM.

Table 1 - Performance indicators for the three different methods (NRM, HM and AHM) identified Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HM	I_{pv}-HM	P_{pv}- HM	V_{pv}-AHM	I_{pv}-AHM	P_{pv}- AHM
1	1	1	1	0.97141684	0.97141684	0.943650676	0.893473351	0.893473351	0.79829463
2	0.971416861	0.971416861	0.943650719	0.946732533	0.946732533	0.89630249	0.918974893	0.918974893	0.844514854
3	0.946732606	0.946732606	0.896302627	0.929865621	0.929865621	0.864650074	0.922319869	0.922319869	0.850673942
4	0.929865706	0.929865706	0.864650231	0.923247877	0.923247877	0.852386643	0.922422989	0.922422989	0.850864171
5	0.923247893	0.923247893	0.852386673	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439
6	0.922434	0.922434	0.850884484	0.922423136	0.922423136	0.850864443	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	0.922423135	0.922423135	0.850864439			
9	0.922423135	0.922423135	0.850864439						

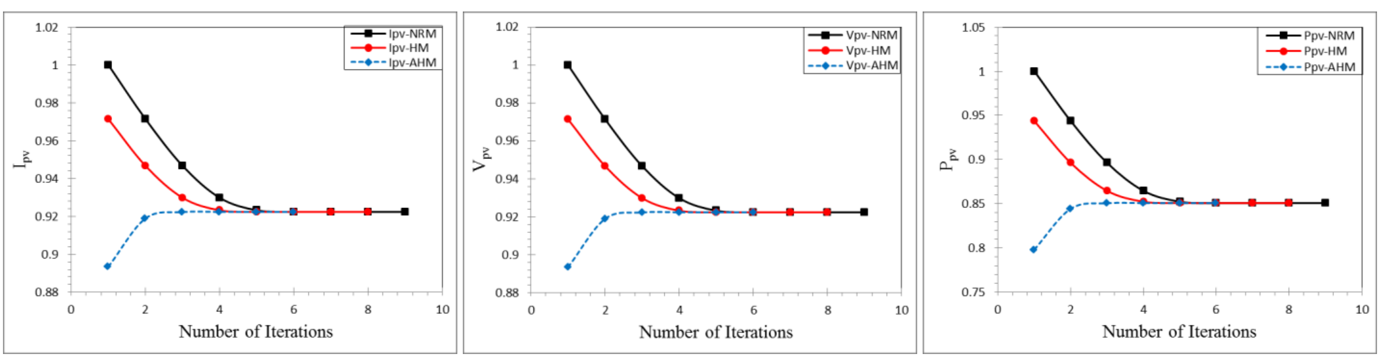

Fig. 2 – Predicted PV parameters from experimental data.

Table 2 - Performance indicators for the three different methods (NRM, HM and AHM) identified Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HM	I_{pv}-HM	P_{pv}- HM	V_{pv}-AHM	I_{pv}-AHM	P_{pv}- AHM
1	1	0.5	0.5	0.971030449	0.485515224	0.471450066	0.877625589	0.438812794	0.385113337
2	0.97103047	0.48551524	0.47145009	0.945421879	0.47271094	0.446911265	0.911522753	0.455761377	0.415436865
3	0.94542197	0.47271098	0.44691135	0.926834345	0.463417173	0.429510952	0.916798952	0.458399476	0.420260159
4	0.92683448	0.46341724	0.42951107	0.918438709	0.459219354	0.421764831	0.917034659	0.458517329	0.420476283
5	0.91843875	0.45921937	0.42176486	0.917066884	0.458533442	0.420505835	0.917035382	0.458517691	0.420476946
6	0.91706688	0.45853344	0.42050584	0.917035399	0.458517699	0.420476961	0.917035382	0.458517691	0.420476946
7	0.9170354	0.4585177	0.42047696	0.917035382	0.458517691	0.420476946			
8	0.91703538	0.45851769	0.42047695	0.917035382	0.458517691	0.420476946			
9	0.91703538	0.45851769	0.42047695						

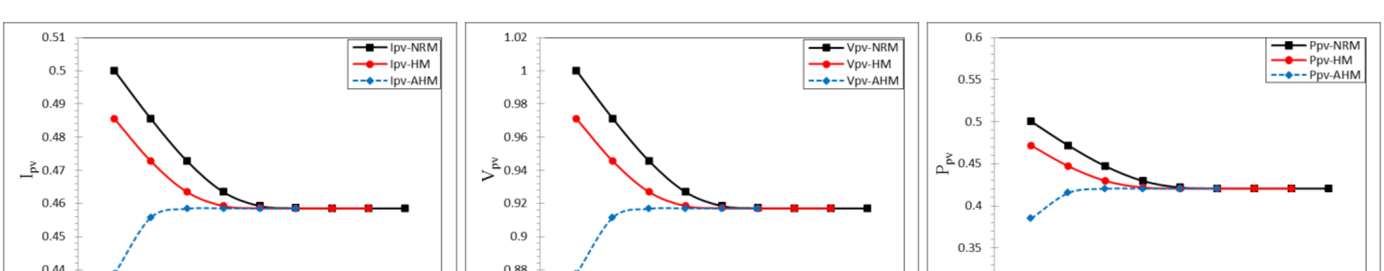

Fig. 3 - Predicted PV parameters from experimental data.

Table 3 - Performance indicators for the three different methods (NRM, HM and AHM) identified Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HM	I_{pv}-HM	P_{pv}- HM	V_{pv}-AHM	I_{pv}-AHM	P_{pv}- AHM
1	1	0.333333333	0.333333333	0.970643767	0.323547922	0.314049774	0.854421872	0.284807291	0.243345578
2	0.970643792	0.323547931	0.31404979	0.944084126	0.314694709	0.297098279	0.901128093	0.300376031	0.27067728
3	0.944084232	0.314694744	0.297098346	0.923594034	0.307864678	0.28434198	0.909824059	0.303274686	0.275926606
4	0.923594243	0.307864748	0.284342109	0.912877747	0.304292582	0.277781927	0.91039934	0.303466447	0.276275653
5	0.91287784	0.304292613	0.277781984	0.910501258	0.303500419	0.276337514	0.910403374	0.303467791	0.276278101
6	0.910501262	0.303500421	0.276337516	0.910403531	0.303467844	0.276278197	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	0.910403374	0.303467791	0.276278101			
9	0.910403374	0.303467791	0.276278101						

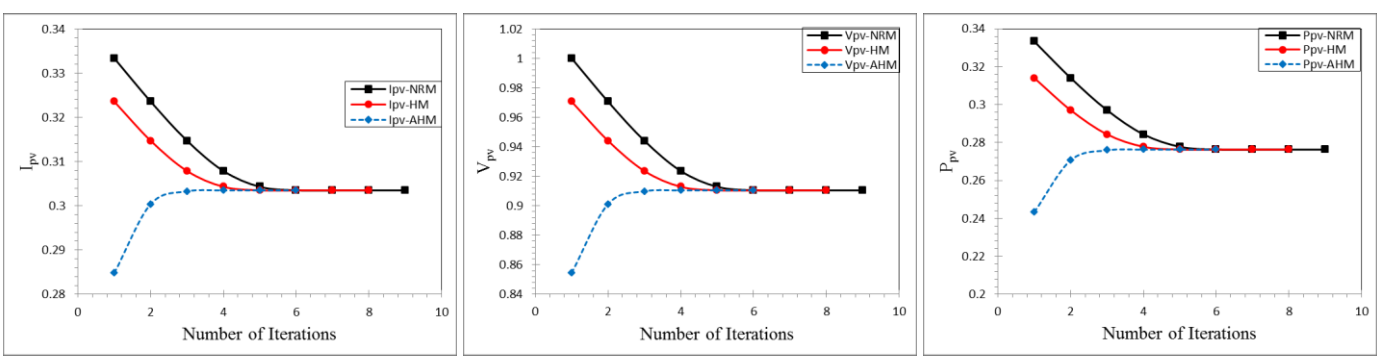

Fig. 4 - Predicted PV parameters from experimental data.

Table 4 - Performance indicators for the three different methods (NRM, HM and AHM) identified Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HM	I_{pv}-HM	P_{pv}- HM	V_{pv}-AHM	I_{pv}-AHM	P_{pv}- AHM
1	1	0.25	0.25	0.970256795	0.242564199	0.235349562	0.816814932	0.204203733	0.166796658
2	0.970256822	0.242564205	0.235349575	0.942718592	0.235679648	0.222179586	0.884826813	0.221206703	0.195729622
3	0.94271872	0.23567968	0.222179646	0.920122669	0.230030667	0.211656431	0.900161317	0.225040329	0.202572599
4	0.920123009	0.230030752	0.211656588	0.906346232	0.226586558	0.205365873	0.901713941	0.225428485	0.203272008
5	0.906346494	0.226586624	0.205365992	0.902077679	0.22551942	0.203436035	0.901740591	0.225435148	0.203284023
6	0.902077706	0.225519427	0.203436047	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028

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						

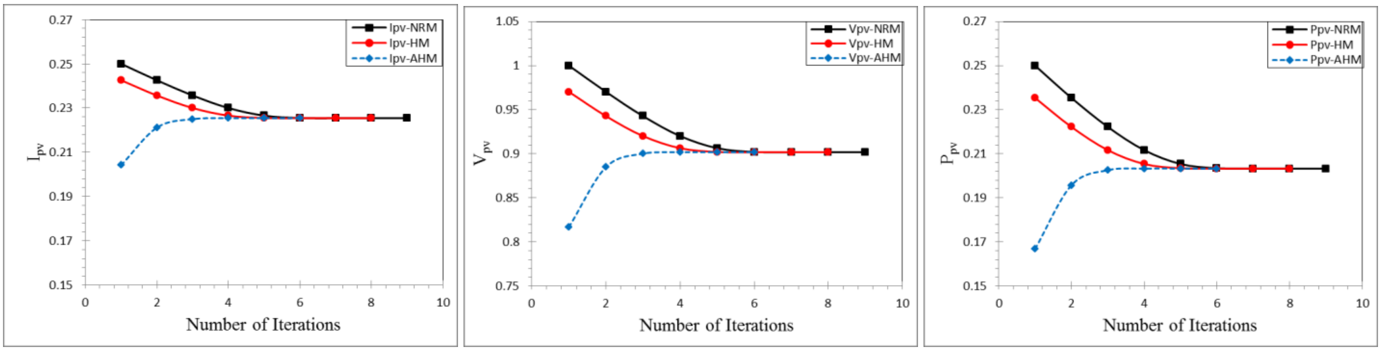

Fig. 5 - Predicted PV parameters from experimental data.

Table 5 - Performance indicators for the three different methods (NRM, HM and AHM) identified Eq. 6.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}-HM	I_{pv}-HM	P_{pv}- HM	V_{pv}-AHM	I_{pv}-AHM	P_{pv}- AHM
1	1	0.2	0.2	0.969869532	0.193973906	0.188129382	0.744511944	0.148902389	0.110859607
2	0.96986956	0.193973912	0.188129393	0.941324576	0.188264915	0.177218391	0.853407466	0.170681493	0.145660861
3	0.941324731	0.188264946	0.17721845	0.916395271	0.183279054	0.167956059	0.883852721	0.176770544	0.156239126
4	0.916395843	0.183279169	0.167956268	0.898534787	0.179706957	0.161472953	0.888853623	0.177770725	0.158012153
5	0.898535645	0.179707129	0.161473261	0.890476758	0.178095352	0.158589771	0.889091907	0.177818381	0.158096884
6	0.890477009	0.178095402	0.158589861	0.889125756	0.177825151	0.158108922	0.889092715	0.177818543	0.158097171
7	0.889125763	0.177825153	0.158108925	0.889092734	0.177818547	0.158097178	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	0.889092715	0.177818543	0.158097171			
10	0.889092715	0.177818543	0.158097171						

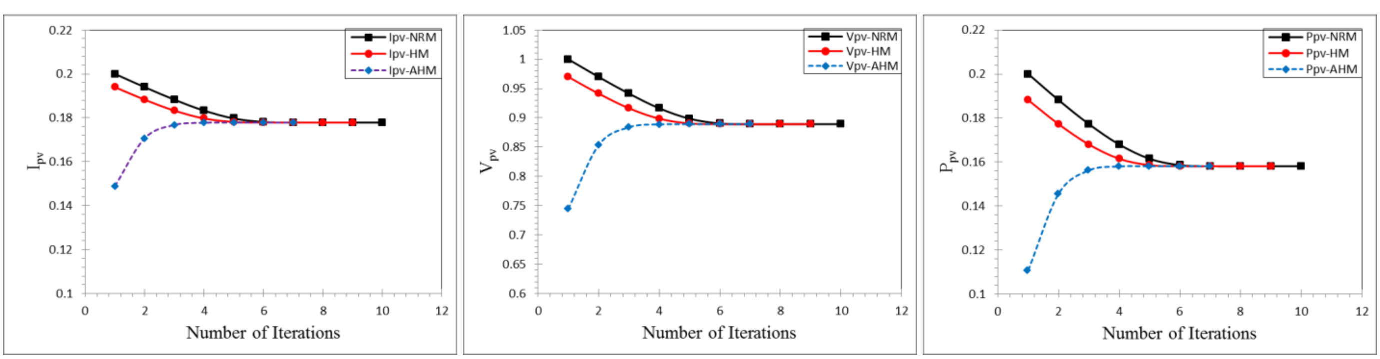

Fig. 6 - Predicted PV parameters from experimental data.

7. Conclusion

A new Accelerated Predictor- Corrector Hally method is introduced in order to obtain the numerical solutions of a single diode equivalent circuit design with a different values of load resistance R. Several algorithms (NRM, HM and AHM) were applied for illustration and good results were achieved for the calculations of the voltage of a solar cell. The following steps have been identified: First, the process of computation presented of a new proposed algorithm in the equation of a solar cell approach is simple; the approximate results are easy to obtain by a few computations; so the approach is considerably powerful. Second Good results obtained depend on the selection of the initial value x_0 for the three algorithms. Third Good results based on the algorithms used to find the involved model.

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