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An Accurate and Fast Computational Algorithm Based on Hybrid Methods

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ABSTRACT

The numerical solutions of nonlinear equation for a single diode equivalent circuit of a solar cell are introduced. Four numerically algorithms, which include newton's; Predictor-Corrector Hally and Accelerated Predictor-Corrector Hally methods are described and compared in the present work. These algorithms are applied to calculate the voltage; current; power of a solar cell with the different values of load resistance programmed by Matlab language. The results showed that the proposed algorithm is the most efficient compare with other three algorithms.

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1. Introduction

Numerical analysis involves the study and evaluation of methods of calculating required numerical results based on given numerical data, making numerical analysis an important part of the science known as information processing. The numerical data given is the input information, the required results are the output information, and the calculation method is known as the arithmetic system. Numerical treatments for solving nonlinear equations

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were introduced by several authors in many fields such as engineering and sciences. Iterative algorithms for treating the nonlinear equation of single diode solar cells had been considered. Here we shall consider the numerical solution of a single-diode photovoltaic cell [1-96].

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)

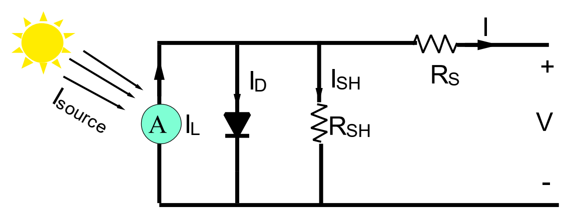

Fig. 1 – PV cell electrical equivalent circuit.

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

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

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

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

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 $i \le x_0$

Step 3- Calculate

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

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 Hally Method (HM)

Method 2: Predictor- Corrector Hally Method (HM)

$$y_n = x_n - \frac{f(x_n)}{\acute{f}(x_n)} \quad (8)$$

$$x_{n+1} = y_n - \frac{2\times f(y_n)\acute{f}(y_n)}{2\times \acute{f}(y_n)^2 - f(y_n)\times \acute{\acute{f}}(y_n)} \quad (9)$$

5. Accelerated Predictor-Corrector Hally 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)

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

Algorithm 2: Predictor- Corrector Hally Method (HM)

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

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

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

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

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

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

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

6. Results and Discussion

Four Algorithms are given based on Eqns. 7, 9, 12, and 15 is achieved in order to solve the roots of Eq. 6 which is a non-linear equation with predict guess v_0. To demonstrate the performance of the four methods is used. The approximate solutions produced by the techniques regarded and list the errors obtained by the four methods. Five various examples are utilized by means of equation 6 which are based on the R-values (load resistance) varies from 1 ohm to 5 ohm Figs 2-6 and Tables 1-5. The results indicate AHM need 6 iterations whereas NRM, ANRM and HM need 9, 8 and 8 iterations respectively for reaching the convergence, this prove that AHM is better than the other techniques.

Table 1 - Numerical order of iteration are reported in the case of R=1 using four various Techniques.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- ANRM	I_{pv}- ANRM	P_{pv}- ANRM	V_{pv}-HM	I_{pv}-HM	P_{pv}-HM
1	1	1	1	0.790453895	0.790453895	0.624817361	0.97141684	0.97141684	0.943650676
2	0.971416861	0.971416861	0.943650719	0.893473304	0.893473304	0.798294545	0.946732533	0.946732533	0.89630249
3	0.946732606	0.946732606	0.896302627	0.918974787	0.918974787	0.844514659	0.929865621	0.929865621	0.864650074
4	0.929865706	0.929865706	0.864650231	0.922319866	0.922319866	0.850673936	0.923247877	0.923247877	0.852386643
5	0.923247893	0.923247893	0.852386673	0.922422989	0.922422989	0.850864171	0.922434	0.922434	0.850884484
6	0.922434	0.922434	0.850884484	0.922423135	0.922423135	0.850864439	0.922423136	0.922423136	0.850864443
7	0.922423136	0.922423136	0.850864443	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439
8	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439	0.922423135	0.922423135	0.850864439
9	0.922423135	0.922423135	0.850864439						

V_{pv}-AHM	I_{pv}-AHM	P_{pv}-AHM
0.893473351	0.893473351	0.79829463
0.918974893	0.918974893	0.844514854
0.922319869	0.922319869	0.850673942
0.922422989	0.922422989	0.850864171
0.922423135	0.922423135	0.850864439
0.922423135	0.922423135	0.850864439

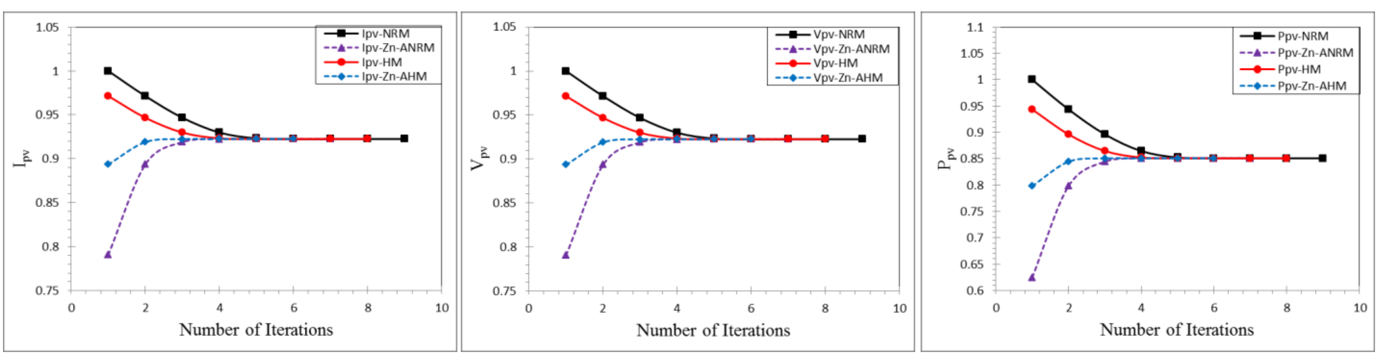

Fig. 2 – Number of iterations per PV parameters of transcendental function using four methods.

Table 2 - Numerical order of iteration are reported in the case of R=1 using four various Techniques.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- ANRM	I_{pv}- ANRM	P_{pv}- ANRM	V_{pv}-HM	I_{pv}-HM	P_{pv}-HM
1	1	0.5	0.5	0.750304127	0.375152064	0.281478142	0.971030449	0.485515224	0.471450066
2	0.97103047	0.48551524	0.47145009	0.877625808	0.438812904	0.385113529	0.945421879	0.47271094	0.446911265
3	0.94542197	0.47271098	0.44691135	0.911522541	0.455761271	0.415436672	0.926834345	0.463417173	0.429510952
4	0.92683448	0.46341724	0.42951107	0.916798941	0.45839947	0.420260149	0.918438709	0.459219354	0.421764831
5	0.91843875	0.45921937	0.42176486	0.917034659	0.458517329	0.420476283	0.917066884	0.458533442	0.420505835
6	0.91706688	0.45853344	0.42050584	0.917035382	0.458517691	0.420476946	0.917035399	0.458517699	0.420476961
7	0.9170354	0.4585177	0.42047696	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946
8	0.91703538	0.45851769	0.42047695	0.917035382	0.458517691	0.420476946	0.917035382	0.458517691	0.420476946
9	0.91703538	0.45851769	0.42047695						

V_{pv}-AHM	I_{pv}-AHM	P_{pv}-AHM
0.877625589	0.438812794	0.385113337
0.911522753	0.455761377	0.415436865
0.916798952	0.458399476	0.420260159
0.917034659	0.458517329	0.420476283
0.917035382	0.458517691	0.420476946
0.917035382	0.458517691	0.420476946

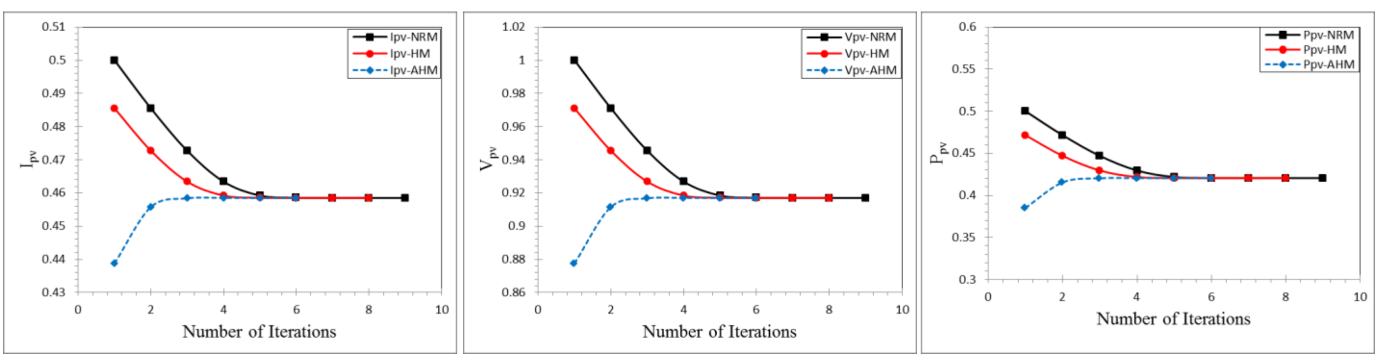

Fig. 3 - Number of iterations per PV parameters of transcendental function using four methods.

Table 3 - Numerical order of iteration are reported in the case of R=1 using four various Techniques.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- ANRM	I_{pv}- ANRM	P_{pv}- ANRM	V_{pv}-HM	I_{pv}-HM	P_{pv}-HM
1	1	0.333333333	0.333333333	0.691850003	0.230616668	0.159552142	0.970643767	0.323547922	0.314049774
2	0.970643792	0.323547931	0.31404979	0.854423029	0.284807676	0.243346237	0.944084126	0.314694709	0.297098279
3	0.944084232	0.314694744	0.297098346	0.90112767	0.30037589	0.270677026	0.923594034	0.307864678	0.28434198
4	0.923594243	0.307864748	0.284342109	0.909824015	0.303274672	0.27592658	0.912877747	0.304292582	0.277781927
5	0.91287784	0.304292613	0.277781984	0.91039934	0.303466447	0.276275653	0.910501258	0.303500419	0.276337514
6	0.910501262	0.303500421	0.276337516	0.910403374	0.303467791	0.276278101	0.910403531	0.303467844	0.276278197
7	0.910403531	0.303467844	0.276278197	0.910403374	0.303467791	0.276278101	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						

V_{pv}-AHM	I_{pv}-AHM	P_{pv}-AHM
0.854421872	0.284807291	0.243345578
0.901128093	0.300376031	0.27067728
0.909824059	0.303274686	0.275926606
0.91039934	0.303466447	0.276275653
0.910403374	0.303467791	0.276278101
0.910403374	0.303467791	0.276278101

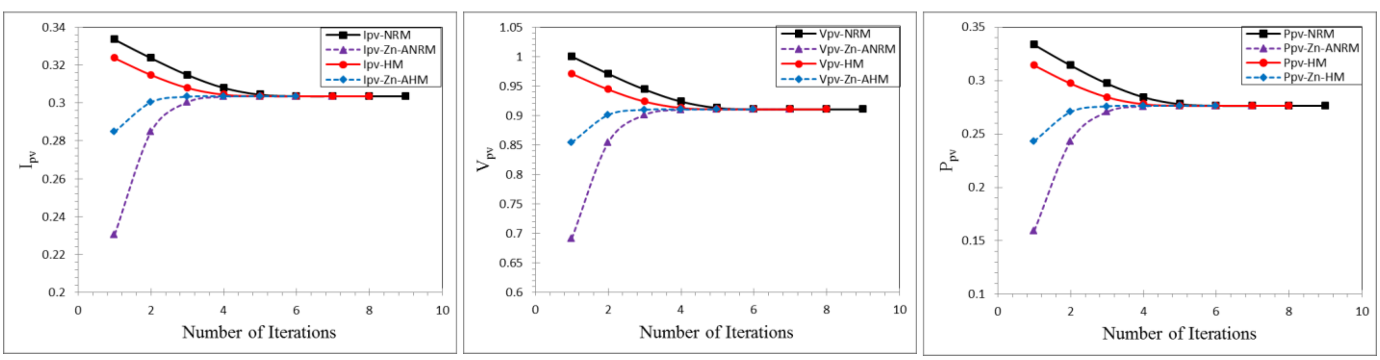

Fig. 4 - Number of iterations per PV parameters of transcendental function using four methods.

Table 4 - Numerical order of iteration are reported in the case of R=1 using four various Techniques.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- ANRM	I_{pv}- ANRM	P_{pv}- ANRM	V_{pv}-HM	I_{pv}-HM	P_{pv}-HM
1	1	0.25	0.25	0.598809171	0.149702293	0.089643106	0.970256795	0.242564199	0.235349562
2	0.970256822	0.242564205	0.235349575	0.816819533	0.204204883	0.166798538	0.942718592	0.235679648	0.222179586
3	0.94271872	0.23567968	0.222179646	0.884826124	0.221206531	0.195729317	0.920122669	0.230030667	0.211656431
4	0.920123009	0.230030752	0.211656588	0.900161102	0.225040276	0.202572502	0.906346232	0.226586558	0.205365873
5	0.906346494	0.226586624	0.205365992	0.901713938	0.225428485	0.203272007	0.902077679	0.22551942	0.203436035
6	0.902077706	0.225519427	0.203436047	0.901740591	0.225435148	0.203284023	0.901742503	0.225435626	0.203284885
7	0.901742503	0.225435626	0.203284885	0.901740602	0.22543515	0.203284028	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						

V_{pv}-AHM	I_{pv}-AHM	P_{pv}-AHM
0.816814932	0.204203733	0.166796658
0.884826813	0.221206703	0.195729622
0.900161317	0.225040329	0.202572599
0.901713941	0.225428485	0.203272008
0.901740591	0.225435148	0.203284023
0.901740602	0.22543515	0.203284028

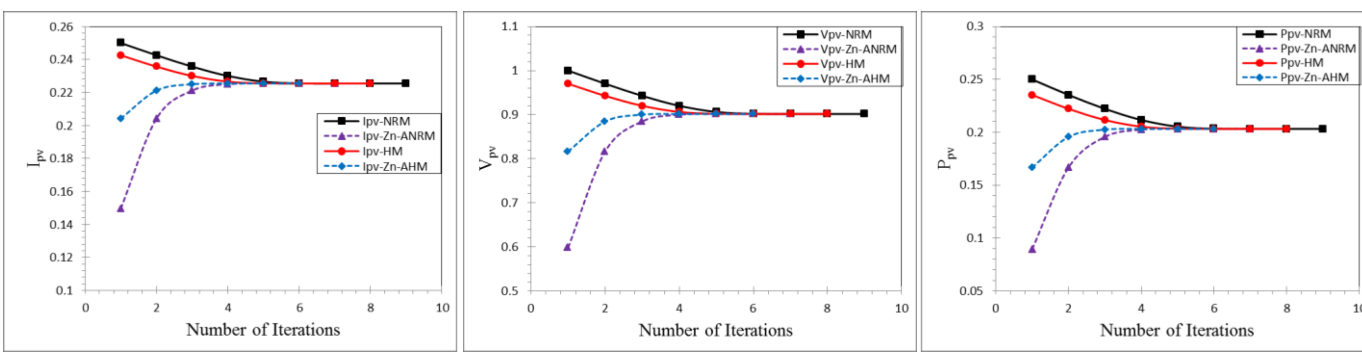

Fig. 5 - Number of iterations per PV parameters of transcendental function using four methods.

Table 5 - Numerical order of iteration are reported in the case of R=1 using four various Techniques.

Iterations	V_{pv}-NRM	I_{pv}- NRM	P_{pv}-NRM	V_{pv}- ANRM	I_{pv}- ANRM	P_{pv}- ANRM	V_{pv}-HM	I_{pv}-HM	P_{pv}-HM
1	1	0.2	0.2	0.427448911	0.085489782	0.036542514	0.969869532	0.193973906	0.188129382
2	0.96986956	0.193973912	0.188129393	0.74453199	0.148906398	0.110865577	0.941324576	0.188264915	0.177218391
3	0.941324731	0.188264946	0.17721845	0.853408948	0.17068179	0.145661366	0.916395271	0.183279054	0.167956059
4	0.916395843	0.183279169	0.167956268	0.88385137	0.176770274	0.156238649	0.898534787	0.179706957	0.161472953
5	0.898535645	0.179707129	0.161473261	0.888853546	0.177770709	0.158012125	0.890476758	0.178095352	0.158589771
6	0.890477009	0.178095402	0.158589861	0.889091906	0.177818381	0.158096884	0.889125756	0.177825151	0.158108922
7	0.889125763	0.177825153	0.158108925	0.889092715	0.177818543	0.158097171	0.889092734	0.177818547	0.158097178
8	0.889092734	0.177818547	0.158097178	0.889092715	0.177818543	0.158097171	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						

V_{pv}-AHM	I_{pv}-AHM	P_{pv}-AHM
0.744511944	0.148902389	0.110859607
0.853407466	0.170681493	0.145660861
0.883852721	0.176770544	0.156239126
0.888853623	0.177770725	0.158012153
0.889091907	0.177818381	0.158096884
0.889092715	0.177818543	0.158097171
0.889092715	0.177818543	0.158097171

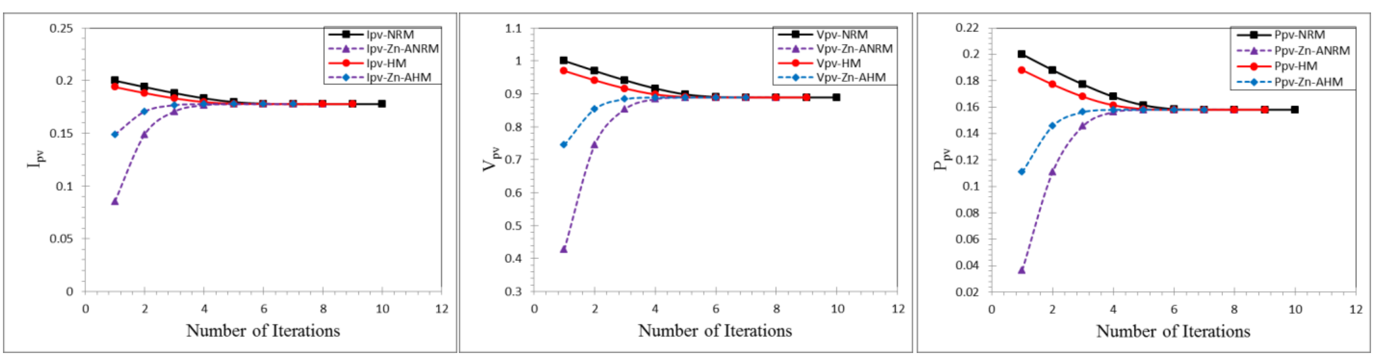

Fig. 6 - Number of iterations per PV parameters of transcendental function using four methods.

7. Conclusion

A new Accelerated Predictor- Corrector Hally, Predictor- Corrector Hally, Accelerated Newton's, Newton's algorithms is described and investigated in order to calculate the voltage; current and power of a single-diode equivalent circuit design numerically with a several values of load resistance R. These Several algorithms were applied for illustration and good results were acquired for the determinations of the three electrical parameters 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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