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Two mathematical models for solving the photovoltaic cell's nonlinear formula

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Abstract

The energy created from resources that can be replenished naturally throughout time is referred to as renewable energy. Sunlight is a great source of energy that can be used for a variety of purposes, such as power generation and the conversion of solar energy into electricity. As a clean, long-lasting, and noiseless source of electricity, photovoltaic (PV) technology is attracting a lot of attention. On the other hand, solar cells have precise controllable parameters and a high level of nonlinearity. A simple example that continues to pique the curiosity of many scholars is root discovery. in order to address the intractability of the conventional photovoltaic (PV) cells model and the nonlinear transcendental equation. The purpose of this work is to describe and analyze two distinct iterative procedures for resolving solar cells' nonlinear problems in the absence of temperature. In an iterative evaluation process, the program MATLAB is used in this paper of acquiring approximations for the solutions to nonlinear equations, some hybrid experiments are constructed. Many examples numerically are tested of the new iterative method. This new method may be regarded as an alternative and promising method for solving nonlinear equations. Additionally, an analysis of accuracy and efficiency (as measured by function evaluations) demonstrates that the proposed technique Dekker's Formula (DM) is superior and has the lowest evaluation when compared to Predictor-Corrector Type (A2).

Keywords: Thermal voltage; Predictor-Corrector technique (A2); Dekker's technique; approximation; comparison;

1. Introduction

Recently, many iterative methods have been employed to solve nonlinear equations and they are many researchers utilized and improved Newton's method is widely used in the field of chemistry as a standard method for solving nonlinear equations, engineering, and physics. Rasheed et al. suggested many experiments and Iterative methods are used to solve a solar cell's nonlinear equation depending on Kirchhoff's current law for equivalent circuit of PV cell. Several iterative methods on the function's first order derivative have been proposed and described [1-10].

The paper presents two numerical iterative techniques, Predictor-Corrector (A1) and Dekker's techniques depend on load resistance (R) ranges between 1 and 5. The suggested technique requires five function evaluations per iteration, whereas the other technique (A2) requires seven function evaluations per iteration. The following steps illustrate the current work's procedure: Sections two, three, and four examine the mathematical procedure and zeros cause analysis for the (A1) and DM strategies, whereas sections five and six contain the mathematical experiments, the discussion and the conclusion.

2. Photovoltaic module

Kirchhoff's process is applicable to the photovoltaic cell-single-diode electrical arrangement [20-30].

$$I = I_{ph} - I_D$$

where:

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

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

and $V_T = \frac{KT}{q} = 27.5\,mV$, k = 1.38×10^{-23} J/K= the Boltzmann constant is a constant that exists in all physical systems, I_0 = diode's reverse saturation current= 10^{-12}A,

I_{ph} = generated current, $m = 1$ to 2 imply the factor involved in recombination., $T = p - n$ the junction's temperature, $q = 1.6 \times 10^{-19}$ C= charge of an electron.

$$I_{ph} = I_{source} ,$$

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

3. Predictor-Corrector technique (A2) [10-15]

Step 1: Suppose A_0 is the approximate value.
Step 2: A_0, determine A_{n+1} (approximate solution) by employing an iterative procedure.

$$A_{n+1} = A_n - \frac{f(A_n)}{f'(A_n)} \quad (4)$$

$$A_{n+1} = A_n - \frac{6\times f(A_n)}{f'(A_n)+4\times f'\left(\frac{A_n+A^*_{n+1}}{2}\right)+f'(A^*_{n+1})} \text{ ,n=0,1,2,3,...} \quad (5)$$

Step 3: If $|A_{n+1} - A_n| < \varepsilon,\ |f(A_n)| < \varepsilon,\ \varepsilon = 10^{-9}$ (tolerance); otherwise, proceed to Step 1.

4. Dekker's technique (DM) [20-30]

DM technique is obtained by combining Dekker's 1969, secant and bisection formulas.
Step 1: The first is referred to as the linear interpolation secant method and is denoted by

$$y_{n+1} = \begin{cases} y_n - \frac{y_n - y_{n-1}}{f(y_n)-f(y_{n-1})} f(y_n) & if\ f(y_n) \neq f(y_{n-1}) \\ m & otherwise \end{cases} \quad (6)$$

Step 2: The bisection method can be used to get the second.

$$I_{pv} = \frac{V_{pv}}{R}; P_{pv} = I_{pv} \times V_{pv} \quad (2)$$

where: I_{pv}, V_{pv}, P_{pv} = the cell's current, voltage, and power, respectively.
Put the appropriate value for I, and obtain:

$$(I_{source}) - 10^{-12}\left(e^{-V/1.2*0.026} - 1\right) = V / R \quad (3)$$

$$m = \frac{a_n + b_n}{2} \quad (7)$$

Step 3: If $|f(a_n)| \geq |f(b_n)|$ $|f(x_n)| < \varepsilon$, $\varepsilon = 10^{-9}$ (8)
where: a_n is the current iterate this implies $f(a_n)$ and $f(b_n)$, the signs of function $f(a_n)$ is in opposition to one another., thus the solution is contained within the interval $[a_n, b_n]$.

5. Results and discussion for numerical examples

Now, we employ Predictor-Corrector Type (A2) technique, nonlinear equation solver (Eq. 5) is used in this work with a guess value $\mathbf{v_0 = 1}$, comparison with DM approach (Eq. 6). All calculations are performed to the precision specified in the number of function evaluations and the number of calculations in the Tables and Figures 1 to 5. In the case of the numerical experiments the value of **R** used are 1 to 5 Ω, which is the circuit's load resistance. Five distinct experiments are carried out in connection with the numerical examples and approximate solutions obtained by these two ways for solving Eq. 3.
According to the Tables and Figures, the DM technique requires five iterations while the A2 technique requires seven, a demonstration of how DM is significantly faster than A2.

Table1: Predicted solutions in to solve Eq. 3 with the absolute error values ε.

Iterations	**V_{pv}-A2**	**I_{pv}- A2**	**P_{pv}- A2**		
1	0.909061968	0.909061968	0.826393662		
2	0.912675411	0.912675411	0.832976406		
3	0.920491417	0.920491417	0.847304449		
4	0.922359246	0.922359246	0.850746579		
5	0.922423038	0.922423038	0.850864262		
6	0.922423135	0.922423135	0.850864439		
7	0.922423135	0.922423135	0.850864439		
Iterations	**V_{pv}-DM**	**I_{pv}-DM**	**P_{pv}- DM**	**ε- A2**	**ε- DM**
1	0.909061968	0.924812944	0.85527898	0.013361166	0.002389809
2	0.922746426	0.922746426	0.851460967	0.009747723	0.000323292
3	0.922425145	0.922425145	0.850868148	0.001931717	2.01066E-06
4	0.922423135	0.922423135	0.850864439	6.38884E-05	9.90161E-11
5	0.922423135	0.922423135	0.850864439	9.61287E-08	0
6				2.23932E-13	
7				0	

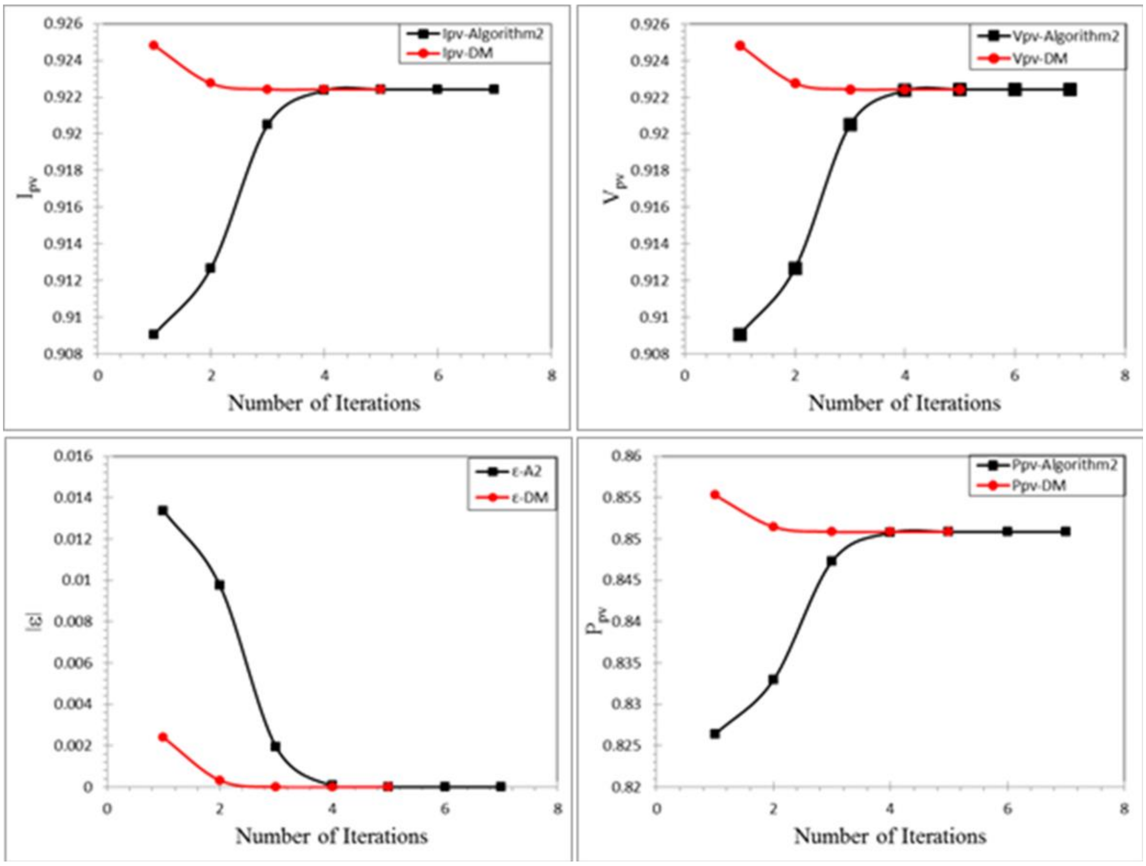

Figure 1. Comparison results of Eq. 3 based on Eqns. 3, 5 and 6.

Table 2: Predicted results in to solve Eq. 3 with the absolute error values ε.

Iterations	V_{pv}-A2	I_{pv}- A2	P_{pv}- A2		
1	0.904579258	0.452289629	0.409131817		
2	0.905657295	0.452828647	0.410107568		
3	0.914052791	0.457026396	0.417746253		
4	0.916889024	0.458444512	0.420342741		
5	0.917034902	0.458517451	0.420476505		
6	0.917035382	0.458517691	0.420476946		
7	0.917035382	0.458517691	0.420476946		
Iterations	**V_{pv}-DM**	**I_{pv}-DM**	**P_{pv}- DM**	**ε- A2**	**ε- DM**
1	0.919679286	0.459839643	0.422904994	0.012456124	0.002643903
2	0.917632869	0.458816434	0.421025041	0.011378087	0.000597487
3	0.917042599	0.458521299	0.420483564	0.002982591	7.21624E-06
4	0.917035384	0.458517692	0.420476947	0.000146358	1.14432E-09
5	0.917035382	0.458517691	0.420476946	4.80851E-07	0
6	0.917035382	0.458517691	0.420476946	5.61473E-12	0
7				0	

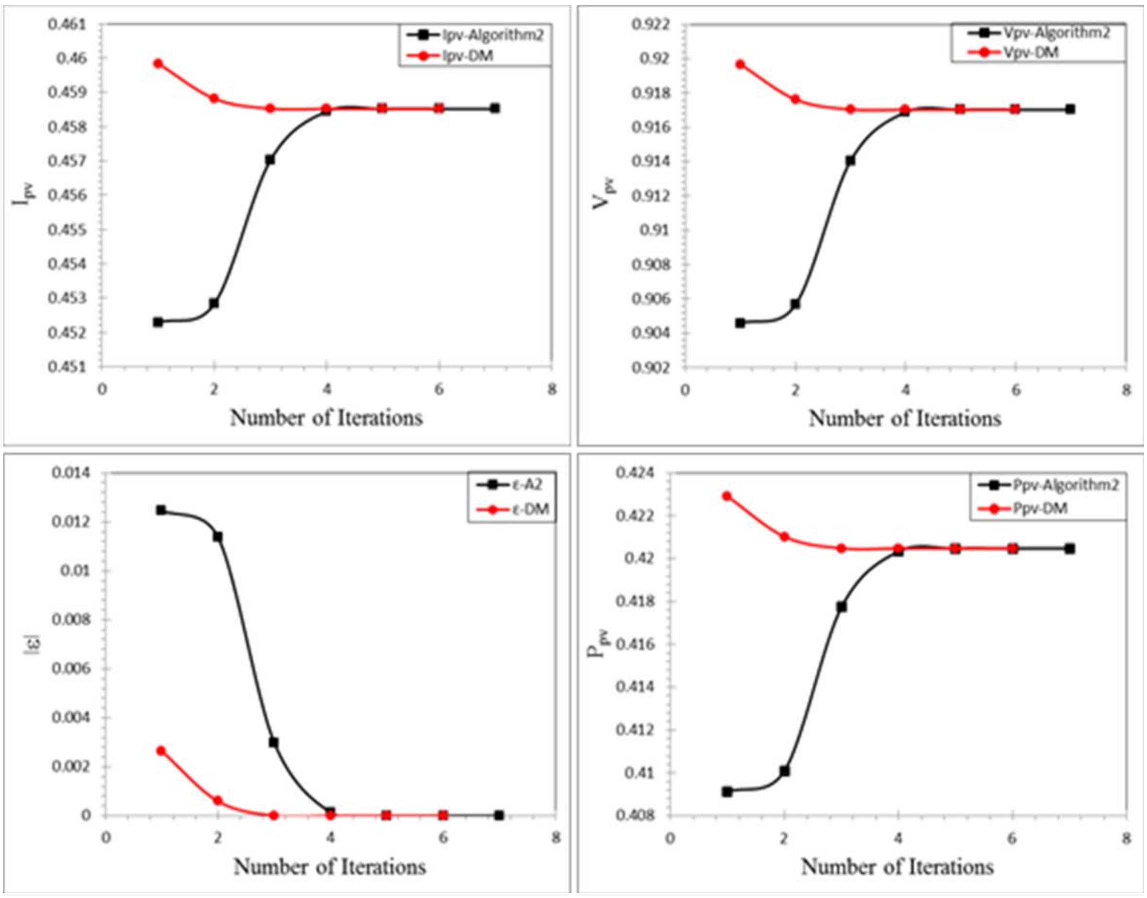

Figure 2. Comparison results of Eq. 3 based on Eqns. 3, 5 and 6.

Table 3: Predicted results in to solve Eq. 3 with the absolute error values ε.

Iterations	V_{pv}**-A2**	I_{pv}**- A2**	P_{pv}**- A2**		
1	0.899816691	0.299938897	0.269890026		
2	0.897407275	0.299135758	0.268446606		
3	0.905697121	0.30189904	0.273429092		
4	0.910042334	0.303347445	0.276059017		
5	0.910400684	0.303466895	0.276276468		
6	0.910403374	0.303467791	0.276278101		
7	0.910403374	0.303467791	0.276278101		
Iterations	V_{pv}**-DM**	I_{pv}**-DM**	P_{pv}**- DM**	ε**- A2**	ε**- DM**
1	0.91301331	0.30433777	0.277864435	0.010586683	0.002609936
2	0.911519924	0.303839975	0.27695619	0.012996099	0.00111655
3	0.910432146	0.303477382	0.276295564	0.004706253	2.87722E-05
4	0.91040339	0.303467797	0.276278111	0.00036104	1.60093E-08
5	0.910403374	0.303467791	0.276278101	2.69045E-06	7.88258E-15
6	0.910403374	0.303467791	0.276278101	1.75739E-10	0
7				0	

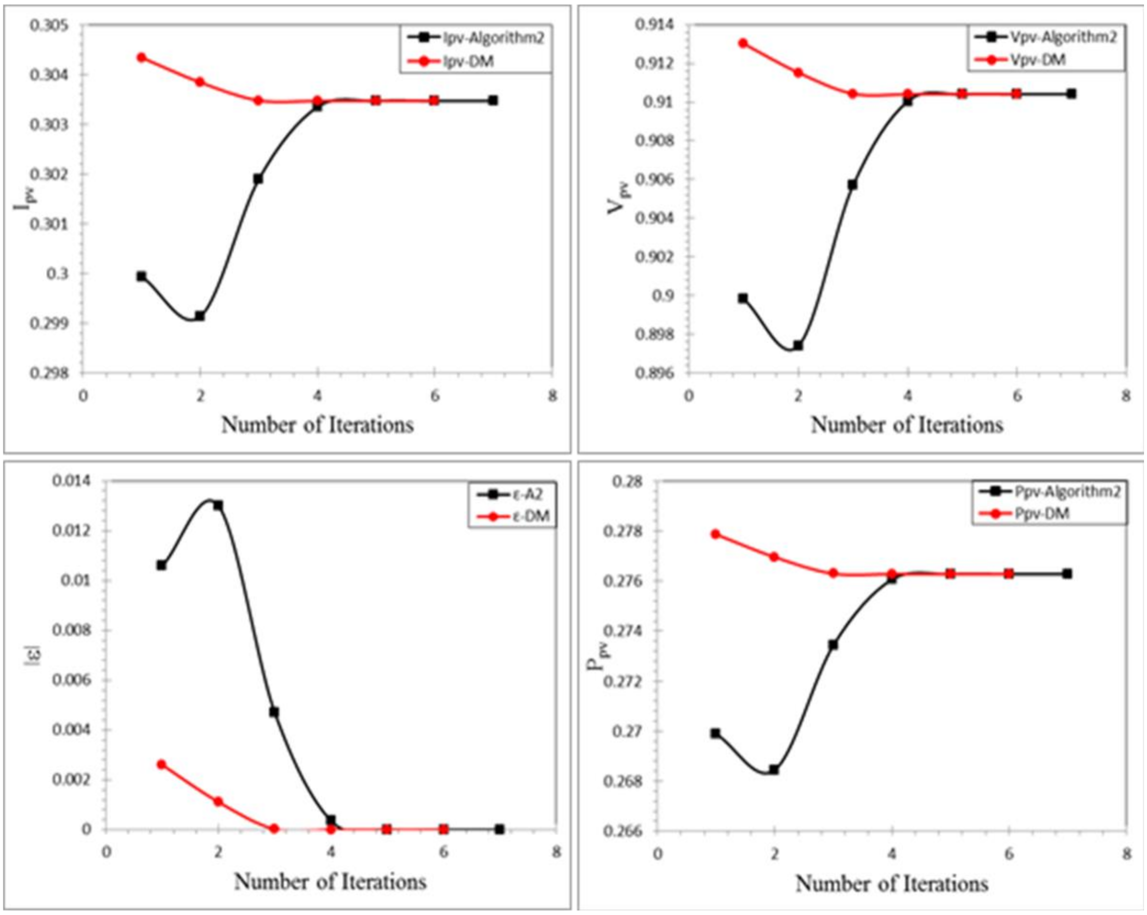

Figure 3. Comparison results of Eq. 3 based on Eqns. 3, 5 and 6.

Table 4: Predicted results in to solve Eq. 3 with the absolute error values ε.

Iterations	V_{pv}-A2	I_{pv}- A2	P_{pv}- A2		
1	0.894754474	0.223688618	0.200146392		
2	0.88761038	0.221902595	0.196963047		
3	0.894168824	0.223542206	0.199884471		
4	0.900742902	0.225185726	0.202834444		
5	0.901722644	0.225430661	0.203275931		
6	0.901740594	0.225435149	0.203284025		
7	0.901740602	0.22543515	0.203284028		
8	0.901740602	0.22543515	0.203284028		
Iterations	V_{pv}-DM	I_{pv}-DM	P_{pv}- DM	ε- A2	ε- DM
1	0.903639094	0.225909773	0.204140903	0.006986128	0.001898492
2	0.903806911	0.225951728	0.204216733	0.014130222	0.002066309
3	0.90187436	0.22546859	0.20334434	0.007571778	0.000133758
4	0.901740905	0.225435226	0.203284165	0.0009977	3.02831E-07
5	0.901740602	0.22543515	0.203284028	1.79584E-05	2.32292E-12
6	0.901740602	0.22543515	0.203284028	7.70016E-09	0
7				0	

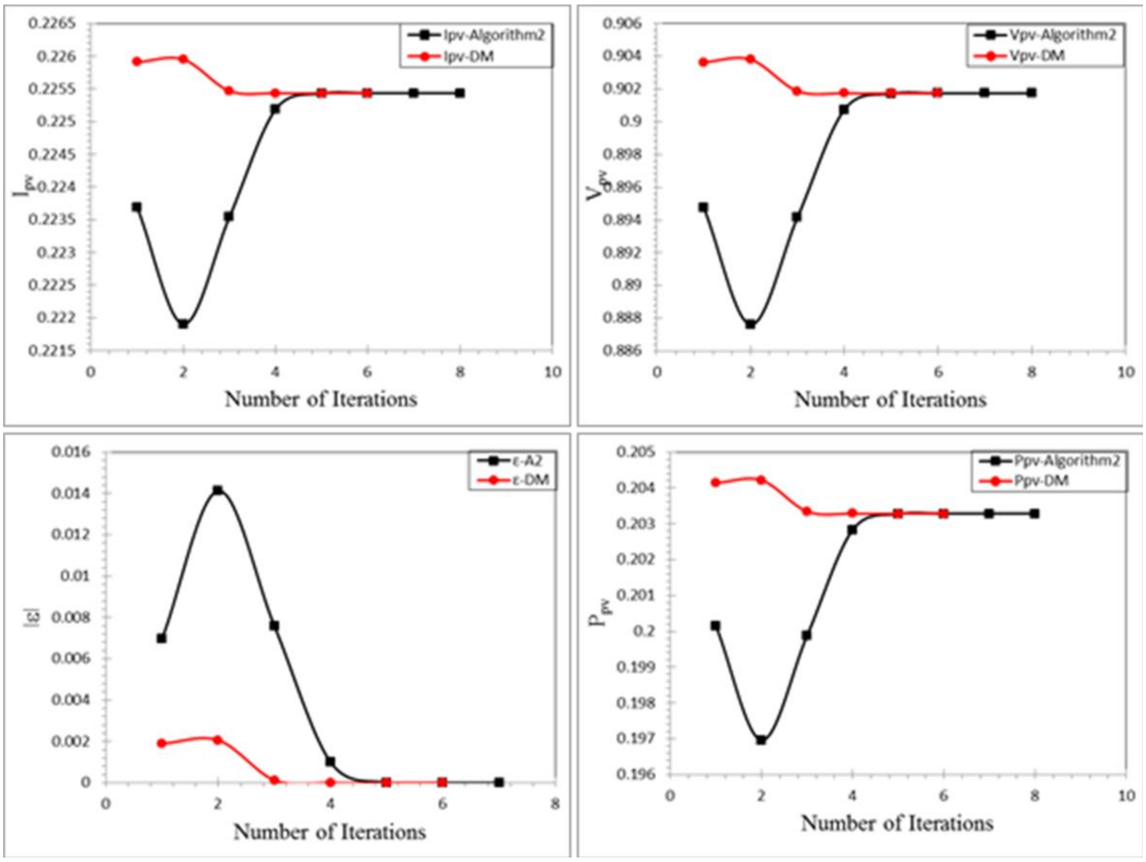

Figure 4. Comparison results of Eq. 3 based on Eqns. 3, 5 and 6.

Table 5: Predicted results in to solve Eq. 3 with the absolute error values ε.

Iterations	V_{pv}**-A2**	I_{pv}**- A2**	P_{pv}**- A2**		
1	0.889371467	0.177874293	0.158196321		
2	0.875855338	0.175171068	0.153424515		
3	0.876941816	0.175388363	0.15380539		
4	0.885772918	0.177154584	0.156918733		
5	0.888923198	0.17778464	0.158036891		
6	0.889092102	0.17781842	0.158096953		
7	0.889092715	0.177818543	0.158097171		
8	0.889092715	0.177818543	0.158097171		
Iterations	V_{pv}**-DM**	I_{pv}**-DM**	P_{pv}**- DM**	ε**- A2**	ε**- DM**
1	0.889021793	0.177804359	0.15807195	0.000278752	7.09216E-05
2	0.892522023	0.178504405	0.159319112	0.013237377	0.003429308
3	0.889885306	0.177977061	0.158379171	0.012150899	0.000792591
4	0.889102851	0.17782057	0.158100776	0.003319796	1.01362E-05
5	0.889092717	0.177818543	0.158097172	0.000169516	1.82848E-09
6	0.889092715	0.177818543	0.158097171	6.12875E-07	1.11022E-16
7	0.889092715	0.177818543	0.158097171	8.69149E-12	0
8				0	

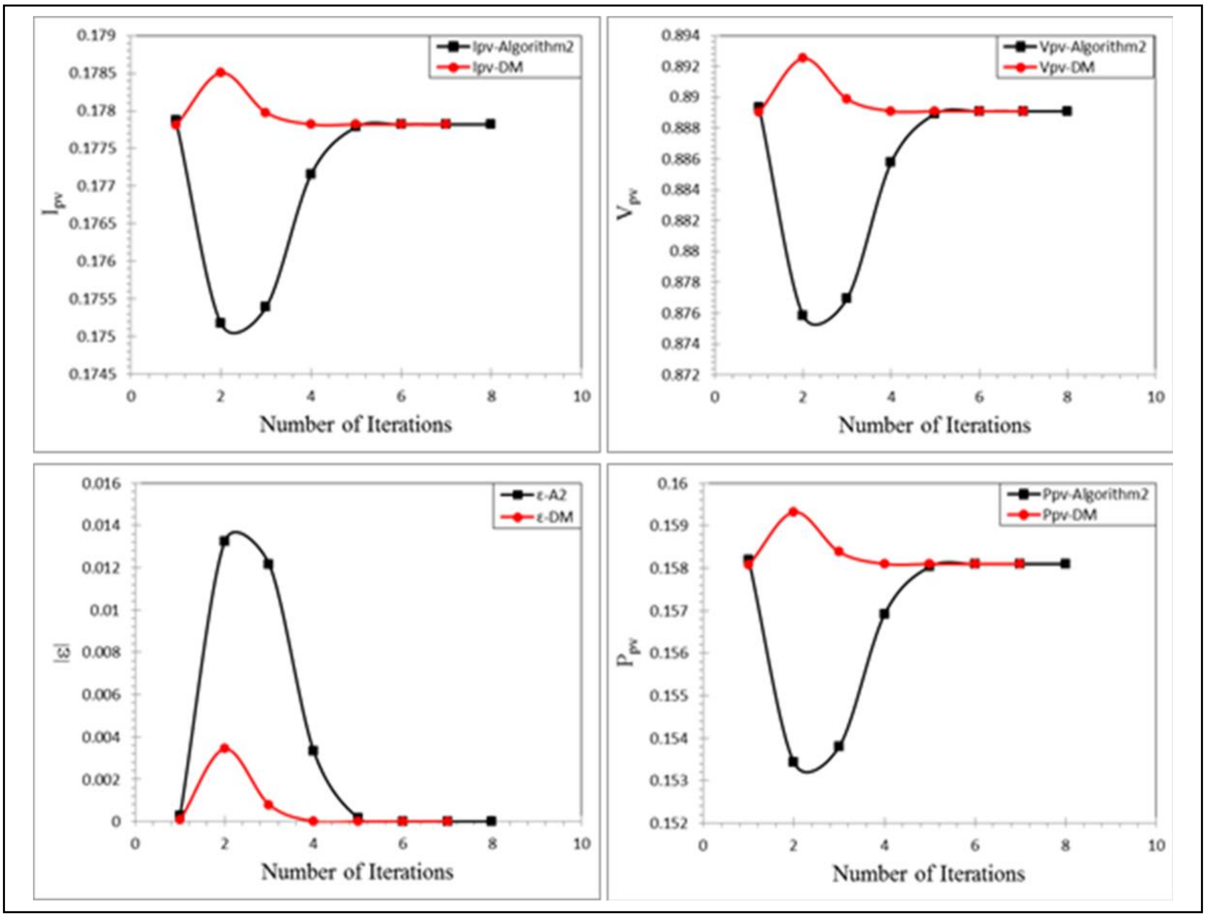

Figure 5. Comparison results of Eq. 3 based on Eqns. 3, 5 and 6.

The analytical results demonstrate that the A2 approach can compete with the DM approach. When the suggested technique (DM) requires fewer function evaluations than A2, the computing time has been lowered, and the (DM) technique has been made more efficient.

6. Conclusion

Two numerical algorithms for solving non-linear functions in science applications such as solar cell devices have been proposed in this work. These methods are not dependent on the function's second derivative. Numerous numerical experiments are conducted using these methods, and the resulting results are compared to demonstrate that the newly proposed algorithm is superior.

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