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Linear Programming Method Application in a Solar Cell

Rasha Jalal Mitlif[a], Mohammed RASHEED[b, *], Suha SHIHAB[c], Taha RASHID[d], Saad Abed Hamad[e]

[a] *Applied Science Department, University of Technology, Baghdad, Iraq, e-mail: rasha.jalal83@yahoo.com, 10096@uotechnology.edu.iq.*

[b] *Applied Science Department, University of Technology, Baghdad, Iraq, e-mail: rasheed.mohammed40@yahoo.com, 10606@uotechnology.edu.iq.*

[c] *Applied Science Department, University of Technology, Baghdad, Iraq, e-mail:alrawy1978@yahoo.com, 100031@uotechnology.edu.iq.*

[d] *Computerand Microelectronics System, Faculty of Engineering, University of Malaysia,Skudai 81310, Johor Bahru, Malaysia, e-mail: tsiham95@gmail.com, taha1988@graduate.utm.my.*

[e] *Saad Husein Abed Hamad- College of Computer Science & Information Technology, Al-Qadisiya University, Al-Diwaniyah, Iraq, e-mail: saad.hussain@qu.edu.iq, shsaadsh2014@gmail.com*

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ABSTRACT

A new ranking function of linear programming problems to find the optimal solution of the solar cell by simplex method has been introduced in this paper. Numerical examples are given to illustrate the proposed method. The results obtained indicated that this technique is active for the PV determinations.

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*Corresponding author: Mohammed RASHEED,

Email addresses: rasheed.mohammed40@yahoo.com, 10606@uotechnology.edu.iq.

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1. Introduction

Correct a decision in a scientific way has been used recently by a linear programming, which is a substantial, and important technique that helps decision makers makes. A part of mathematical programming issues was the linear programming, which contains a non-linear and linear; in addition, mathematical programming is also a friction of an overall topic, defined operational research, or operations research, every which relate to matters of organization and management, transportation, agriculture, industry, etc. Linear mathematical programming is a matter of preference, and here preference matters are those mathematical matters that seek to maximize or reduce linear (dependent) function placed into linear mathematical constraints as well. In operations research, linear programming (LP) plays vital role in decision making of, it is a method utilized to recognize the solution corresponding to the limitations availability of resources. The linear programming (LP) has basically 3 components in a model: firstly, the objective (maximization or minimization) function; secondly, the resource constraints of inequalities; and thirdly, the no negativity of the variables (known as the automatic constraint) to be consistent with the real life applications. Last sixty years, linear programming has one of the most dynamic areas in applied mathematics. Dantzig's simplex method used linear programming [1-5]. The optimal values of different types of solar cells parameters have various structures can be measured by means of linear programming method [6-22]. For more applications [23-68].

For the summarizing of this paper: in section two: some basic definitions of linear programming model, in section three: algorithm of a linear programming method for solving problems using simplex method, in section 4: contains numerical examples with the results, finally, in section 5: contains the conclusion of the results.

2. The Proposed Model – Linear Programming [5]

For decision variables n and m constraints variables, the general linear programming model has been used which is optimizing (maximizing or minimizing) the objective function in the following form

$(\text{Max or Min})\ Z = k_1 x_1 + k_2 x_2 + \cdots + k_n x_n$

Subject to

$a_{11} x_1 + a_{12} x_2 + \cdots + a_{1n} x_n \ (\geq , = , \leq) \ b_1$

$a_{21} x_1 + a_{22} x_2 + \cdots + a_{2n} x_n \ (\geq , = , \leq) \ b_2$

. . .

. . .

. . .

$a_{m1} x_1 + a_{m2} x_2 + \cdots + a_{mn} x_n \ (\geq , = , \leq) \ b_m$

The above model can also be expressed as follows.

$(\text{Max or Min}) Z = \sum_{j=1}^{n} k_j x_i$ ... (Objective function)

Subject to

$\sum_{j=1}^{n} a_{ij} x_j \ (\leq , = , \geq) \ b_i \ , i = 1 , 2, \dots , m$

and $x_j \geq 0 , j = 1,2, \dots , m.$

where: the coefficients $k_1, k_2, \dots, k_n$: called the per unit profit of decision variables $x_1, x_2, \dots, x_n$ for the data of the suggest function; $a_{11}, a_{12}, \dots, a_{mn}$: called the quantity of resource utilized per unit of the decision variables; b_i: a constant called the total availability of the i^{th} resource; Z: called the measure of performance (profit, cost or reverence) … etc.

3. Linear Programming Problem – Simplex Method [3-4]

A method for solving linear programming problem has been achieved by using simplex technique in this section, as follows

1. Devise the linear programming problem

A mathematical model is formed the problem. The forms of the simplex method consist of the following properties:

Determine the suggest function for LPB given is to be maximized or minimized.

The variables should be non-negative, and the constraints could be formed into equations.

2. Put the initial simplex table with slack variables in the solution. The constraint of type <or> converted into an equation. Adding a slack variable or subtracting a surplus variable on the left hand side of the constraint.
3. Select the decision variables, (the solution).
4. Select the replace variables.
5. Compute new row data for the entering variables.
6. Correct remaining rows.
7. Duplicate (3) until gives the results of the LPB

4. Numerical Examples

Table 1 illustrate the values of the photovoltaic's cell parameters have been demonstrated practically by O. A. Sultan et al. by applying a linear programming problem for these results we obtained as follows [23-61].

Table 1 - The effect of temperature on the parameters of solar cell.

T (^{o}C)	J_{sc} (mA/cm^2)	V_{oc} (V)	R_m (Ω)	J_m (mA/cm^2)	V_m (V)	FF	η_m (%)	τ (μs)	R_s (kΩ)	R_{sh} (kΩ)
5	3.52	2.1	5	3.38	1.2	0.55	5.9	-	0.26	4.5
14	4.86	2.2	5	3.52	1.35	0.44	6.9	15.6	0.18	10
30	4..6	1.97	5	4	1.1	0.48	6.4	18.5	0.11	3.9
50	4.8	1.8	5	3.4	1.2	0.47	5.9	23.1	0.12	1.8
60	4.4	1.75	5	3.75	0.82	0.39	4.45	26	1	1.2
70	4.5	1.76	5	3.9	0.85	0.41	4.8	29.5	1	1.25

Example 1

Using WIN QSB program; simplex method is applied as the initial simplex tableau Table 2.

Table 2 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	3.6			
C1	0.55		<=	0.9
C2		4.0656	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 3.

Table 3 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.6000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.5500	0	1.0000	0	0.9000	1.6364
Slack_C2	0	0	4.0656	0	1.0000	100.0000	M
	C(j)-Z(j)	3.6000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 4.

Table 4 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.6000	0	0	0	R. H. S.	Ratio
X1	3.6000	1.0000	0	1.8182	0	1.6364	
Slack_C2	0	0	4.0656	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-6.5455	0	5.8909	

$\text{MAX } Z = 3.6\, X_1$

Subject to

$0.55\, X_1 \leq 0.9$

$4.0656\, X_2 \leq 100$

$X_1, X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving linear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1 = 1.6364$, $X_2 = 0$, MAX Z = 5.8909

Error = (exact − applied/exact) × 100%

E = 0.00154237

Example 2

Using WIN QSB program; simplex method is applied as the initial simplex tableau is illustrated in Table 5.

Table 5 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	3.3			
C1	0.44		<=	0.9
C2		4.70448	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 6.

Table 6 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.3000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.4400	0	1.0000	0	0.9000	2.0455
Slack_C2	0	0	4.7045	0	1.0000	100.0000	M
	C(j)-Z(j)	3.3000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 7.

Table 7 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.3000	0	0	0	R. H. S.	Ratio
X1	3.3000	1.0000	0	2.2727	0	2.0455	
Slack_C2	0	0	4.7045	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-7.5000	0	6.7500	

MAX Z = 3.3 X_1

Subject to

$0.44 \times X_1 \leq 0.9$

$4.70448 \times X_2 \leq 100$

$X_1, X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving linear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1 = 2.0455$, $X_2 = 0$, MAX Z = 6.7500

Error = (exact − applied/exact) × 100%

E = 0.02173913

Example 3

Using WIN QSB program; simplex method is applied and the initial values is illustrated in Table 8.

Table 8 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	3.4			
C1	0.48		<=	0.9
C2		4.34976	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 9.

Table 9 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.4000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.4800	0	1.0000	0	0.9000	1.8750
Slack_C2	0	0	4.3498	0	1.0000	100.0000	M
	C(j)-Z(j)	3.4000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 10.

Table 10 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.4000	0	0	0	R. H. S.	Ratio
X1	3.4000	1.0000	0	2.0833	0	1.8750	
Slack_C2	0	0	4.3498	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-7.0833	0	6.3750	

$MAX\ Z = 3.4\ X_1$

Subject to

$0.48\ \times X_1 \leq\ 0.9$

$4.34976\ \times X_2 \leq 100$

$X_1\ , X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving linear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1\ = 1.8750\ \ , X_2\ = 0\ \ , MAX\ Z = 6.3750$

$$\text{Error}\ = \frac{\text{exact} - \text{applied}}{\text{exact}} \times 100\%$$

$\mathbf{E = \ 0.00390625}$

Example 4

Using WIN QSB program; simplex method is applied and the initial values is illustrated in Table 11.

Table 11 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	3			
C1	0.47		<=	0.9
C2		4.0608	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 12.

Table 12 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.0000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.4700	0	1.0000	0	0.9000	1.9149
Slack_C2	0	0	4.0608	0	1.0000	100.0000	M
	C(j)-Z(j)	3.0000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 13.

Table 13 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.0000	0	0	0	R. H. S.	Ratio
X1	3.0000	1.0000	0	2.1277	0	1.9149	
Slack_C2	0	0	4.0608	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-6.3830	0	5.7447	

$\text{MAX } Z = 3 \times X_1$

Subject to

$0.47 \times X_1 \leq 0.9$

$4.0608 \times X_2 \leq 100$

$X_1, X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving linear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1 = 1.9149, \; X_2 = 0, \; \text{MAX } Z = 5.7447$

$\text{Error} = (\text{exact} - \text{applied}/\text{exact}) \times 100\%$

$E = 0.02632203$

Example 5

Using WIN QSB program; simplex method is applied and the initial values is illustrated in Table 11.

Table 11 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	3			
C1	0.47		<=	0.9
C2		4.0608	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 12.

Table 12 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.0000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.4700	0	1.0000	0	0.9000	1.9149
Slack_C2	0	0	4.0608	0	1.0000	100.0000	M
	C(j)-Z(j)	3.0000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 13.

Table 13 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	3.0000	0	0	0	R. H. S.	Ratio
X1	3.0000	1.0000	0	2.1277	0	1.9149	
Slack_C2	0	0	4.0608	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-6.3830	0	5.7447	

$\text{MAX } Z = 1.9\, X_1$

Subject to

$0.39 \times X_1 \leq 0.9$

$3.003 \times X_2 \leq 100$

$X_1, X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving libear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1 = 2.3077,\ X_2 = 0,\ \text{MAX } Z = 4.3846$

$\text{Error} = (\text{exact} - \text{applied}/\text{exact}) \times 100\%$

$E = 0.01469663$

Example 6

Using WIN QSB program; simplex method is applied, Table 14 illustrate the initial values.

Table 14 - The value of the solar cell parameters using simplex method.

Variable -->	X1	X2	Direction	R. H. S.
Maximize	2.1			
C1	0.41		<=	0.9
C2		3.2472	<=	100
LowerBound	0	0		
UpperBound	M	M		
VariableType	Continuous	Continuous		

The second simplex tableau illustrated in Table 15.

Table 15 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	2.1000	0	0	0	R. H. S.	Ratio
Slack_C1	0	0.4100	0	1.0000	0	0.9000	2.1951
Slack_C2	0	0	3.2472	0	1.0000	100.0000	M
	C(j)-Z(j)	2.1000	0	0	0	0	

X_1 is entering variable and c_1 is leaving slack variable as shown in Table 16.

Table 16 - The value of the solar cell parameters using simplex method.

		X1	X2	Slack_C1	Slack_C2		
Basis	C(j)	2.1000	0	0	0	R. H. S.	Ratio
X1	2.1000	1.0000	0	2.4390	0	2.1951	
Slack_C2	0	0	3.2472	0	1.0000	100.0000	
	C(j)-Z(j)	0	0	-5.1220	0	4.6098	

$\text{MAX Z} = 2.1\ X_1$

Subject to

$0.41 \times X_1 \leq 0.9$

$3.2472\ X_2 \leq 100$

$X_1, X_2 \geq 0$

Simplex method by means of WIN QSB program is utilized for solving linear problem; the optimal solution of above-mentioned linear programming problem is achieved as follows

$X_1 = 2.1951,\ X_2 = 0\ ,\text{MAX Z} = 4.6098$

$\text{Error} = (\text{exact} - \text{applied}/\text{exact}) \times 100\%$

$E = 0.039625$

5. Conclusion

A new ranking function of simplex method for solving linear programming problems is proposed in this paper. Numerical examples are presented to show the effectiveness of the suggested method. Simplex method is used to find the optimal solution for linear programming models that include three variables or less for solar cell applications. The results showed that this method is considered efficient in dealing with the problems of linear programming in practical life. Numerical examples are presented to show the effectiveness of the suggested method.

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