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Selection of Solar Panel using Multi Criteria Decision Making Techniques

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Abstract*— Solar energy is one of the largest sources and most utilized resources of renewable energy. It is an inexhaustible, easily available and non polluting source of energy to overcome the energy crisis in the developing countries. Solar power generation is the best alternative compared to the conventional power generation practices when economic burden and environmental efforts are taken into consideration. Solar energy is harvested using photovoltaic cells. Solar Panel consists of an array of photovoltaic cells and plays a vital role in solar power generation. The main objective of this study is to select the best solar panel model among various alternatives available on the market which assures better efficiency with reduced cost. Selection of solar panel involves both subjective and quantifying criteria. The Criteria Importance Through Inter-criteria Correlation (CRITIC) method is used to find the objective weights of the criteria considered. Complex Proportional Assessment Method (COPRAS) and Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE II) are employed to select the best solar panel. Both the methods selected the alternative P6 as the best solar panel which has higher efficiency, less weight and low cost when compared to the other alternatives taken into consideration.

Keywords—Solar Panel Selection, CRITIC method, MCDM, COPRAS method, PROMETHEE II method

INTRODUCTION

To overcome the increasing energy demand many countries have adopted renewable energy as an apt alternative in order to reduce the negative impacts on the environment and the problems associated with the use of fossil fuels. Solar energy represents the largest resource of renewable energy with resource potential exceeding the global energy demands. The utilization of solar energy is increased for the past decade because of the technological developments and the support extended by the government for the utilization of renewable energy. Many countries have recommended the domestic utilization of solar energy rather than the utilization of fossil fuels.

The solar energy can be utilized by two methods. One is the solar thermal source, in which the heat radiated from the sun is used for heating water and to generate power. Second is with the photo voltaic cells in which the particular electrical properties of semi conducting material are applied to convert the sunlight into electricity. Solar panel comes under the photo voltaic system of power generation. Zhang et al. suggested that both the methods enhances the efficiency of conversion of solar energy into electricity ensuring an effective, economical way of utilizing the available energy [1]. Solar panel cost varies with dimensions, capacity, make and robustness. Due to the availability of many alternatives in the market it is essential to select the best solar panel using multi criteria decision making techniques.

Zavadskas et al. proposed that the computational methods in multi criteria decision making methods can be used for the subjective evaluation of the performance [2]. Cavallaro employed PROMETHEE method for assessing the solar energy technologies [3].Pohekar applied multi criteria decision making techniques in making decisions on sustainable energy planning [4]. Beltran employed analytical network process for the selection of solar projects [5]. Amin et al. carried out a study to analyze the performance of four different types of solar panels under malaysia weather [6]. Kahraman et al. performed a comparative analysis using fuzzy AHP to select the best renewable energy alternative for a country [7].

Ramachandra et al. developed an user friendly decision support system for assessing the solar energy potential [8]. Wang et al. reviewed the methods in different stages of multi criteria decision making for sustainable energy considering the criteria in technical, economic and environmental aspects of energy supply [9]. Chandrasekar et al. used AHP method to select the solar tracking system among four alternatives [10]. Cavallaro evaluated the thermal storing of solar photovoltaic plant using fuzzy TOPSIS method [11].

Desmond EseogheneIghravwe evaluated hybrid renewable energy systems using critic topsis framework. He considered ten technical and nine economic criteria for evaluation[12].Yongqi employed Critic topsis methods to evaluate the economic benefit of Distributed energy generarion projects [13].Mohammad rezataghizadehYazdi et al. ranked the thin film solar cells by Promethee II method and the weights for nine criteria is determined by CRITIC method [14]. FundaSamanlioglu and ZekiAyag selected the best location for solar power plant in Turkey by employing fuzzy AHP and PROMETHEE techniques. Fuzzy AHP is used to weigh the criteria and PROMETHEE is applied to rank the alternatives [15]. Lazim Abdullah et al. carried out the supplier selection problem by PROMETHEE method by considering seven economical and environmental criteria [16].

SukrenSeker selected site for solar power plants using fuzzy AHP and COPRAS approach [17]. Yanbin Li selected the distributed energy system among seven alternatives based on five criteria by DEA, TOPSIS and COPRAS methods [18]. DipanjanGhose et al. employed fuzzy COPRAS method to find the optimal material for solar electric vehicle application [19]. Chatterjee employed COPRAS method to rank renewable energy sources [20]. ChiranjibBhowmik et al. selected the optimal green energy sources by applying entropy – COPRAS methods [21]. MarijaBlagojevic solved a fluorescent lamp selection problem employing COPRAS method [22].

From the above literature it is confirmed that only few works are reported regarding the selection of solar panel. The main objective of this study is to determine the best solar panel using the COPRAS method and PROMETHEE II methods in combination with CRITIC weight method.

II. METHODOLOGY

A. *CRITIC Method*

The **CRITIC** (Criteria Importance Through Inter-criteria Correlation) is a method employed to find the weights of the criteria in the MCDM techniques. It belongs to the class of correlation methods. The steps involved in calculation of the weights are as follows.

Step 1 :

Normalizing the decision matrix

$$\bar{x}_{ij} = \frac{x_{ij} - x_j^w}{x_j^b - x_j^w} \tag{1}$$

Where X_{ij}^b is the best value of the response.

X_{ij}^w is the worst value of the response.

For the beneficial criteria , the maximum value is considered as best and the minimum value is taken as worst. But for non beneficial criteria minimum value is taken as best and maximum value is considered as worst.

Step 2 :

Calculating the Standard Deviation σ_j for each Criteria.

Step 3 :

Determining the symmetric matrix of $n \times n$ with elements r_{jk}, which is the linear correlation coefficient between the vectors x_j and x_k.

Step 4 :

Calculation of measure of the conflict created by criterion with respect to the decision situation defined by the rest of criteria.

$$\sum_{k=1}^{m}(1-r_{jk}) \tag{2}$$

Step 5 :

Compute the quantity of information in relation to each criterion.

$$c_j = \sigma_j \times \sum_{k=1}^{m}(1-r_{jk}) \tag{3}$$

Step 6 :

Calculating the Objective Weights.

$$W_j = \frac{c_j}{\sum_{k=1}^{m} c_j} \tag{4}$$

Where W_j is the objective weight of criteria.

B. COPRAS Method

Complex Proportional Assessment (COPRAS) method was developed by Zavadskas and Kaklauskas [23]. This method is applied to evaluate both the maximizing and minimizing criteria. It is used to rank the alternatives by determining the relative significance and priority of the alternatives. They also determine the best among the available alternatives based on their importance for a particular application.

Step 1 :

Formation of Decision Matrix. $X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & & & \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$ (5)

Where

m = number of alternatives

n = number of criterions

Step 2 :

Normalization of Decision Matrix. The decision matrix is formed with number of output responses.

$$\bar{X} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1m} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2m} \\ \vdots & & & \\ \bar{x}_{n1} & \bar{x}_{n2} & \cdots & \bar{x}_{nm} \end{bmatrix} \tag{6}$$

Where

$$\bar{X}_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{7}$$

Where i = 1,2,3…. .m and j = 1,2,3,…n

Step 3 :

Determination of Weighted Normalized Decision Matrix. The determined weights are multiplied with the normalized decision matrix.

$$\hat{X}_{ij} = W_j \times \bar{X}_{ij} \tag{8}$$

Where W_j is the weightage of criteria

Step 4 :

Determine Maximizing Index (S_i^+) and Minimizing Index (S_i^-).

$$S_i^+ = \sum_{i=1}^{k} \hat{X}_{ij} \tag{9}$$

$$S_i^- = \sum_{i=k+1}^{m} \hat{X}_{ij} \tag{10}$$

where S_i^+ is the weighted normalized value of beneficial criteria and S_i^- is the weighted normalized value of non beneficial criteria. Higher the value of S_i^+ better is the alternative and lower the value of S_i^- better the alternative is.

Step 5 :

The relative significance (Q_i) of all output responses are calculated .

$$Q_i = S_i^+ + \frac{\sum_{i=1}^{k} S_i^-}{S_i^- \sum_{i=1}^{n} \frac{1}{S_i^-}} \tag{11}$$

C. PROMETHEE II Method

PROMETHEE method (Preference Ranking Organisation Method for Enrichment Evaluation) is an outranking method which is used to rank a finite set of alternatives involving multiple conflicting criteria with multiple decision makers. The PROMETHEE method is a multi criteria decision making system which helps in ranking of alternatives.

In this paper PROMETHEE II is applied to rank the alternatives based on the criteria which needs to be maximized or minimized.

Step 1 : Normalization of the evaluation matrix is performed using equation (12) for beneficial criteria and equation (13) fornon beneficial criteria.

$$R_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \tag{12}$$

$$R_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (13)$$

Step 2 : Calculation of evaluation difference of i^th alternative with respect to other alternatives.

Step 3 : Determining the preference function $P_j(a,b)$

$$P_j(a,b) = 0 \text{ if } \left(R_{aj} \le R_{bj}\right),\ D\left(M_a - M_b\right) \le 0 \quad (14)$$

$$P_j(a,b) = \left(R_{aj} - R_{bj}\right) if R_{aj} \ge R_{bj}, D\left(M_a - M_b\right) \ge 0 \quad (15)$$

Step 4 : Compute the aggregated preference function

$$\pi(a,b) = \frac{\left[\sum_{j=1}^{n} W_j P_j(a,b)\right]}{\sum_{j=1}^{n} W_j} \quad (16)$$

Step 5 : Finding Leaving (Positive) flow for a^th alternative ϕ^+

$$\phi^+ = \frac{1}{m-1}\sum_{b=1}^{m} \pi(a,b), (a \ne b) \quad (17)$$

Entering (Negative) flow for a^th alternative ϕ^-

$$\phi^- = \frac{1}{m-1}\sum_{b=1}^{m} \pi(b,a), (a \ne b) \quad (18)$$

Where m= number of alternatives.

Step 6 : Ranking of the alternatives depending on the net flow value $\phi(a)$

$$\phi(a) = \phi^+(a) - \phi^-(a) \quad (19)$$

The higher value of the net flow indicates the better alternative. The net flow provides the complete ranking of alternatives.

III. CASE STUDY

The case study is conducted to demonstrate the applicability of the proposed method for selecting the solar panel on the basis of criteria chosen. The criteria considered in the selection process include Efficiency (C_1), Cost per Watt (C_2), Weight (C_3), Temperature Coefficient (C_4) and Life (C_5).

In this study eight potential solar panel models (P_1 to P_8) are considered and the criteria taken for selection is defined as listed below.

Efficiency (C_1) :

It is expressed in %. higher value is preferred. Maximization of this criteria is beneficial

Cost per Watt (C_2) :

It is expressed in rupees. Price of solar panel should be minimized.

Weight (C_3) :

It is expressed in Kg. Solar panel with less weight is given priority. It needs to be minimized.

Temperature Coefficient (C_4) :

It refers to the impact of heat has on a solar panel's operation after installing it. The lower value of temperature coefficient is desirable. It comes under minimization criteria.

Life (C_5) :

The operation of solar panel with prescribed efficiency with the given tolerance is considered as life. Higher the value, the better is the solar panel.

IV. RESULTS AND DISCUSSION

The decision matrix formed with the alternatives and the criteria considered are given in Table 1.

TABLE I Decision Matrix

Alternatives	Criteria				
	Efficiency in % C_1	**Cost per watt in Rs. C_2**	**Weight in Kg C_3**	**Temperature Coefficient in %/°C C_4**	**Life in Years C_5**
Max/Min	Max	Min	Min	Min	Max
P_1	18.3	66.3	18.8	0.4	12
P_2	18	87.36	18.2	0.41	12
P_3	17.8	47.58	18	0.38	10
P_4	18.05	51.48	18.5	0.37	12
P_5	15.3	80.2	18.8	0.4	9
P_6	19.1	54.6	16.8	0.38	10
P_7	18	67.08	18.5	0.36	20
P_8	17	66.8	19	0.42	10

With the above data of the alternatives the values are normalized according to the criteria. The weight obtained for the criteria by CRITIC method is presented in Table 2 .

TABLE II
Weights obtained by CRITIC Method

W_1	W_2	W_3	W_4	W_5
0.149	0.251	0.198	0.162	0.238

From the above table it is found that the cost is the most important criteria followed by life of the solar panels. Both the tangible and intangible factors are taken into consideration and final ranking is obtained by COPRAS and PROMETHEE II methods.

TABLE III
Ranking of Alternatives by COPRAS method

Alternatives	CRITIC – COPRAS method	Rank
P_1	0.122	5
P_2	0.106	7
P_3	0.138	3
P_4	0.140	2
P_5	0.097	8
P_6	0.156	**1**
P_7	0.127	4
P_8	0.113	6

Table IV

Ranking of Alternatives by CRITIC – COPRAS method

Alternatives	CRITIC – PROMETHEE II method	Rank
P_1	-0.058	5
P_2	-0.193	6
P_3	0.150	4
P_4	0.162	3
P_5	-0.367	8
P_6	0.281	**1**
P_7	0.276	2
P_8	-0.252	7

Among the eight solar panels, it is found that the panel P_6 is the best solar panel when compared to the other seven panels available in the market.

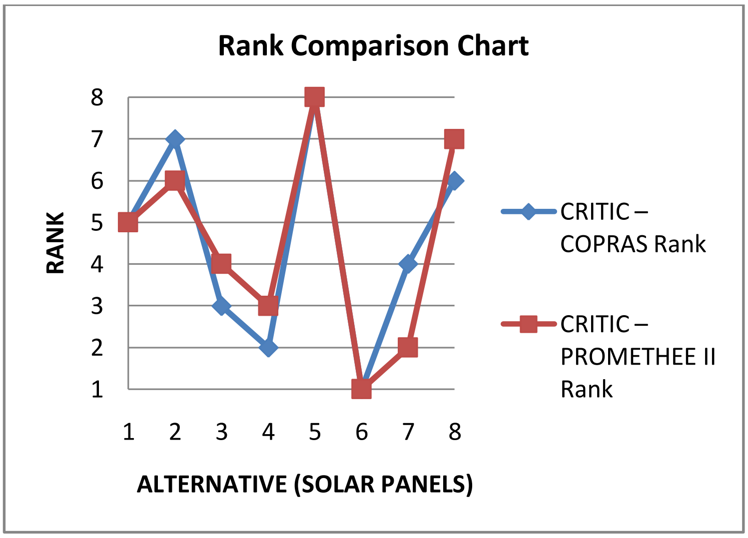

Fig 1.Comparison of Ranking by COPRAS and PROMETHEE II methods

The ranking of alternatives by COPRAS and PROMETHEE methods is illustrated in Figure 1. Both the methods ranked Solar panel model P_6 as the best alternative which possess the desirable characteristics of higher efficiency , less weight and low cost when compared with the other alternatives.

V. CONCLUSIONS

- Selection of the optimal solar panel defined through five criteria's is performed using the two MCDM techniques COPRAS and PROMETHEE II in combination with the CRITIC weighing method.
- The weights obtained for the criteria showed that the cost is the most influencing criteria followed by life in solar panel selection.
- The ranking of the best alternative is same in both the methods but differs for other alternatives. The ranking proved that the panel with higher efficiency, less weight and low cost is desirable for application.
- It is concluded that the multi criteria decision making techniques can be applied to solve the problem of selecting the best choice of Solar panel. It has been proved in the case solved using COPRAS and PROMETHEE II techniques.

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