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The selection of the best solar panel for the photovoltaic system design by using AHP

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Abstract

There has been numerous efforts by researchers worldwide cooperating to reduce the material costs of photovoltaic panels, efficient novel products and improve their energy efficiency and procreate innovative and practices based on photovoltaic system design technology. The aim of this paper is to select the best solar panel for the photovoltaic system design by using AHP (Analytical Hierarchy Process) from the multi-criteria decision making methods. Among 200W solar panel brands, the problem of selecting the best solar panel is evaluated, using fifteen electrical, three mechanicals, three economic, three customers and two environment related criteria. Used data is obtained from the solar panel companies worldwide.

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Keywords: AHP; Solar panel; Renewable energy; Multi-criteria decision making; Photovoltaic

1. Introduction

Solar panels have conventionally been used for less scale energy generation, especially for commercial or residential use in complexes or individual buildings. These panels generally range from 18%-12% efficiency and there are two different crystal types polycrystalline and monocrystalline [1]. Polycrystalline panels are usually less efficient due to the presence of only one crystal but are cheaper while monocrystalline is a small piece more expensive but generally more efficient [2]. The total cost of the solar panel is obtained in relation with size (in W), the brand, the physical size, the longevity /durability and any certifications the panel may have. Selecting the panel on price alone is not sensible, as it may not be appropriate for the designed field or it may not have the certification to characterize for government discounts, or may not have the warranty needed for payback period of

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the energy produced [3]. In the solar panel market, the prices per kW/h of electricity obtained are high comparison to the electricity generating systems [4] which enhances the payback time noteworthy. If the payback period is very long, consumers will not commandeer the photovoltaic system technology [5]. The higher the efficiency of a solar panels the earlier investment can be redeemed by reselling electricity back to the system or by having a 'free' resource of electricity. Thus, one of the most significant decisions in the photovoltaic system design is the selection of these solar panels. AHP is one of the most powerful and popular methods for efficient decision making used in advisable project design. It is a multi-criteria decision making approach that facilitates complex, bad-structured problems by working-out the decision elements in a hierarchical structure.

In this study, a solar panel assessment system is composed, which includes electrical, mechanical, economic, customer and environment criteria. And then, the comparative analysis of different solar panel brands is made by using the AHP. Among selected popular solar panel brands for 200W, the best solar panel selection is obtained by evaluating comprehensively.

2. Multi-Criteria Decision Making in Solar Panels Selection

In an AHP hierarchy for choosing a solar panel, the goal would be to choose the best panel. This study aims to contribute to the existing literature significantly by helping decision makers in selecting the best solar panel based on various groups of criteria. Electrical, mechanical, financial, environmental, and customer related factors are the four main criteria that are often used in evaluation of various investment projects [4-6] for making a decision. These criteria can be subdivided into several. In this study, the electrical criterion is considered under 15. The cost criterion is subdivided into variable cost, total investment cost and state support. The environmental criteria include area and material manufacturing effect. Finally, the customer satisfaction is measured using service, availability of spare parts, and reliability. Six alternative solar panels are compared using AHP technique. While measurements for some criteria are readily available, some others like customer satisfaction can only be estimated with respect to other variables. As it is the case in all multi-criteria decision making methods, the relative weights of such criteria need to be determined. In AHP, this is accomplished by pairwise comparison of the elements, starting with the main criteria.

2.1. Main and Sub Criteria Priorities

The main criteria priorities are determined as electrical (50.5%), mechanic (23.5%), financial (13.8%), customer (7.7%) and environmental (4.5%). In the next step, the groups of sub-criteria under each main criterion need to be compared two by two. For example; In the electrical subgroup, each pair of sub-criteria is compared regarding their importance with respect to the electrical criterion. These are the resulting weights for the criteria based on pairwise comparisons. At this point, the comparison for electrical criterion has been made, and the AHP method has derived the local priorities for this group. These priorities reflect on how much a sub-criterion contributes to the priority of its parent, thus we need to calculate the global priority of each sub-criterion. That will show us the priority of each sub-criterion with respect to the overall goal. The global priorities throughout the hierarchy should add up to one. The global priorities of each electrical sub-criterion are calculated by multiplying their local priorities with the priority of electrical criterion. In the financial subgroup, there are three sub-criteria, namely cost per watt, total cost of investment and state support available. These elements are compared as to how important they are with respect to the financial criterion. Environmental factors considered are the area required to install the panels and environmental effects of the material manufacturing process. Comparison of these elements with respect to the environmental considerations leads to the resulting weights. Finally, there are three sub-criteria in the customer satisfaction subgroup; service, spare parts, and reliability. These elements are compared as to how they add value towards the customer satisfaction. Table 1 shows solar panel characteristics for this study [7].

2.2. Pairwise Comparison of the Alternatives with Respect to the Criteria

After determining the priorities of each criterion with respect to the overall goal of selecting the best solar panel and priorities of sub-criteria with respect to their associated main criteria, the panel alternatives need to be compared two by two with respect to each sub-criterion. In order to measure the customer satisfaction towards the solar panels, three sub-criteria are defined: customer service, spare parts available, and the reliability of the company. Service is evaluated to be positively related to the number of branches available for each company. Spare parts are measured by the inventory levels of the companies while the reliability is measured by their market shares and sales. The companies are ranked from 1 to 4 to be able to generate a medium of comparison.

Table 1. Solar panel characteristics [7]

	P1	P2	P3	P4	P5	P6
Electrical Characteristics						
PTC power rating (W)	175	180	179	184.8	177.5	185.9
STC Power per unit of area (W/m^2)	142.1	156.7	136.5	156.7	135.1	172.3
Peak Efficiency (%)	14.21	15.67	14.2	15.67	13.5	17.2
Power Tolerances (%)	-9/+9	0/+3	-3/+32	0/+5	-3/+3	0/+10
Number of Cells	50	72	54	72	54	96
Imp (A)	8.16	5.42	7.89	5.17	7.60	5.59
Vmp (V)	24.50	36.90	25.38	38.70	26.30	55.80
Isc (A)	8.70	5.80	8.24	5.50	8.22	3.83
Voc (V)	30.80	45.60	33.53	45.90	33.30	68.70
NOCT (^{0}C)	-	45	-	45	-	-
Temp. Coefficient of Power (%K)	-0.50	-0.40	-0.50	-0.38	-0.45	-0.29
Temp. Coefficient of Voltage (V/K)	-0.5	-0.4	-0.5	-0.38	-0.45	-0.17
Series Fuse Rating (A)	15	10	15	15	15	15
Maximum System Voltage (V)	600	1000	600	1000	600	600
Lower energy density(W/m^2)	11.52	11.95	11.82	13.28	11.26	14.89
Mechanical Characteristics						
Length* Width* Depth (mm)	1679.4*838.2*50	1580*808*35	1481*989*47	1580*808*35	1495*990*50	1319*880*46
Frame Color	bronze	clear	black	clear	clear	black
Weight (kg)	15.4	14.5	35	15.5	18	15
Financial Properties						
Support of gov	0.30	0.33	0.32	0.35	0.32	0.36
Price ($)	300	300	499	300	319	600
Cost per Watt ($)	1,05	1,05	1,75	1,05	1,05	2,10
Environment						
Area (sqm)	1.40	1.27	1.46	1.27	1.48	1.16
Material	Policryst.	Monocryst.	Monocryst.	Monocryst.	Policryst.	Monocryst.
Customer Satisfaction						
Service support	3	1	6	5	2	4
Spare part	5	2	6	4	1	3
Reliability	5	2	6	4	3	1

The next step in applying the AHP technique is two by two comparisons of the panel alternatives with respect to each sub-criterion. Remainder of this section presents the priorities obtained under each subcategory using this technique.

2.3. Making the Decision

Based on the calculations above, the relative priorities corresponding to the attractiveness of each solar panel about all factors of electrical, mechanical, financial, environmental and customer satisfaction are presented. The global electrical priorities of the panels indicate that P6 is the panel that contributes most to the overall goal in terms of electrical properties with a global priority of 0,173. According to the global mechanic priorities of the panels, P6 is once again the best panel that contributes the most to the overall goal of selecting the best solar panel. The global financial priorities of the panels indicate that P4 has the highest global priority in terms of financial considerations, although the gap with the remaining panels is very small. P6, however, has the lowest score in this category. The environmental priorities show that P6 is once again the leading panel towards the overall goal. The customer service related priorities indicates that P2 contributes the most towards the overall goal, while P6 ranking the second.

In overall, adding the global priorities in all categories, the obtained results indicate that the model P6 is the alternative that contributes the most to the goal of choosing the best solar panel that satisfies all the criteria selected.

3. Conclusions

In the case study, electrical category is the most important criterion, followed by mechanical features. Under the electrical category, PTC power rating is the most important objective of the experts, followed by the STC power per unit of area. This means that the PTC power rating is the most important factor in selecting solar panels. Under the mechanic characteristics, material type is the highest concern. Material manufacturing process has the biggest priority among the environmental criteria. Under the customer satisfaction category, reliability is the criterion with the highest priority.

After considering electrical, mechanical, financial, environmental and customer satisfaction performance of each panel we can conclude that P6 is the most suitable one that can be used in a solar plant. Although the results may be case specific, the proposed model can be tailored and applied to other cases in different locations or countries as a reference when selecting the most appropriate solar panels

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