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COMPREHENSIVE DECISION-MAKING FOR EVALUATING WIND TURBINES

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Abstract: In this study, the AHP method was used to choose the best 7MW wind turbine for a wind farm design. Five diverse wind turbine brands were analyzed based on experts' opinions on four groups of characteristics of these turbines. The data used is obtained from real companies.

Keywords: AHP, Wind turbine select, Renewable energy, Energy efficiency, comparison.

1. Introduction

The structure of wind power system contains three milestones. Firstly, wind power is captured by turbine blades. Meanwhile the rotor changes it to rotational power conducted via the drive turn to the generator. And then the produced electricity is fed to the grid or contacted to the load. The primary parts of a wind turbine include a rotor that has airfoil formed blades added to a center, an engine that exists a drive turn including the generator, connecting shafts, a tower, a gearbox, a ground attached electrical device, support bearings, and other mechanism [1]. For wind turbines, there are numerous diverse sizes and various materials. For wind farm, the selection of the most proper wind turbine is very important because the system's capital cost is very high and wind turbines total up to 64% of total expense. For this reason, the wind turbine should be selected by assessing all of the criteria to fulfill the objective required such asless cost, having lower environmental impact, more robustness, and more efficiency.

The various multi-criteria decision-making methods are widely performed in the wind energy system in recent years. Chen et al. analyzed FAHP approach associated with the opportunities, benefits, risks and costs concept to evaluate wind farm projects [2]. Minguez et al. designed the suitable selection of the most appropriate support structures' options for 5.5 MW wind turbine with TOPSIS [10]. Wu et al. applied AHP for location choosing problem of wind farm using a wide diversity of criteria such as economics, risks, and accessibility [3]. Kolios et al. determined a methodology based on the TOPSIS for evaluation and classification of diverse support structures for wind turbines [4]. Lee et al. used a multi-

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criteria decision making method, with the combination of AHP and the profits, opportunities, costs, and risks notion for wind farm project [5].Chen et al. applied ANP to assess the wind firm system [6].

In this paper, a wind turbine assessment system is composed, which includes technical, economic, customer and environment criteria. And then, the comparative analysis of five different wind turbine brands is made by using AHP. Among selected popular wind turbine brands for 7MW, the best wind turbine selection is obtained by evaluating comprehensively.

1. Multi-Criteria Decision Making in Wind Turbine Selection

In an AHP hierarchy for choosing a wind turbine, the goal would be to choose the best turbine. Technical, economic, environmental, and customer related factors are the four main criteria that are used in majority of the related literature for making a decision. These criteria are often subdivided into several sub-criteria. In this study, the technical criterion is subdivided into output, capacity, rotor diameter, hub height, cut-out wind speed, and nominal wind speed. The cost criterion is subdivided into total cost and state support. The environmental criteria include noise and electromagnetic effects. Finally, the customer satisfaction is measured using service, availability of spare parts, and reliability. Five alternative 7 MW wind turbines are compared using AHP technique. The hierarchy composed of these criteria is constructed as shown in the figure below:

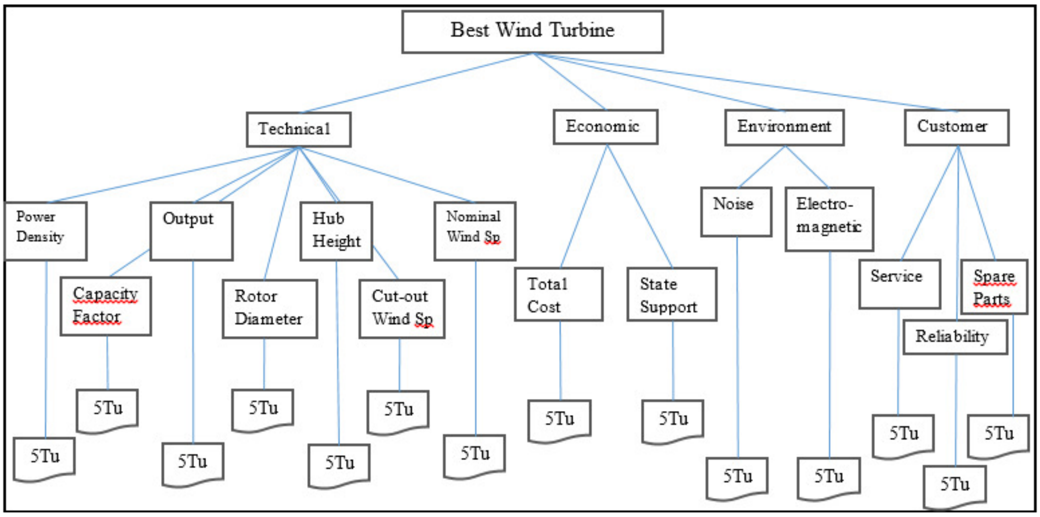

Fig. 1. Hierarchy of Criteria

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. Below are the resulting priorities of technical, economic, environmental, and customer related factors. Upon calculations, the resulting priorities of technical, economic, environmental, and customer related factors are as follows, respectively: 54%; 32%; 5%; 9%. In the next step, there are groups of sub-criteria under each main criterion to be compared two by two. In the technical subgroup, each pair of sub-criteria is compared regarding their importance with respect to the technical criterion. Below are the resulting weights for the criteria based on pairwise comparisons.

Table 1. Technical sub-group priorities

	Annual Output	Capacity Factor	Nominal Rotor Diameter	Hub Height	Cut-out Wind Speed	Nominal Wind Speed	Power Density
Weight	22,4	11,1	6	5,8	8,1	13,1	33,6

At this point, the comparison for technical criterion has been made, and the AHP method has derived the local priorities for this group. These priorities reflect on how much it 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 technical sub-criterion is calculated by multiplying their local priorities with the priority of technical criterion which results in the following values:

In the economic subgroup, there is only one pair of sub-criteria, namely total cost of investment and state support available. These elements are compared as to how important they are with respect to the economic criterion. Environmental factors considered are noise and electromagnetic effects. Comparison of these elements with respect to the environmental consideration steads to the resulting weights. Finally, there are three sub-criteria in the customer satisfaction subgroup, namely service, spare parts, and reliability. These elements are compared as to how they add value towards the customer satisfaction.

Table 2. Global Priorities of Technical Sub-Group

	Annual Output	Capacity Factor	Nominal Rotor Diameter	Hub Height	Cut-out Wind Speed	Nominal Wind Speed	Power Density
Weight	0,121	0,059	0,032	0,031	0,043	0,07	0,181

Table 3. Global Priorities of Financial, Environmental and Customer Sub-Groups

	Financial		Environmental		Customer		
	Opr. Cost	St. Support	Noise	Elec. Mgn.	Service	Spare	Reliability
Weight	0,24	0,08	0,041	0,008	0,031	0,007	0,051

3-Pairwise Comparisonof the Alternatives with Respect to the Criteria

After determining the priorities of each criterion with respect to the overall goal of selecting the best wind turbine and priorities of sub-criteria with respect to their associated main criteria, the turbine alternatives need to be compared two by two with respect to each sub-criterion.

In order to measure the customer satisfaction towards the wind turbines, three sub-criteria is 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 10 to be able to generate a medium of comparison.

The next step in applying the AHP technique is two by two comparisons of the turbine alternatives with respect to each sub-criteria. In order to design an objective scheme for this purpose, the maximum and minimum values of the alternatives for each sub-criteria is determined. This range is divided into nine even classes since AHP requires pairwise comparisons on a scale from 1 to 9. Finally each alternative is placed in one of these classes based on their values to compare them with eachother. Remainder of this section presents the priorities obtained under each subcategory using this scheme.

Table 4. Technical Priorities

	Annual Output	Capacity	Nom. Diam.	Height	Cut-Out WS	Nom. WS	Power Density
T1	0,0069	0,0055	0,0034	0,0191	0,0087	0,0061	0,0188
T2	0,0043	0,0022	0,0010	0,0058	0,0087	0,0023	0,0056
T3	0,0469	0,0287	0,0099	0,0017	0,0087	0,0260	0,0553
T4	0,0220	0,0064	0,0091	0,0031	0,0087	0,0105	0,0509
T5	0,0408	0,0171	0,0091	0,0017	0,0087	0,0260	0,0509

Table 5. Financial, Environmental, Customer Priorities

	Total Cost	Support of Government	Max. sound power (dB)	Electromagnetic effects	Max Service support	Spare part	Reliability
T1	0,0442	0,0023	0,0029	0,0023	0,0022	0,0005	0,0021
T2	0,1341	0,0077	0,0012	0,0077	0,0041	0,0009	0,0067
T3	0,0115	0,0023	0,0005	0,0023	0,0013	0,0003	0,0036
T4	0,0375	0,0255	0,0033	0,0255	0,0073	0,0016	0,0120
T5	0,0128	0,0041	0,0003	0,0041	0,0165	0,0037	0,0272

4. Conclusion

This study aims to find the most effective 7 MW wind turbine brand based on various criteria exist in the literature. A list of criteria is evaluated and divided into four groups. Each criterion is appointed a relative weight as a result of expert evaluations. Finally, AHP method is applied to the resulting scheme. Based on the calculations above, the relative priorities corresponding to the attractiveness of each wind turbine about all factors of technical, financial, environmental and customer satisfaction are presented below:

Table 6. Wind turbine comparison

	Technical	Economic	Environment	Customer	Total
T1	0,0684	0,0464	0,0052	0,0048	**0,1248**
T2	0,0300	0,1418	0,0089	0,0116	**0,1923**
T3	0,1771	0,0137	0,0027	0,0052	**0,1987**
T4	0,1107	0,0631	0,0288	0,0210	**0,2235**
T5	0,1543	0,0168	0,0044	0,0473	**0,2229**

The obtained results indicate that T4 and T5 are the two models with the highest priorities, T4having slightly higher global priority of 0.2235and it is the alternative that contributes the most to the goal of choosing the best wind turbine that satisfies all the criteria selected.T3 is also the most efficient turbine in terms of technical properties, while T2 is the most economical alternative. T4 is ranked higher than the others with a significant difference in terms of environmental characteristics while T5 has the highest customer ranking.

References

[1] D. Ancona, J. McVeigh, Wind turbine-materials and manufacturing fact sheet, Princeton Energy Resources International, LLC, 2001.

[2] HH. Chen, HY. Kang, A. Lee. Strategic selection of suitable projects for hybrid solar-wind power generation systems. Renew Sustain Energy Rev 2010; 14:413–41.

[3] Y. Wu, S. Geng. Multi-criteria decision making on selection of solar, wind hybrid power station location: a case of China. Energy Convers Manag. 2014; 81:527-533.

[4] K. A, M. Collu, A. Chahardehi, FP. Brennan, MH. Patel. A multi-criteria decision making method to compare support structures for offshore wind turbines. In: European Wind Energy Conference, Warsaw, 2010.

[5] L. AHI, C. Hung, HY. Kang. Multi-criteria decision making on strategic selection of wind farms. Renew Energy 2009;34(1):120–6.

[6] HH. Chen, H-Y, Kang, AH. Lee. Strategic selection of suitable projects for hybrid solar-wind power generation systems. Renew Sust. Energy Rev. 2010; 14:413–21.