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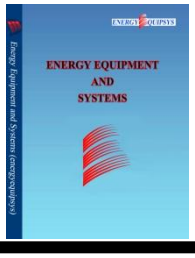

Identification and assessment of training needs for employees of wind farms

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ABSTRACT

In this paper, the training needs of wind farm employees have been specified, assessed and prioritized. For this purpose, first of all, the main tasks of wind farm employees have been identified. Afterwards, four criteria—including task complexity, task importance, task time duration and task frequency—have been considered to assess and prioritize tasks. In this respect, the Analytic Hierarchy Process (AHP) has been applied to obtain weights of the criteria. Afterwards, all the wind farm employees' tasks have been assessed on the basis of the four abovementioned criteria, and the job assessment indicator has been calculated. This procedure results in the prioritization of tasks. Finally, the appropriate training courses for the identified tasks have been specified and they have been prioritized and ranked, based on the average of job assessment indicators for the related tasks.

Keywords: Wind Energy; Wind Farm; Training Need Assessment; Training Courses; Task Prioritization.

1. Introduction

Wind is one of the most reliable sources of energy generation. Wind power is one of the major renewable energy sources that has been utilized widely in recent years. It is considered a major source of energy generation. Similar to other new recent technology-related contexts, this field requires expert human capital to plan, design, implement, check, control and improve the related systems. Certainly, without appropriate human resource development programmes, it is not possible to efficiently utilize the new technologies related to wind energy generation and utilization. In previous researches, the identification of training needs and the assessment of the energy-related systems have been considered to some extent. Xie et al. [5], for example, studied the current status of wind energy-related training and education programmes in the universities and training centres in China. In this respect, they highlighted the related opportunities and challenges by considering the incremental trend of using wind energy as a source of electricity. They stated it is necessary that training programmes will be developed at different levels based on a systematic framework. In addition, it is specified that on-the-job training can present effective and suitable services in the identification and utilization of new technologies related to wind energy.

Jain et al. [3] stated that the dearth of effective education and training about the application of solar energy-related equipment result in equipment failure, causing financial loss and decline in the confidence of solar energy customers in Botswana. In the research, human resource training needs related to new and renewable sources of energy have been determined and evaluated. On the basis of that, seven training plans to enhance the capabilities of human resources—including heating and photovoltaic technologies, solar energy technologies, energy technologies for supervisory, procurement of energy-related equipment and services, maintenance, and finally leadership—have been presented. In addition, they made some suggestions about

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training facilities and the budget required to implement new training plans. Doyle and Humphreys [2] investigated issues related to the Environmental Development Action (Enda) programme in Dakar, Senegal. This programme concerns the utilization of energy resources, energy systems and the related environmental aspects. The objective of this programme is to find and highlight efficient and applicable solutions for energy systems. For this purpose, research and training are considered the two main drivers. One of the main target groups for training programmes comprises African policymakers. Andrews and Playfoot [1] focus on challenges of Mozambique in the education and training system to enhance the expertise and skill levels of oil and gas industry technicians. In this respect, they studied and highlighted problems related to human resource development and training. Orsak [4] specified and assessed the training needs of human resources in respect of the application of solar energy technologies. They considered three main issues:

a) What are the main solar heating and cooling systems?
b) What is the demand for expert human resources?
c) What are the critical skills and core competencies of human resources that are required?

Despite the importance of training in wind energy as a renewable source of energy generation, there is no research about the identification and assessment of training needs in this area. Therefore, in this research, training needs are identified, assessed and prioritized in the different stages of a wind farm, such as design, procurement, installation, commissioning, operation and maintenance. The main research questions that have been considered are as follows:

- What are the main tasks of wind farm employees?
- What are the priorities of the identified tasks?
- What are the training needs of wind farm employees and the related programmes?
- What are the priorities of the identified training programmes?

The structure of this paper is as follows. After the introduction in Section 2, the main tasks of wind farm employees have been identified. Section 3 is dedicated to the determination of criteria to assess the tasks of wind farm employees. Afterwards, the procedure to obtain the importance of assessment criteria have been explained in Section 4. Section 5 is assigned to the prioritization of tasks and the assessment of training needs, based on the criteria considered. Finally, the conclusions of this research have been stated in Section 6.

2. Identification of the main tasks of wind farm employees

In this part, the main tasks of employees are identified by the review of their job descriptions and semi-structured interviews with the experts. These included a number of questions, as follows:

- What are the main tasks in the study phase of a wind farm?
- What are the main tasks about the technical design of a wind farm?
- What are the main tasks about the commission of a wind farm?
- What are the main tasks about the operation and maintenance of a wind farm?
- What are the other main tasks of wind farm employees?

The results of the interviews have been analysed and classified. The tasks extracted are shown in Table 1.

3. Determination of criteria to assess tasks of wind farm employees

As the first step, it is necessary to find the important criteria for the assessment of wind farm employees' tasks. In this respect, interviews have been conducted with the experts. Based on the experts' statements, the following criteria have been identified as important perspectives to assess wind farm employees' tasks:

- Task complexity (C1)
- Task importance (C2)
- Task time duration (C3)
- Task frequency (C4)

Table 1: Main tasks of wind farm employees

Taks Code	Main tasks of wind farm employees
T01	Design of horizontal axis wind turbines (HAWT)
T02	Design of the hub, controls, generator, supporting structure and foundation
T03	Design of the shape and dimensions of the blades
T04	Design of the sensors of turbine control system
T05	Design of actuators
T06	Design of control algorithms
T07	Design of turbine tower
T08	Design of turbine gearbox
T09	Design of turbine generator
T10	Calculation of wind turbine efficiency
T11	Calculation of commercial viability of wind turbines
T12	Identify and analyze constraints imposed by the site
T13	Selection of a specific turbine model
T14	Predict the energy production of wind farm
T15	Analyze and address environmental issues of wind farm
T16	Analyze Visual influence of wind farm
T17	Analyze Noise produced by operating turbines
T18	Calculate Turbine loads
T19	Understanding and analyzing of ground conditions and infrastructure
T20	Wind farm layout design
T21	Wind turbine placement based on the wind distribution
T22	Performing standard tests for the electrical infrastructure
T23	Inspection of routine civil engineering quality records
T24	Calculate availability indicator of wind turbines
T25	Calculate reliability indicator of wind turbines
T26	Calculate maintainability indicator of wind turbines
T27	Scheduling preventive maintenance
T28	Scheduling overhaul maintenance
T29	Vibration turbine analysis
T30	Estimation of Fixed and variable costs of wind farm
T31	Wind farm locating
T32	Wind farm technologies study
T33	Economic analysis of wind farms

4. Determination of the importance of assessment criteria

In this stage, a pairwise comparison between the abovementioned criteria has been carried out by using an Analytic Hierarchy Process (AHP) to specify the degree of importance of the abovementioned criteria in order to prioritize wind farm employees' tasks. In this research, the range 1–9 has been used to indicate the relative importance between the criteria considered, so that '1' means equal importance and with increments from '2' to '9', the degree of the relative importance will increase. Table 2 shows the relative range for the comparison that was considered.

Table 2. Pairwise comparison range for task prioritization criteria

First Criterion in comparison	More importance for first criteria								Equal importance	More importance for second criteria								Second Criterion in comparison
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C2																		C1
C3																		C1
C4																		C1
C3																		C2
C4																		C2
C4																		C3

To obtain the weights of the criteria considered, a meeting with wind farm experts was held. First, the framework and the procedure considered was presented. Afterwards, the questionnaire of the pairwise comparison was distributed amongst them. For each of the six comparisons (as shown in Table 1), the average of the obtained scores was entered in Expert Choice software. The related view of the software (pairwise comparison questionnaire) is given in Fig.1.

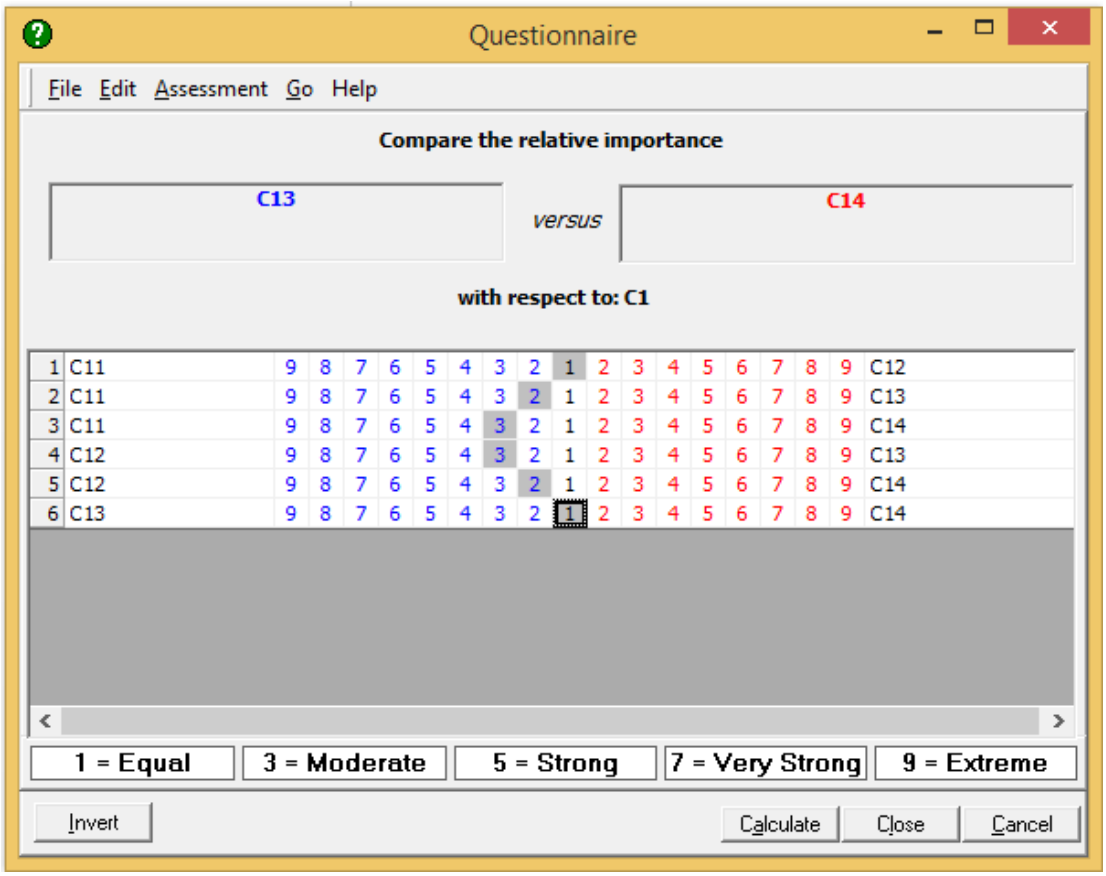

Fig.1. A view of the pairwise comparison about tasks of wind farm employees (in Expert Choice software)

Afterwards, weights of the criteria were calculated and the inconsistency rate obtained, which is equal to 0.02 and is less than the permissible limit (0.1). Therefore, the weights obtained are acceptable, as is shown in Fig.2 and Table 3.

Table 3. Weights of the wind farm task assessment criteria

Criterion	Weights
C1	W1=0.355
C2	W2=0.355
C3	W3=0.145
C4	W4=0.145

5. Tasks prioritization and assessment of training needs based on the criteria considered

In this step, the tasks of wind farm employees have been assessed on the basis of the identified criteria. For this purpose, a five-point Likert scale has been used as follows:

- 1: Very low
- 2: Low
- 3: Moderate
- 4: High
- 5: Very high

Using the abovementioned scale, a questionnaire has been prepared to assess the condition of each task from the criteria considered, including 'task complexity (C1)', 'task importance (C2)', 'task time duration (C3)' and 'task frequency (C4)'. Afterwards, for each task, the assessment indicator has been calculated as follows.

Job assessment indicator = (W1×C1) + (W2×C2) + (W3×C3) + (W4×C4)

For each task, values of the four criteria are obtained by the average of the respondents' opinions. In addition, criteria weights are the same as Table 3. According to this, the job assessment indicator is obtained for each of the wind farm tasks (Table 4).

The results of the table above show that the following tasks are the most important tasks on the basis of their job assessment indicator.

- Designing the turbine generator (4.065)
- Understanding and analysing ground conditions and infrastructure (4.065)
- Predicting the energy production of a wind farm (4)
- Estimating fixed and variable costs of a wind farm (3.92)
- Designing the wind farm layout (3.92)
- Conducting the wind farm feasibility study (3.92)

Afterwards, for each task, the appropriate training courses have been obtained. In addition, for each course, the average of the related job assessment indicators has been calculated. These are shown in Table 5.

Fig.2. Weights of the wind farm task assessment criteria (Calculated in Expert Choice Software)

Table 4. Values of the job task assessment criteria and the related indicator

Taks Code	Main tasks of wind farm employee	C1	C2	C3	C4	Job assessment indicator
T15	Analyze and address environmental issues of wind farm	4	3	2	3	3/21
T17	Analyze Noise produced by operating turbines	2	3	2	4	2/645
T16	Analyze Visual influence of wind farm	3	2	1	2	2/21
T24	Calculate availability indicator of wind turbines	1	4	1	5	2/645
T26	Calculate maintainability indicator of wind turbines	1	3	1	5	2/29
T25	Calculate reliability indicator of wind turbines	1	4	1	5	2/645
T18	Calculate Turbine loads	3	4	4	3	3/5
T11	Calculation of commercial viability of wind turbines	3	4	2	2	3/065

Taks Code	Main tasks of wind farm employee	C1	C2	C3	C4	Job assessment indicator
T10	Calculation of wind turbine efficiency	2	3	2	3	2/5
T05	Design of actuators	4	5	3	1	3/775
T06	Design of control algorithms	3	4	2	2	3/065
T02	Design of the hub, controls, generator, supporting structure and foundation	5	4	3	1	3/775
T04	Design of the sensors of turbine control system	4	4	2	2	3/42
T03	Design of the shape and dimensions of the blades	4	5	2	1	3/63
T08	Design of turbine gearbox	4	4	3	1	3/42
T09	Design of turbine generator	5	4	5	1	4/065
T07	Design of turbine tower	4	4	4	1	3/565
T01	Design of horizontal axis wind turbines (HAWT)	4	4	3	1	3/42
T33	Economic analysis of wind farms	3	5	4	1	3/565
T30	Estimation of Fixed and variable costs of wind farm	4	5	4	1	3/92
T12	Identify and analyze constraints imposed by the site	3	3	3	2	2/855
T23	Inspection of routine civil engineering quality records	2	3	3	3	2/645
T22	Performing standard tests for the electrical infrastructure	2	4	3	4	3/145
T14	Predict the energy production of wind farm	3	5	3	5	4
T28	Scheduling overhaul maintenance	4	4	3	3	3/71
T27	Scheduling preventive maintenance	3	4	2	5	3/5
T13	Selection of a specific turbine model	4	4	2	3	3/565
T19	Understanding and analyzing of ground conditions and infrastruture	4	5	5	1	4/065
T29	Vibration turbine analysis	2	3	2	4	2/645
T20	Wind farm layout design	4	5	4	1	3/92
T31	Wind farm locating	4	4	3	1	3/42
T32	Wind farm technologies study	4	5	3	2	3/92
T21	Wind turbine placement based on the wind distribution	3	5	3	2	3/565

Table 5. Related courses for tasks and average of job assessment indicators

Training course code	Training course title	Related tasks	Average of job assessment indicators
C01	Environmental analysis of wind farms	Analyze and address environmental issues of wind farm, Analyze Noise produced by operating turbines, Analyze Visual influence of wind farm	2.688
C02	Maintenance of wind turbines	Scheduling overhaul maintenance, Scheduling preventive maintenance, Calculate availability indicator of wind turbines, Calculate reliability indicator of wind turbines, Vibration turbine analysis, Calculate maintainability indicator of wind turbines	2.906
C03	Procurement in wind farms	Selection of a specific turbine model	3.565

Training course code	Training course title	Related tasks	Average of job assessment indicators
C04	Turbine design	Design of turbine generator, Design of actuators, Design of the hub, controls, generator, supporting structure and foundation, Design of the shape and dimensions of the blades, Design of turbine tower, Calculate Turbine loads, Design of the sensors of turbine control system, Design of turbine gearbox, Design of horizontal axis wind turbines (HAWT), Calculation of commercial viability of wind turbines, Design of control algorithms, Calculation of wind turbine efficiency	3.433
C05	Wind distribution study	Wind turbine placement based on the wind distribution	3.565
C06	Wind farm commissioning	Performing standard tests for the electrical infrastructure, Inspection of routine civil engineering quality records	2.895
C07	Wind farm feasibility study	Predict the energy production of wind farm, Estimation of Fixed and variable costs of wind farm, Wind farm technologies study, Economic analysis of wind farms, Wind farm locating	3.765
C08	Wind farm layout design	Wind farm layout design	3.920
C09	Wind farm site analysis	Understanding and analyzing of ground conditions and infrastructure, Identify and analyze constraints imposed by the site	3.460

The table above shows that the prioritization of the training courses for wind farm employees to assist them in their daily tasks are stated as follows.

1) Wind farm layout design (C08)
2) Wind farm feasibility study (C07)
3) Procurement in wind farms (C03)
4) Wind distribution study (C05)
5) Wind farm site analysis (C09)
6) Turbine design (C04)
7) Maintenance of wind turbines (C02)
8) Wind farm commissioning (C06)
9) Environmental analysis of wind farms (C01)

The above ranking of the training courses indicates that courses of a technical nature, such as C04, C02, C06 and C01, have less importance, while courses that include managerial and economic issues like C08, C07, C03, C05 and C09 have higher importance. Therefore, it has been found that the abovementioned courses that involve managerial and economic aspects, and are obtained from the process of the assessment of training needs, should be considered the first priority to plan, implement, check and evaluate training programmes for wind farm employees.

6. Conclusion

In this research, a procedure has been proposed and applied to obtain the assessment of training needs. As the first step, the main tasks of designing, commissioning, implementing and maintaining a wind farm have been identified. After that, the important criteria for task assessment have been identified, so that the weights of 'task complexity' and 'task importance' are shown to be greater than 'task duration' and 'task frequency'. Based on the criteria specified, tasks are assessed and ranked, so that the results indicate tasks such as the 'design of turbine generator', 'understanding and analysing ground conditions and infrastructure', 'predicting the energy production of wind farms', 'estimation of fixed and variable costs of wind farms', 'wind farm layout design' and 'wind farm feasibility study'. Afterwards, related courses are assessed. Following this, it is specified that training courses that include managerial and macro aspects like 'wind farm layout design', 'wind farm feasibility study', 'procurement in wind farms', 'wind distribution study' and 'wind farm site analysis' are the most important training needs for wind farm employees.

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