Constructive Response Task (Sample) : Wind Power Generation

Wind power generation is the conversion of wind kinetic energy into electrical energy or electricity, through the use of wind turbines. In recent years, there has been much interest in wind power generation as one of the measures against global warming, mainly for two reasons. Firstly, compared to other forms of small-scale power plants, it can generate electricity inexpensively. Secondly, its emission of carbon dioxide per unit power generation is relatively low.

Figure 1 shows the total amount of electricity supplied by wind power generation, worldwide, between 1997 and 2014. According to this figure, the capacity of wind power generation has grown by more than 10 percent each year, amounting to more than fifty times factor increase during the past 17 years. In order to improve the overall cost effectiveness of wind power generation e.g. in wind farms, a number of design parameters need to be taken into account including the location, wind turbine structure and design, safety systems, etc.

Respond to the following questions which focus on the wind turbines used for wind power generation from a mechanical engineering point of view.

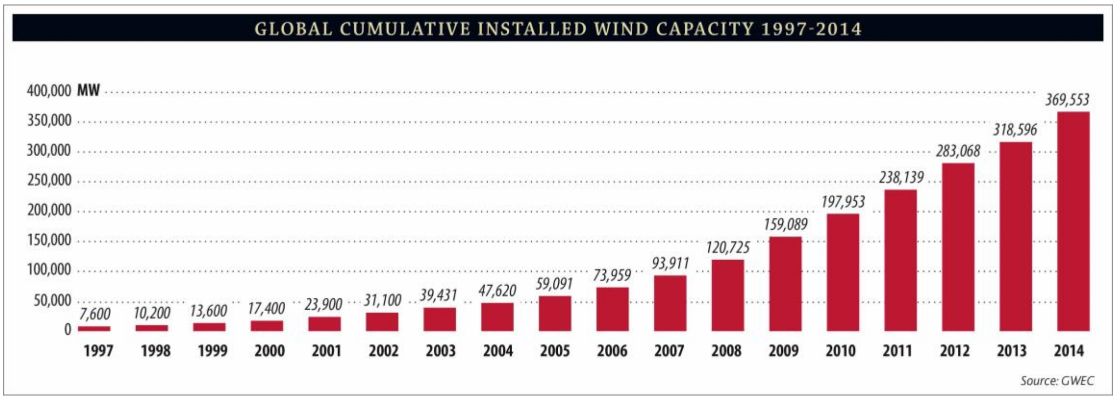

Figure1. Growth in electricity supplied by wind power generation worldwide

Source : The Global Wind Energy Council , *Global Wind Statistics 2014.*

http://www.gwec.net/wp-content/uploads/2015/02/3_global_cumulative_installed_wind_capacity_1997-2014.jpg

Question 1. Examine the locational condition or site of a wind farm for wind electrical power generation.

Figure 2 shows a wind farm for wind power generation. List and explain two reasons below why this is a good site for wind power generation.

Figure 2: An example of a wind farm

Photograph of Otonrui Wind Farm, provided by Horonobe City.

Learning outcomes to be evaluated: The ability to analyse and to examine the function and efficiency of machines by applying basic knowledge of mechanical engineering by explanation of the locational condition of a wind farm.

Underlying competence:

- BES2: The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering.
- EA2: The ability to apply knowledge and understanding to analyse engineering products, processes and methods.
- EA6: The ability to analyse mass and energy balances, and efficiency of systems.

Difficulty level: Easy

Point for grading: Lists two features out of three below or equivalent, and explains the reasons for each of them appropriately.

(a) The wind farm is located on flat land along a seashore and hence there is no obstacle to block the wind from flowing around the wind turbines.

- The wind kinetic energy can be utilized effectively with little loss because the wind directly blows against the wind turbines to a maximum degree.
- The wind turbine blades rotate freely because the wind flows around the stationarily tower and against the turbines.

(b) Many wind turbines are installed in one location.

- All wind turbines can be manufactured to the same design requirements because the local environment for all turbines is basically the same. This reduces the manufacturing and design costs required in designing and producing the turbines.

- The cost for installation and maintenance of wind turbines is reduced because many turbines are located adjacent to each other.
- The cost for installation and maintenance of accompanying facilities to recover the electric energy generated by all turbines is reduced because such facilities can be also installed on-site.

(c) No building or structure is located around the wind farm.

- A wind turbine can be designed specifically for the wind conditions at the location because there is no limitation on size of the wind turbine. This increases the efficiency in generating the electric energy.
- There is no possibility to cause damage to the neighbouring buildings or structures in case of accidents such as the collapse of wind turbine column.

Allotment of marks

4: Two features are listed and both are explained appropriately.

3: Two features are listed and one of them is explained appropriately.

2: Two features are listed but none of them is explained appropriately.

2: Only one feature is listed and explained appropriately.

1: Only one feature is listed but not explained appropriately.

0: No feature is listed.

Question 2. Examine the "shape of the blades" of wind turbines used for wind power generation.

Compare the shapes of the blades for a traditional windmill and a wind turbine shown in Figures 3a and 3b, respectively. Explain from a mechanical engineering point of view two features of blades that characterise wind turbines for wind power generation.

Figure 3a Traditional windmills.

Martijn Roos. www.mroosfotografie.nl

http://free-photos.gatag.net/2014/11/07/040000.html

Figure 3b Wind turbines used for wind power generation.

http://sozai-free.com/sozai/01541.html

Learning outcomes to be evaluated: The ability to analyse and to examine the structure and function by applying basic knowledge of mechanical engineering (especially, fluid mechanics) though explanation of the shape of blades

Underlying competence:

- BES2: The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering
- EA2: The ability to apply knowledge and understanding to analyse engineering products, processes and methods

Difficulty level: Average

Point for grading: Lists two features out of four below or equivalent, and provides explaination on the reasons for each of them appropriately.

(a) Working principle: The traditional windmill utilizes the drag forces acting on the blades to generate rotational torque, whereas the wind turbine utilizes the lift forces acting on the blades. The turbine with the lift force type of blade can produce less torque but can achieve higher rotational speed than that of the drag force type blade. The turbine with the lift force type of blade is efficient at higher rotational speeds.

(b) Aspect ratio: The blade of the wind turbine used for wind power generation is long and thin, namely has a large aspect ratio. If the aspect ratio of the blade is larger, the ratio of the lift force to the drag force (the lift to drag ratio) becomes larger, which is beneficial in starting up the turbine. A large aspect ratio is also beneficial for the strength and rigidity against the bending and torsion of the blade.

(c) Taper ratio: The blade of the wind turbine used for wind power generation is tapered towards the tip, namely it has a large taper ratio. If the taper ratio of the blade is larger, the bending moment at the root of the blade becomes smaller, which is beneficial for the bending strength of the blade.

(d) Material: It seems that the blade of the traditional windmill has a wooden frame while the blade of the wind turbine used for wind power generation is made of fibre reinforced plastics (FRP). FRP has a larger specific strength (strength per unit weight), a larger specific rigidity (rigidity per unit weight) and shows better durability compared with wood.

Allotment of marks

4: Two features are listed and both are explained appropriately.

3: Two features are listed and one of them is explained appropriately.

2: Two features are listed but none of them is explained appropriately.

2: Only one feature is listed and explained appropriately.

1: Only one feature is listed but not explained appropriately.

0: No feature is listed.

Question 3. Examine the "Number of blades" of a wind turbine for wind power generation.

From a mechanical engineering point of view, identify three advantages of having many blades or few blades, and provide possible explanation why large-scale wind turbines used for wind power generation often have three propeller type blades.

Learning outcomes to be evaluated: The ability to analyse and to examine the structure and function by applying basic knowledge of mechanical engineering though explanation of the number of blades

Underlying competence:

- BES2: The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering
- EA2: The ability to apply knowledge and understanding to analyse engineering products, processes and methods
- EA6: The ability to analyse mass and energy balances, and efficiency of systems

Difficulty level: Difficult

Point for grading: Listing three advantages/disadvantages out of seven below or equivalent, and explaining reasons why large-scale wind turbines used for wind power generation often have three propeller type blades.

Advantages of few blades:

(a) The lift force produced by each blade is large because of little aerodynamic interference between adjacent blades.

(b) The slipstream of the wind turbine is less turbulent. This means that the wind kinetic energy of the slipstream is small for a given wind kinetic energy incident on the wind turbine. Therefore, the energy efficiency of the wind turbine is large.

(c) The total drag force of the wind turbine against the wind is small, which is beneficial for the strength of the wind turbine column.

(d) The cost for producing the blades for one turbine is low.

(e) The risk of failure of the blades for one turbine is low.

Advantages of many blades:

(f) The total stability of the turbine is good because the forces acting on every blades are uniform.

(g) The turbine is easy to rotate because a large torque is produced.

Possible explanation having three propeller type blades:

Having three blades is thought to be a good compromise between the advantages and disadvantages for the wind speed are usually assumed.

Allotment of marks

4: Three advantages/disadvantages are listed.

3: Three advantages are listed but no disadvantage is listed, or vice versa.

3: One advantage and one disadvantage are listed.

2: Only two advantages are listed but no disadvantage is listed, or vice versa.

1: Only one advantage or disadvantage is listed.

0: No advantage or disadvantage is listed.

Question 4. What are the "responsibilities of a mechanical or power engineer" in designing wind turbines for wind power generation?

Only one year after the wind turbine was constructed, it became apparent that the wind velocity could be larger than assumed in the initial design. In order to prevent the collapse of wind turbine column due to strong wind, identify three potential countermeasures that are technically possible for different levels of risk. For each countermeasure, evaluate their advantages and/or disadvantages from a broad perspective, including the non-technical aspects.

Learning outcomes to be evaluated: The ability to identify an engineering problem and to propose countermeasures for the problem, and the ability to demonstrate understanding commitment to professional ethics, responsibilities and norms of engineering practice

Underlying competence:

- ED1: The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements
- EP3: The ability to demonstrate understanding of applicable techniques and methods, and their limitations
- EP4: The ability to demonstrate understanding of the non-technical implications of engineering practice

Difficulty level: Average

Point for grading: Lists three technically possible countermeasures out of five below or equivalent, and examines advantages and/or disadvantages of these countermeasures.

(a) Continuous use: Continuous use of the wind turbine is one of the possible countermeasures if the risk of collapse is very low. The cost for the immediate countermeasure is lowest but the safety of neighbours should be sufficiently secured against collapse in the worst case.

(b) Reinforcement of column: Reinforcement of the column is a countermeasure of rather low cost if the risk of collapse is not very high. The efficiency of the wind turbine would not be changed directly by this countermeasure.

(c) Replacement of blades: If the risk of collapse is not very high, the strength margin of the column could be expanded by changing the blade shapes and decreasing the total drag force. However, changing the blade shapes would decrease the efficiency of the wind turbine. It is likely to be more expensive than column reinforcement.

(d) Replacement of column: If the risk of collapse is rather high, replacement of the column is a technically possible countermeasure. However, it should require very high cost because the wind turbine would have to be scapped and new column built up again.

(e) Demolished: Whether the risk of collapse is high or low, the wind turbine should be demolished if the risk of possible damage to facilities or human injury is possible.

Allotment of marks

Give 1 point for each countermeasure technically possible. Give another 1 point if advantage and/or disadvantage are explained appropriately for each countermeasure.

The maximum score to be given is 6, that is, for three countermeasures with appropriate explanations of advantages and/or disadvantages.

Competence Framework: Mechanical Engineering

Engineering Generic Skills	
EGS1 (1)	The ability to function effectively as an individual and as a member of a team.
EGS2	The ability to use diverse methods to communicate effectively with the engineering community and with society at large.
EGS3(1)	The ability to recognise the need for and engage in independent life-long learning.
EGS4	The ability to demonstrate awareness of the wider multidisciplinary context of engineering.
Basic and Engineering Sciences	
BES1(2)	The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering. The basics of mathematics include differential and integral calculus, linear algebra, and numerical methods.
BES2	The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering.
BES3(2)	The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues: high-level programming; solid and fluid mechanics; material science and strength of materials; thermal science: thermodynamics and heat transfer; operation of common machines: pumps, ventilators, turbines, and engines.
Engineering Analysis	
EA1	The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods.
EA2	The ability to apply knowledge and understanding to analyse engineering products, processes and methods.
EA3	The ability to select and apply relevant analytic and modelling methods.
EA4	The ability to conduct searches of literature, and to use data bases and other sources of information.
EA5	The ability to design and conduct appropriate experiments, interpret the data and draw conclusions.
EA6(2)	The ability to analyse mass and energy balances, and efficiency of systems; hydraulic and pneumatic systems; machine elements.

Engineering Design	
ED1	The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements.
ED2	The ability to demonstrate an understanding of design methodologies, and an ability to use them.
ED3(2)	The ability to carry out the design of elements of machines and mechanical systems using computer-aided design tools.
Engineering Practice	
EP1	The ability to select and use appropriate equipment, tools and methods.
EP2	The ability to combine theory and practice to solve engineering problems.
EP3	The ability to demonstrate understanding of applicable techniques and methods, and their limitations.
EP4	The ability to demonstrate understanding of the non-technical implications of engineering practice.
EP5(3)	The ability to demonstrate workshop and laboratory skills.
EP6	The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice.
EP7	The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and be aware of their limitations.
EP8(2)	The ability to select and use control and production systems.

Source: OECD(2011)、 “A Tuning-AHELO Conceptual Framework of Expected/Desired Learning Outcomes in Engineering,” *OECD Education Working Papers, No.60*. OECD Publishing (http://dx.doi.org/10.1787/5kghtchn8mbn-en) (pp. 28-29, 35)

1) Despite its importance, this competence was not measured in the OECD-AHELO Feasibility Study.

2) Competences unique to the field of mechanical engineering. (In the OECD-AHELO Feasibility Study, assessment tools were developed in the field of civil engineering.)

3) In the AHELO Feasibility Study, this competence was listed not as an “engineering practice” competence, but as an “engineering analysis” competence.