DESIGN, CONSTRUCTION OF HORIZONTAL AXIS WIND TURBINE FOR THE ELECTRIFICATION OF ELECTRICAL CLASS

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Abstract : The wind turbine was proposed to be designed and constructed with an estimated power output of 65w at maximum speed and 30w at minimum speed from a generator with currents of 5.4amps to 10.8amps under the gear ratio of 1:4 However, after the work was done, the maximum power output was found to be 40w and the current of 6.7amp which is within the range. The blade is constructed from a laminated wood material with relevant diameter of 80 inches with three blades. The work was tested and mounted on the top of the building to reach the required heights of 10m. Based on the test, the efficiency of the wind turbine was found to be 56%.

***IndexTerms* - Wind turbine, power output, laminated wood, design, generator.**

I. INTRODUCTION

Wind is simply air in motion. Winds are created by the sun's uneven heating of the atmosphere in combination with the irregular surface of the earth and the earth's rotation. These winds can be "harvested" using wind turbines and used to make electricity. The force of the wind makes the wind turbine blades spin, and the energy of this motion is converted into electricity by a generator. Wind energy is a free, renewable resource. A wind turbine is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels. Wind was shown to have the "lowest relative greenhouse gas emissions, the least water consumption demands and... the most favourable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas. Wind power was probably used in Persia (present-day Iran) about 500–900 AD. The wind wheel of Hero of Alexandria marks one of the first recorded instances of wind powering a machine in history. However, the first known practical wind power plants were built in Sistan, an Eastern province of Iran, from the 7th century. These "Panemone" were vertical axle windmills, which had long vertical drive shafts with rectangular blades. Made of six to twelve sails covered in reed matting or cloth material, these windmills were used to grind grain or draw up water, and were used in the grist milling and sugarcane industries.

The first electricity-generating wind turbine was a battery charging machine installed in July 1887 by Scottish academic James Blyth to light his holiday home in Marykirk, Scotland. Some months later American inventor Charles F. Brush was able to build the first automatically operated wind turbine after consulting local University professors and colleagues Jacob S. Gibbs and Brinsley Coleberd and successfully getting the blueprints peer-reviewed for electricity production in Cleveland, Ohio. 1.1

1.2 TYPES OF WIND TURBINE

There are two main types of wind turbines:

1.2.2 Horizontal axis wind turbines (HAWT)

This is a propeller type rotor mounted on the horizontal axis. As mentioned previously, the blades need to be aligned with the wind and this is done by either a simple tail, or an active yaw. These are more efficient at producing electricity than VAWTs however they are impacted more by changes in wind direction. Horizontal axis wind turbines (HAWTs), constitute the most common type of wind turbine in use today. In fact all grids connected commercial wind turbines are today designed with propeller-type rotors mounted on a horizontal axis on top of a vertical tower. In contrast to the mode of operation of the vertical axis turbines, the horizontal axis turbines need to be aligned with the direction of the wind, thereby allowing the wind to flow parallel to the axis of rotation. Insofar as concerns horizontal axis wind turbines, a distinction is made between upwind and downwind rotors. Upwind rotors face the wind in front of the vertical tower and have the advantage of somewhat avoiding the wind shade effect from the presence of the tower. Upwind rotors need a yaw mechanism to keep the rotor axis aligned with the direction of the wind. Downwind rotors are placed on the lee side of the tower. A great disadvantage in this design is the fluctuations in the wind power due to the rotor passing through the wind shade of the tower which gives rise to more fatigue loads. Theoretically, downwind rotors can be built without a yaw mechanism, provided that the rotor and nacelle can be designed in such a way that the nacelle will follow the wind passively. This may, however, induce gyroscopic loads and hamper the possibility of unwinding the cables when the rotor has been yawing passively in the same direction for a long time, thereby causing the power cables to twist. As regards large wind turbines, it is rather difficult to use slip rings or mechanical collectors to circumvent this problem. Whereas, upwind rotors need to be rather inflexible to keep the rotor blades clear of the tower, downwind rotors can be made more flexible. The latter implies possible savings with respect to weight and may contribute to reducing the loads on the tower. The vast majority of wind turbines in operation today have upwind rotors.

1.2.2 Vertical axis wind turbines (VAWT)

Vertical axis wind turbines (VAWTs), such as the one with C shaped blades, are among the types of turbine that have seen the light of day in the past century. The machine, which is the world's largest wind turbine, is no longer operational. Classical water wheels allow the water to arrive tangentially to the water wheel at a right angle to the rotational axis of the wheel. Vertical axis wind turbines are designed to act correspondingly towards air. Though, such a design would, in principle, work with a horizontal axis as well, it would require a more complex design, which would hardly be able to beat the efficiency of a propeller-type turbine. The major advantages of a vertical axis wind turbine, that the generator and gearbox are placed on the ground and are thus easily accessible, and that no yaw mechanism is needed. Among the disadvantages are an overall much lower level of efficiency, the fact that the turbine needs total dismantling just to replace the main bearing, and that the rotor is placed relatively close to the ground where there is not much wind.

These are aligned in the vertical axis (like the rotor blades on a helicopter). These are only really deployed within urban areas, where the flow of air is more uneven. Due to their alignment, wind direction.

1.3 USES OF WIND TURBINE

1. Wind energy facilities convert energy from the motion of wind into electricity that is sent to energy consumers via electric transmission systems.
2. Wind turbines can convert the energy in the wind into mechanical power that can be used for a variety of activities like pumping water.

Advantages and of Wind-Generated Electricity

1.3.1.1 A Renewable Non-Polluting Resource

Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. According to the U.S. Department of Energy, in 1990, California's wind power plants offset the emission of more than 2.5 billion pounds of carbon dioxide, and 15 million pounds of other pollutants that would have otherwise been produced. It would take a forest of 90 million to 175 million trees to provide the same air quality.

1.3.2 Disadvantages

1.3.2.1 Cost Issues

Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators. Roughly 80% of the cost is the machinery, with the balance being site preparation and installation. If wind generating systems are compared with fossil-fueled systems on a "life-cycle" cost basis (counting fuel and operating expenses for the life of the generator), however, wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses.

1.3.2.2 Environmental Concerns

Although wind power plants have relatively little impact on the environment compared to fossil fuel power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and birds and bats having been killed (avian/bat mortality) by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

1.3.2.3 Supply and Transport Issues

The major challenge to using wind as a source of power is that it is intermittent and does not always blow when electricity is needed. Wind cannot be stored (although wind-generated electricity can be stored, if batteries are used), and not all winds can be harnessed to meet the timing of electricity demands. Further, good wind sites are often located in remote locations far from areas of electric power demand (such as cities). Finally, wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued than electricity generation. However, wind turbines can be located on land that is also used for grazing or even farming.

II. RESEARCH METHODOLOGIES

Materials and methods

Materials and methods in every design of any component be it mechanical or any other types of the parts, choice of the material is necessary for design to conform and served for the purpose it designed to be. Choice of the suitable materials can be considered as a basic step to design a product that can perform the function as it required. Below are the types of materials and reasons of selecting the materials that is required in this wind turbine project.

1. Mild steel
2. Wood
3. Electrical copper wire (cables)

1.4.1.1 MILD STEEL

Mild steel is a type of carbon steel with a low amount of carbon – it is actually also known as “low carbon steel.” Although ranges vary depending on the source, the amount of carbon typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having a carbon contents from 0.30% to 2.0%. If any more carbon than that is added, the steel would be classified as cast iron. Mild steel is not an alloy steel and therefore does not contain large amounts of other elements besides iron; you will not find vast amounts of chromium, molybdenum, or other alloying elements in mild steel. Since its carbon and alloying element content are relatively low, there are several properties it has that differentiate it from higher carbon and alloy steels.

Less carbon means that mild steel is typically more ductile, machinable, and weldable than high carbon and other steels; however, it also means it is nearly impossible to harden and strengthen through heating and quenching. The low carbon content also means it has very little carbon and other alloying elements to block dislocations in its crystal structure, generally resulting in less tensile strength than high carbon and alloy steels. Mild steel also has a high amount iron and ferrite, making it magnetic. The lack of alloying elements such as those found in stainless steels means that the iron in mild steel is subject to oxidation (rust) if not properly coated. But the negligible amount of alloying elements also helps mild steel to be relatively affordable when compared with other steels. It is the affordability, weldability, and machinability that makes it such a popular choice of steel for consumers. The reason for selecting mild stell are:

1. Weldability
2. Machinability
3. Cheaper

4. Easy to manipulate because of its low carbon contents
5. Flexibility
6. Availability

1.4.1.2 WOOD

Several species of wood can be used for wind turbine blades. Wood is applied as plywood or in lamellas to minimize the impact of imperfections like knots on the strength. It is important for the resistance of the wood that the water content is low. High water content will result in low mechanical values, rot and fungus. The humidity shall be controlled during storage and manufacturing. Coating and sealing shall be qualified as part of design to govern the long-term water content in the wood. Choosing Wood for Wind Turbine Blades Red Cedar is an excellent wood for wind turbine blades. It is easy to carve, has few knots and a nice grain, it is relatively inexpensive, and it is very strong and durable. Therefore it is much easier and cheaper to purchase standard lengths of 2×4 cedar and glue (laminate) them together. Standard woodworker's polyurethane glue and a load of clamps is all you need for this job. The reasons for selecting wood are:

1. Flexibility
2. Availability
3. Lighter
4. Cheaper
5. Suitability

1.4.1.3 CABLE WIRE (COPPER WIRE)

Copper is a vital metal in making wind power possible. The outdoor environment places great demand on cables, connectors, and generator windings used for wind power installations, especially for those situated offshore.

Copper is used in:

1. generator windings
2. power cables
3. Earthing and lightning protection
4. transformers
5. control systems

1.5 Generator / Alternator

An alternator is an electrical generator that converts mechanical energy to electrical energy in the form of alternating current.[For reasons of cost and simplicity, most alternators use a rotating magnetic field with a stationary armature.Occasionally, a linear alternator or a rotating armature with a stationary magnetic field is used. In principle, any AC electrical generator can be called an alternator, but usually the term refers to small rotating machines driven by automotive and other internal combustion engines.

III. BASIC EQUATIONS OF WIND TURBINE

Power = = ½ ρ $\times V^3 \times A \times CP$, where

ρ =density of air

A= Swept area = $A = \pi r^2$(m^2)

V= wind speed (m/s)

Cp= power coefficient =PT/PW

P= power

W= work done= force x distance

PT= work done/time

1V. Wind Energy Assessment of Kazaure Town in Jigawa State and analysis.

The wind assessment of Kazaure was measured and data was collected in the years between January 2017 to December 2019 at mean wind speed data measured at 10m height was collected and extrapolated to 50m height level for statistical analysis, the minimum Weibull average wind speed was found to be 8.60m/s and the maximum average wind speed was 11.24m/s while the maximum power density was 440.03w/m 2 and the highest was 947.26w/m 2 at the 10m height level.

2.0 Energy Audit of the Class

The energy audit of the electrical class at department of electrical engineering Hussaini Adamu Federal Polytechnic Kazaure, was calculated below based on the load that the wind turbine can afford for the requirement of the power needed.

Number of bulbs 8
Number of watts for each bulb 5w
Number of class is one
Overall power used for the class
Energy consumed = number of bulbs x number of watts
= 8 x 5
= 40Watts

2.1 CURRENT USED

Using the formular
P = V2/R
Where
V = 12V
R =?
P = 40W
R = V/P = 122/40
= 144/40

= 3.6
Total resistance is R= 3.6
Therefore to find the current
I = V/R = 12/3.6
I = 3.3A

2.2 Power coefficient of the turbine

Power = = ½ ρ ×V 3×A×CP
Cp= power coefficient =PT/PW
Where
PW = work done/time
Work done = force x distance
F =mass x acceleration
Acceleration = velocity/time
= 8.6/60
= 0.143m/s2
F =mass x acceleration where 4kg is the mass of the blade
= 4kg x 0.143m/s2
= 0.572N
Work done = force x distance
= 0.572 x 2.032
= 1.162Nm
PW = work done/time = 1.162/60 = 0.0193w
Power extracted by the turbine PT= work done / time
F =mass x acceleration
= 0.3 x 0.572N
= 0.1716Nm
Work done = force x distance
= 0.1716n x 2.032
= 0.3486Nm
PT = work done/time
= 0.3486/60
= 0.0058Nm/s
CP = PT/PW = 0.0058/0.0193
= 0.3011

2.3 IDEAL POWER

Ideal power =½ ρ ×V ^{3}×A
Where = $A = \pi r^2$
= 3.142 x 1.016^2
= 3.142 x 1.0322
= 3.2433m^2
Ideal power =½ ρ ×V ^{3}×A
= ½ x 1.22 x 8.6^3 x 3.2433m^2
= ½ x 1.22 x 636.056 x 3.2433
= 2516.7629 watts

2.4 ACTUAL POWER

Actual power
P= ½ ρ ×V ^{3}×A×CP
= ½ x 1.22 x 8.6^3 x 3.2433m^2 x 0.3011
= ½ x 1.22 x 636.056 x 3.2433 x 0.3011
= 757.797/2
=378.8986W
= 0.3788KW
Efficiency of a turbine is Overall efficiency is = cp x electrical machine efficiency
Electrical machine efficiency is= power output/power input
= 75/40
Overall efficiency = 0.3011 x 75/40 x 100
= 56.45
= 56%

IV. RESULTS AND DISCUSSION

The results was obtained successfully where different parameters measured and tested with no problem encountered in the process of obtaining the exact value of the calculated terms practically.

The design and construction of a wind turbine is achieved based on the requirements of the horizontal axis wind turbine for the production of a direct current D.C to the direct appliances and for the electrification of electrical Engineering Department. The turbine is set and installed on top of the building. The system contains difference LED signal that control the flow of current from the turbine to the battery and from battery to the appliances, so as to indicate any failure, overcharge or undercharge. All possible measurement and tests were carried out to ensure that the system is working efficiently based on the maintenance and the safety precaution towards the lifespan of the wind turbine (horizontal axis wind turbine). This is to ensure that the aim and objectives of this design was achieved successfully.

TABLE OF RESULTS

1	Wind speed m/s	8.6m/s
2	Output E.m.f (volt)	12V
3	Output current (I) I = V/R	6.7A
4	Ideal power Ideal power =½ ρ ×V ^{3}×A	2516.7629 watts
5	Actual power P= ½ ρ ×V ^{3}×A×CP	378.8986 watts
6	Electrical resistance R = V^{2}/P	1.8 ohms
7	Power	40watts
8	Efficiency of the turbine	56%

REFERENCES

[1] AHMAD, Y. H. and Donald R.H. (1986). An illustrated history power. 54. Cambridge University Press, England, ISBN 0-521-42239-6.

[2] Anan, N. and Brush, M. (1890). Windmill Dynamo': Scientific American, vol 63 no. 25, 20, p. 54], U.S.A

[3] Apan, p. (2011). Floating Wind Power Plant". Breakbulk. Hywind Scotland, Scotland. P 32.

[4] Cavey, J. L. (2004). "The 800 KVA BEST: " Romani Aerogenerator". ISBN 198-423-01, france.

[5] Charles, F. B. (2008). A Wind Energy Pioneer: the Wayback Machine., Danish Wind Industry Association. San Francisco, California, United States.

[6] Clive, P. J. M. (2014). The emergence of eolics, TEDx University of Strathclyde , Glasgow, United Kingdom Retrieved 9 May 2014.

[7] Clive, P. J. M. (2008). Windpower 2.0: technology rises to the challenge Environmental Research Web, Retrieved: 9 May 2014. IOP Publishing at institute of physics, united kingdom.

[8] Danish, E. A. (2000). Technical Criteria for the Danish: Approval Scheme for WindS Turbines; middle east and central asia

[9] Dansk, E. and Forenings, U. (1999). Lightning protection of wind turbines, 25, Edition, P 34, germany.

[10] Det, N. V. and Hovik, N. (2000), Environmental Conditions and Environmental Loads, Classification Notes No. 30.5.

[11] Dietrich, L. (1995). ; westlichen Windmill, Archiv für Kulturgeschichte, china Vol. 77, pp.1-30 (18ff.)

[12] Dimitri, R. S. (1946). Pioneer in the North Sea: Insel Neuwerk Turbine, in IEEE Power and Energy Magazine, united state department of energy, pp. 62-68

[13] Donald, R. H. (1991). "Mechanical Engineering in the Medieval Near East", Scientific American, U, S , p. 64-69. at the Wayback Machine.)

[14] Drachmann, A. G. (1961). Heron's Windmill, Centaurus press, Islamabad Pakistan, 7 pp. 145-151

[15] DS, 412. (1998). The Danish Code of Practice for Loads for the structural use of steel, in turbines Dans Ingeniorforening.; pp221-229,

[16] Eggleston, D. M. and Stoddard, F. S. (2007). Wind Turbine Engineering Design, Van Nostrand Reinhold Co. Inc., New York, N.Y.
[17] Energy Kite Systems http://www.energykitesystems.net
[18] Erich, H. (2006). Wind turbines: fundamentals, technologies, application, economics, Birkhäuser, england, ISBN 3-540-24240-6, page 32,
[20]Systems, (1999). Wind turbine power performance testing. part 12 1st edition.
[21] The World Wind Energy Association (2014). 2014 Half-year Report. WWEA. pp. 1–8.
[22] Thomsen, K. (1998).The Statistical Variation of Wind Turbine Fatigue Loads, Riso National Laboratory, at the Technical University of Denmark Riso-R-1063(EN).
[23] Warnes, k. and Poul, C. (2013). "Pioneered Wind Mill Power in Denmark", Denmark, Retrieved 20 January 2013.
[24] www.gwec.net/global-figures/wind-in-numbers/