The University of British Columbia

EECE 492

Wind Power Energy Generation

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Abstract

This report examines the wind power systems, with a particular focus on wind turbine systems. It begins with a brief background with regards to wind power generation systems. The two types of wind turbines, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT) are compared. Also, the components which compose a wind turbine are examined in detail with their functionalities. Lastly, there is a quick overview with respect to cost analysis and where wind power systems are recommended.

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List of Abbreviations

AC	Alternating Current
DC	Direct Current
HAWT	Horizontal Axis Wind Turbines
KW	Kilowatts
KWh	Kilowatt hours
MPH	Miles Per Hour
VAWT	Vertical Axis Wind Turbines

1: Introduction

In the past few decades, the topic of renewable energy has become popular worldwide amongst engineers. Power generation consisted of creating much harm to the environment as the systems produced many harmful chemicals such as greenhouse gases. Engineers are focusing on determining alternative ways to generate power without any or little harm to the environment. The system that will be looked at in this report is wind power generation.

This report will consist of some background information with regards to wind power generation. Next, it will display the components that compose the wind power generation system. Moreover, it will go over the advantages and disadvantages of wind power generation system. Lastly, there will be some calculations with respect to the costs associated with wind power generation.

2. Wind Power

Wind power energy has been in effect since early 5000 B.C. when wind energy propelled boats in the Nile River. Next, in 200 B.C. simple windmills began to pump water in China. Nevertheless, the first practical windmill wasn't made until the 7th century of our current era in Afghanistan [1]. It wasn't until the 1300's when the configuration of the windmill was transformed from the vertical formation to the horizontal formation. The Dutch were the first to apply this transformation to windmills [2]. Basically the Dutch affixed the standard post mill to the top of a multi-story tower, having different floors dedicated to grinding grain, removing chaff, storing grain, and living quarters for the windsmith and his family on the bottom floor [2]. However, it wasn't until the 1800's until the first large windmill was produced for the purpose of generating electricity. There were two large windmills created simultaneously to generate electricity. One was built in 1887 in Scotland by prof. James Byth in the garden of his cottage and it was used to generate power for his cottage. This was the first house in the world to have electricity which was generated through wind power. The next one was built in 1888 in Ohio by Charles F. Brush which was connected to a dynamo which was able to charge a bank of batteries to operate up to 100 incandescent light bulbs, three arc lamps, and various motors in his laboratory [1].

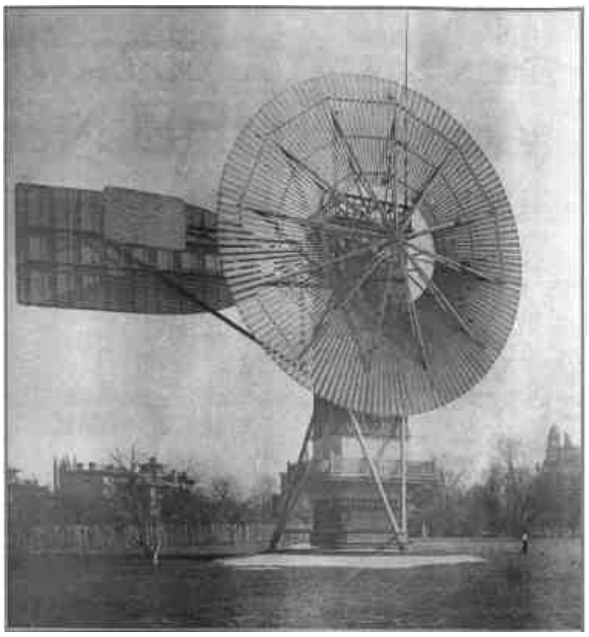

Figure 2.1: Brush Windmill

Wind power generation is rapidly growing as fossil fuels are depleting at a hastily rate. As environmental concerns are becoming a worldwide topic, engineers have no choice but to research and uncover alternative methods to generate energy which has minimum harm to the environment. Wind power is expected to grow worldwide in the twenty-first century [3].

3. Wind Turbines

3.1. Configurations

Wind turbines can be configured or arranged in two different ways: Horizontal Axis Wind Turbines (HAWT), and Vertical Axis Wind Turbines (VAWT). The two configurations will be discussed in further detail in the next section.

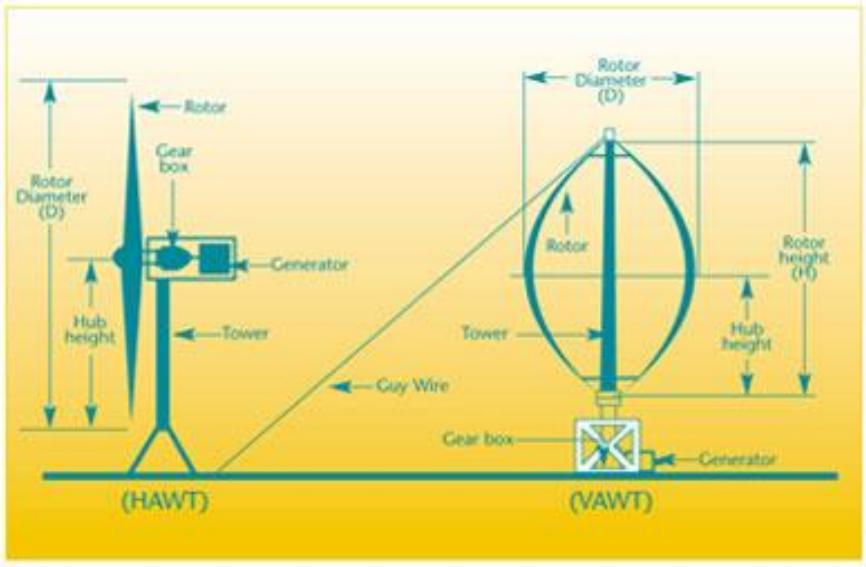

Figure 3.1: HAWT vs. VAWT

3.1.1. HAWT

HAWT have the main rotor shaft and electrical generator at the top of a tower. The advantage of the HAWT includes it allowing the angle of attack to be adjusted so that the turbine is able to capture the maximum amount of wind energy. Also, another advantage is the ability to pitch the rotor blades in a storm so that the damage is minimized [4]. The biggest disadvantage

of the HAWT is that is to be directed towards the wind. This causes the whole system to be in a consistent rotation [5].

Figure 3.2: HAWT

3.1.2. VAWT

VAWT have the main rotor shaft arranged vertically. The rotor rotates around the tower and allows the wind to be collected from any direction. The main advantage of the VAWT is that all of the components are located on the ground and are easily accessible for maintenance [6]. VAWTs have the capability to produce electricity at lower wind speeds due to the fact that the orientation of their rotors allows them to rotate much easier. The main disadvantage is that they are less efficient than HAWTs because of the additional drag that they have as their blades rotate into the wind [6].

Figure 3.3: VAWT

3.2. Components

The main components that the wind turbine includes are the rotor, the blades, the tower, and the generator. The components will be discussed in further detail in the following section.

3.2.1. The Rotor

The rotor is the portion of the wind turbine that collects from the wind. The rotor consists of multiple blades, coordinated in a way so when the wind blows it causes the rotor to turn, therefore driving the whole system. These blades are shaped in a way so that it will be the most efficient and the maximum amount of wind is captured, and they are capable of withstanding different types of weather.

3.2.2. The Blades

Blades use a technique very similar to the way airplanes move through the sky. The design of the blade is in a way so that the speed of the tip of the blade relative to the speed of the air is given as the ratio called tip-speed-ratio. The blades of the rotor are connected to a hub that is then connected to the main shaft of the turbine. The hub is fixed to the rotor shaft which drives the generator through a gearbox.

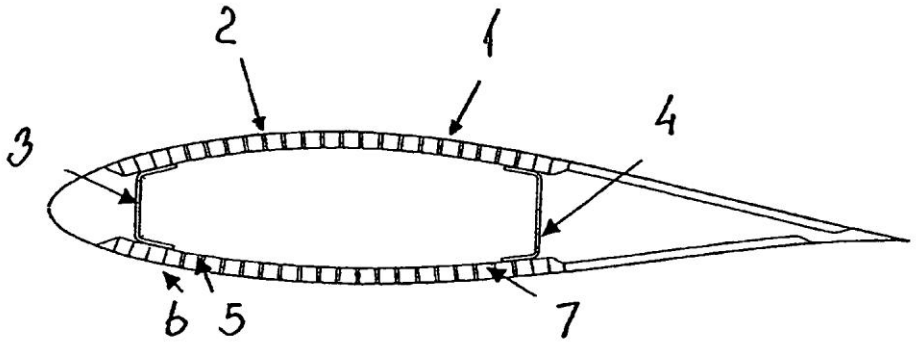

Figure 3.4: Wind Turbine Blade

3.2.3. The Tower

Towers are very important when it comes down to selecting the proper height and type both for safety aspects and environmental aspects. Generally speaking, the taller the tower, the more power it will be capable of generating. There are three basic types of towers: Tilt-up towers, fixed, guyed towers, and freestanding towers [8]. The advantages and disadvantages of these three different types of towers can be seen in table 3.1.

Tower Type	Advantages	Disadvantages
Tilt-up	No climbing	Large footprint
	Maintenance on ground	Four sets of guy wires
	Medium cost	Need relatively level site
	Pipe locally available	Cannot climb for minor work
		Takes longer to assemble
Fixed, guyed	Modest footprint	Three sets of guy wires
	Lowest cost	Must climb
	Uneven sites OK	Crane cost
Freestanding	Small footprint	High cost
	No guy wires	Must climb
	Uneven sites OK	Cost of crane installation
	Safest installation (crane)	

Table 3.1: Tower Type Advantages and Disadvantages

3.2.4. The Generator

The generator is usually mounted in a nacelle at the top of the tower, behind the hub of the turbine rotor. Wind turbines usually turn at the speed at which the turbine produces electricity most efficiently. According to the demand of the consumers, the turbine can be fitted with an alternator, thus producing an alternating current (AC) or generator, which then creates a direct current (DC).

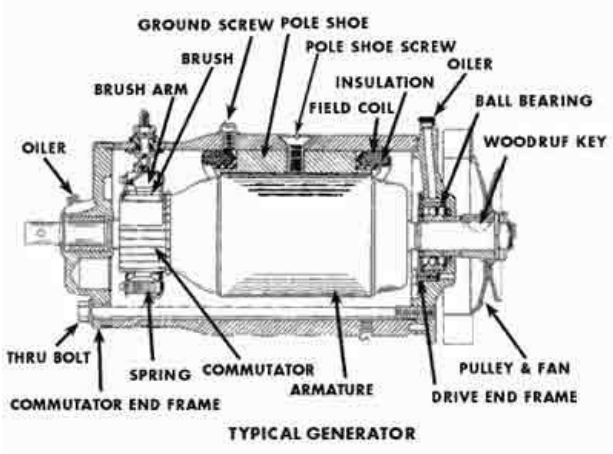

Figure 3.5: Generator

4. Cost Analysis of Wind Power

The implantation of wind power to generate electricity for your household has both its advantages and its disadvantages. Residential wind turbine systems are much less expensive than solar panels and geothermal systems, which are seemed as their eco-friendly counterparts. Before obtaining the total cost, average wind speed, cost to connect system to grid, Provincial and Federal tax rebates/incentives, and the cost of capital must be considered.

4.1. Average Wind Speed

The wind speed has to be taken into consideration due to the fact that it has the biggest effect on the system. If the wind speeds in your area is insufficient to turn the blades fast enough to generate electricity, then your investment is basically wasted. There is always the risk that optimum energy production will not always be achieved due to the fact that wind is an unpredictable part of our weather. It is recommended to consult a detailed map that charts the local winds in your area to determine if a wind turbine system to generate electricity is feasible

4.2. Cost to Connect System

The connection of a wind turbine system to a power grid is a great idea if your site if already connected to the public utility grid. Utility systems in many provinces are permitted to connect your wind turbine system to the grid. This will be beneficial for both the consumer and the utility provider.

4.3. Provincial and Federal Tax Rebates

The benefits of producing or generating your own electricity will not only be advantageous for the environment but it will also save you money. There are many programs both provincially and federally speaking, that provide incentives and rebates towards the consumer for choosing a "green" alternative [10].

4.4. Capital Cost

The wind turbine system that I used for this analysis is manufactured by Bergey Wind Co. The Bergey 1KW system is rated to generate about 156 KWh per month assuming an average wind speed of 25 mph. Using a more realistic assumption, The system would generate 100 KWh for wind speeds of 14 mph. This results in the average home to utilize about 750 KWh a month in energy. The installation of the system with the original cost is $6000 USD. This results in $0.26 per KWh.

5. Conclusion

Upon considering the report above, we can conclude that the installation of wind turbine systems for a household can greatly affect the environment the consumer. There are costs that come with the system such as maintenance and installation costs, along with some risks due to the fact that wind conditions can be inconsistent depending on your location. The overall view will result in a positive means.

The research and results of this study indicate wind power is a popular topic in this century and it is an excellent source of alternative energy. Wind power has been in existence since the beginning of history and it has evolved and expanded as technology advanced. In the twenty-first century, wind power is expect to grow worldwide as fossil fuels are depleting at a rapid rate. The investment into wind power systems will be a great success in the long run as it will provide benefits for the consumers and the environment. However, this method should be only implemented in regions where there is constant wind with reasonable speeds. In conclusion, wind power generation systems have been proven to be an outstanding method of eco-friendly energy generation which also generate financial savings; hence they should be considered as an alternative investment for residents who possess the necessities for this type of energy.

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