A Review On Design Of Wind Turbines For Renewable Energy Generation

Er. Rashi Mathur, Er. Vikas Mathur

Jodhpur.

Abstract:

This research paper presents a comprehensive study on the design, performance analysis, and optimization of wind turbines for renewable energy generation. The paper discusses the key aspects of both technologies, including design principles, operational efficiency, environmental impact, and economic feasibility.

Introduction:

Importance of renewable energy sources in mitigating climate change:

The importance of renewable energy sources in mitigating climate change cannot be overstated. These sources of energy play a crucial role in addressing the challenges of climate change for several key reasons such as :

1. Reduction of Greenhouse Gas Emissions
2. Clean and Sustainable Energy Supply
3. Air and Water Quality Improvement
4. Adaptation and Resilience
5. Job Creation and Economic Benefits
6. Global Energy Independence
7. Technological Advancements
8. Mitigation of Land and Water Resource Impacts

Significance of wind turbines in the renewable energy landscape

1. Abundant and Inexhaustible Resources:
    - Wind, which power wind turbines are abundant and virtually inexhaustible energy resources. They are available in many parts of the world, making them reliable sources of renewable energy.
2. Zero Greenhouse Gas Emissions:
    - Wind generation produce little to no direct greenhouse gas emissions. This does not release carbon dioxide (CO_2) or other pollutants, contributing to climate change mitigation and improved air quality.
3. Reduced Dependence on Fossil Fuels:
    - Wind turbines reduce our reliance on fossil fuels, such as coal, oil, and natural gas, which are finite resources associated with environmental degradation and supply volatility.
4. Energy Independence:
    - By harnessing wind locally, communities and nations can enhance their energy independence and security, reducing vulnerability to energy supply disruptions and price fluctuations.

5. Economic Benefits:
   - The wind energy industries create jobs and stimulate economic growth. They offer opportunities for manufacturing, installation, maintenance, research, and development, contributing to local and national economies.
6. Technological Advancements:
   - Ongoing research and development have led to significant improvements in wind turbine technologies. These advancements have increased efficiency, lowered costs, and expanded the range of applications.
7. Energy Access:
   - Wind energy can be deployed in remote or off-grid locations, providing clean and reliable power to areas with limited access to electricity, which can improve the quality of life and promote economic development.
8. Environmental Benefits:
   - Wind turbines have a lower environmental impact compared to many other energy sources. They consume fewer resources and have less habitat disruption. Wind turbines can even serve as habitats for certain bird species.
9. Grid Integration and Energy Storage:
   - Innovations in grid integration and energy storage technologies are making it easier to manage the intermittent nature of wind, ensuring a stable and reliable electricity supply.

Types of Wind Turbine

Wind turbine turns around their horizontal or vertical axis's. Also they can also include blade or not. Therefore, we have to classify them.

1. Horizontal Axis
2. Vertical Axis

1.Horizontal Axis:

Large Three Bladed Horizontal Axis wind turbines can be given as an example. These turbines have a tower that has rotor shaft and electrical generator system at the centrum. And these parts must be pointed into the wind. This situation can be solved by wind vane for small turbines but large turbines generally use wind sensor in order to solve the problem.

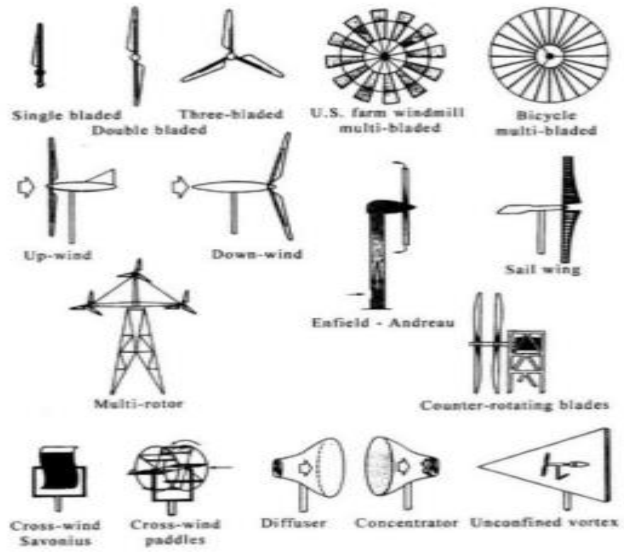

Figure 1 : Horizontal Axis Turbine

Most horizontal axis turbines have their rotors upwind of the supporting tower. Downwind machines have been built, because they do not need an additional mechanism for keeping them in line with the wind. In high winds, the blades can also be allowed to bend, which reduces their swept area and thus their wind resistance.

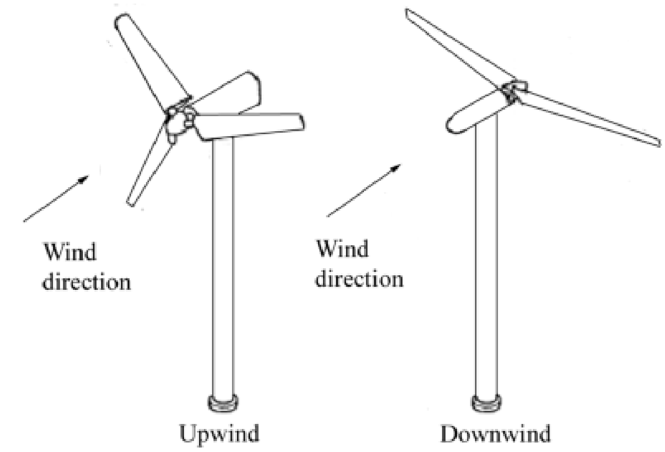

Figure2: Upwind and Downwind

For wind farm type horizontal axis turbines, three blades are usual. Because, these have low torque ripple, which helps to good reliability. The blades usually colored white because planes need to see them.

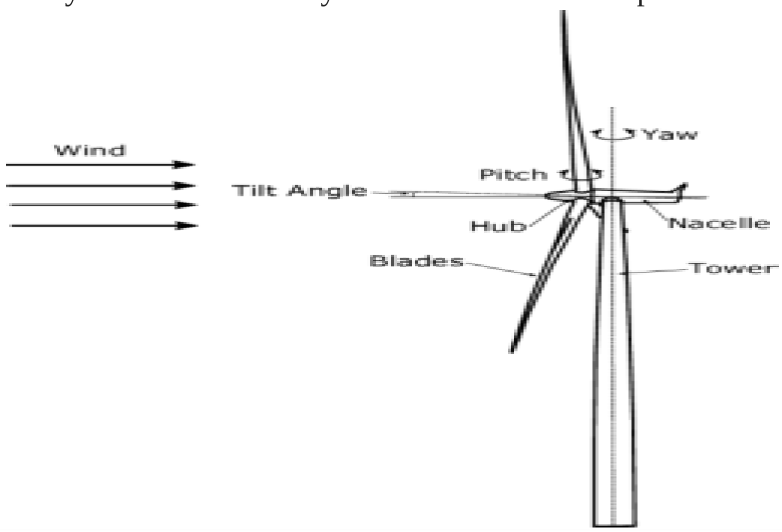

Figure.3: Horizontal Wind Turbine

2.Vertical Axis

Vertical-axis wind turbines have the main rotor shaft positioned vertically. One advantage of this method is that the turbine does not need to be pointed into the wind to be effective and this give us advantage for changeable wind direction areas. Also, the generator and gearbox can be positioned near the ground. Therefore, maintenance of gearbox and generator can be easily completed. However, these type of turbines produce much less energy than horizontal axis.

Subtypes of vertical axis wind turbines:

Darrieus Wind Turbine: They are efficient enough, but produce large torque ripple and cyclical stress on the tower, which causes poor reliability. Also they have to take extra force at the start of motion because their starting torque is very low.

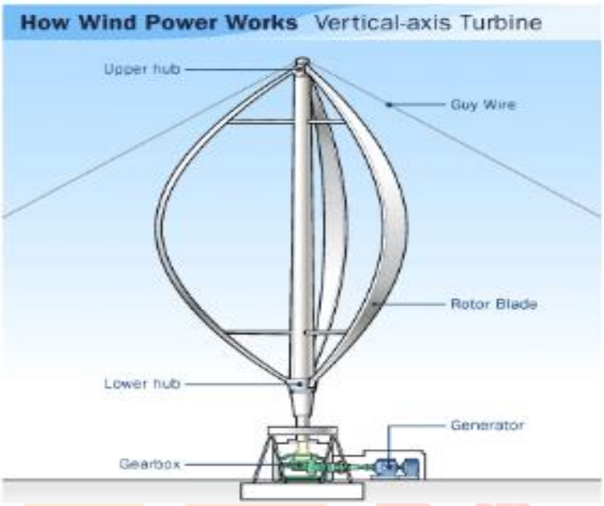

Figure.4:Working Principle of Darrieus Vertical Axis Wind Turbine

Giromill Wind Turbine: A subtype of Darrieus turbine with straight, as opposed to curved, blades. The cycloturbine variety has variable pitches to reduce the torque pulsation and it is self-starting.

Figure.5: Giromill Wind Turbine

Savonius Wind Turbine: These are drag-type devices with two (or more) scoops that are used in anemometers, and in some high reliability low efficiency power turbines. They are always self-starting if there are at least three scoops.

Figure.6: Savonius Wind Turbine

Parts of Wind Turbine

As mentioned before wind turbine converts wind energy's kinetic energy to mechanical energy and mechanical energy to electrical energy. Nowadays the industry has lots of wind turbine types. Nevertheless, wind turbines share the same components every brand.

General turbine components below disclosed.

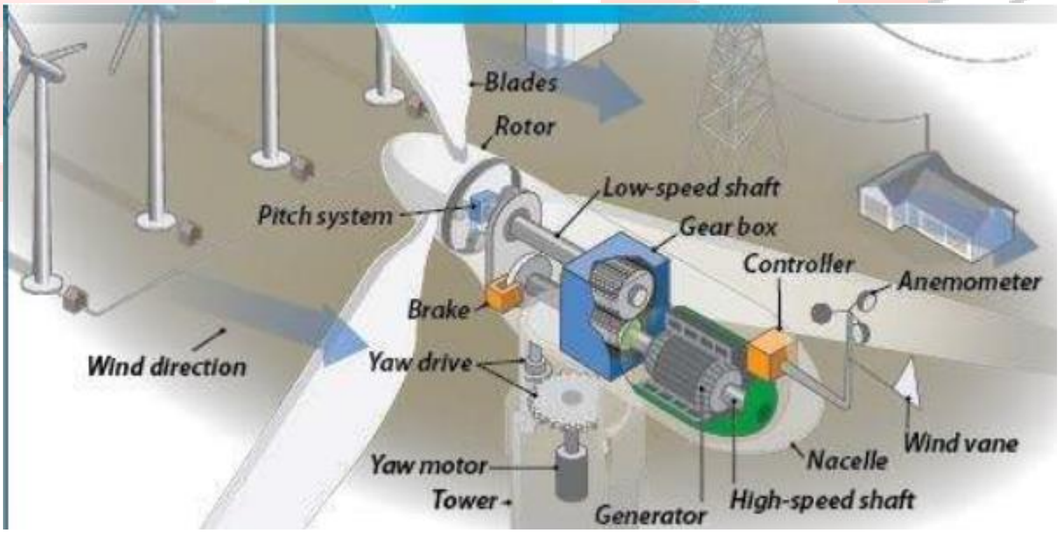

Figure.7: Wind Turbine Components

Tower

The tower is the largest and heaviest part of the wind turbine. Generally, tower has cylindrical conical but manufacturing of the tower is very hard and it cost directly to cost. Height of the towers are generally 20 meters starting up to 100 meters. The towers, which are very large in size, are manufactured as modules are combined where the turbine will be erected.

Figure.8: Tower Types in Wind Turbines (Steel Cage and Cylindrical Tube)

Blades

Rotor blades are the point where the wind turns kinetic energy into mechanical energy. When the wind forces the blade to move, some of the wind energy is transferred to the rotor. Wings can be fixed or angled. This is an important feature for the braking mechanism. Furthermore, it is also facilitated to start when the mechanism starts. For wings, another issue is that the cross-section changes when moving from tip to root.

Effect of the blade number:

- Lift/Drag ratio (L/D)
- Wing tip speed ratio (λ)
- Cost
- Connecting angle
- Sound pollution
- Desired Weight level
- Desired output power level

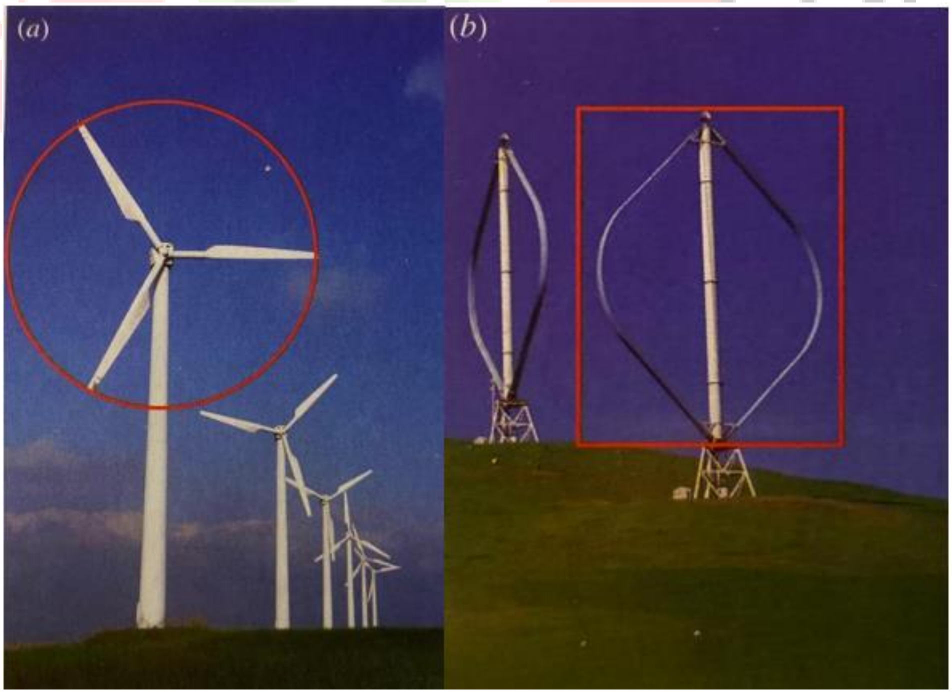

Figure 9 : Two different turbines blades and sweep areas

The torque we get from the blades is a low rpm suitable for the generator. Generators will have an average of 1200-1550 revolutions per minute they must have a spin to produce energy. The inside of the gearbox, we can separate it as low speed shaft, gearbox and highspeed .With the rotation of the propellers, torque is transferred from the hub to the low-speed shaft section where it will turn 50 times faster sent to high speed shaft section. Thus, our output to the required 1200-1500 revolutions provided. In emergencies, stopping with mechanical brakes inside the gearboxes can be provided and necessary repairs can be made.

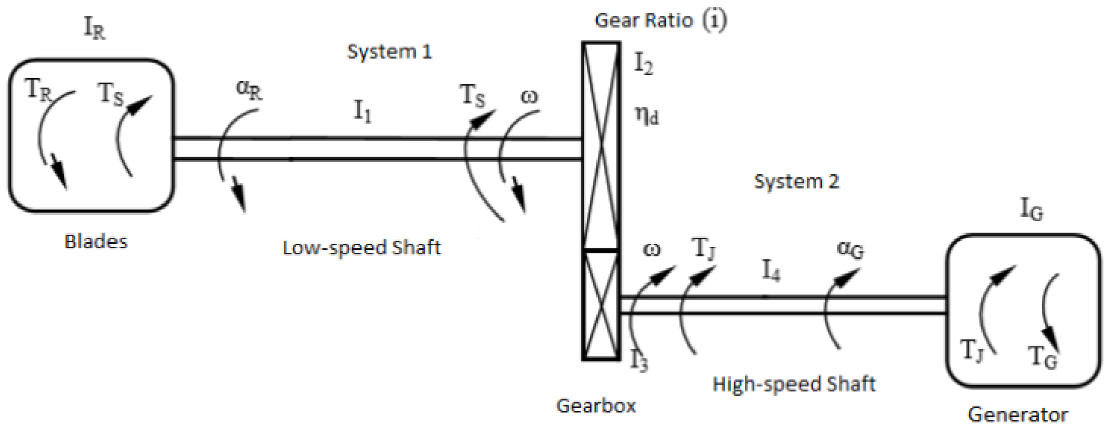

Figure.10: Wind Turbine Gearbox

Generator

The generators used can be alternating current or direct current generators. Electric power will be obtained, even if there is an insufficient alternative current or direct current, these currents can be made suitable with electronic devices. Generally, direct current generators are not used in large wind energy. Because economically alternative current generators are more price/ performance efficient. Direct current generators are used in small diameter wind turbines. And some wind turbines have two generators for low and high currents.

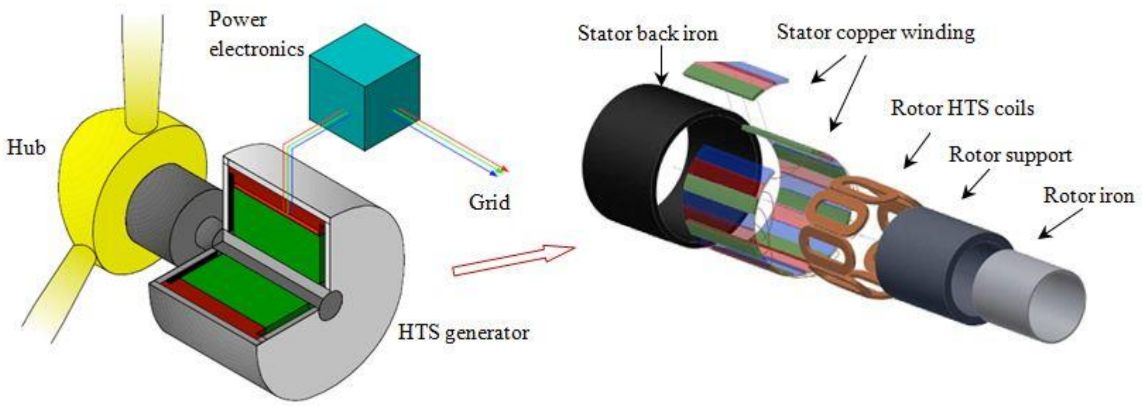

Figure.11: Wind Turbine Generator

Brake System

Braking systems of the latest and modern turbines are divided into two. The aerodynamic braking system is based on turning the blades about 90 degrees on the longitudinal axis side or rotating the blades 90 degrees. The fact that the wings are fixed or angled is a factor affecting the aerodynamic brake design.

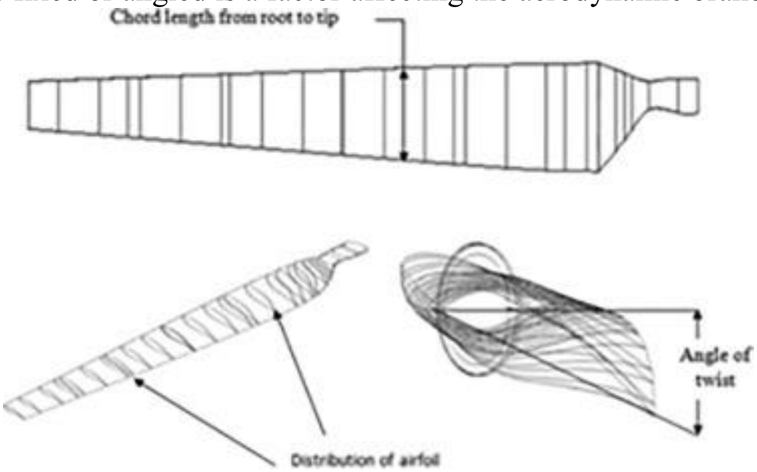

Figure.12 Aerodynamic braking system

In the mechanical braking system, another braking system, the situation consists of slowing down and stopping the turbine in a controlled manner which helps streamline braking. It is used to control the speed control event, which we will see in our next tit les. The mechanical brake system is placed inside the gearbox.

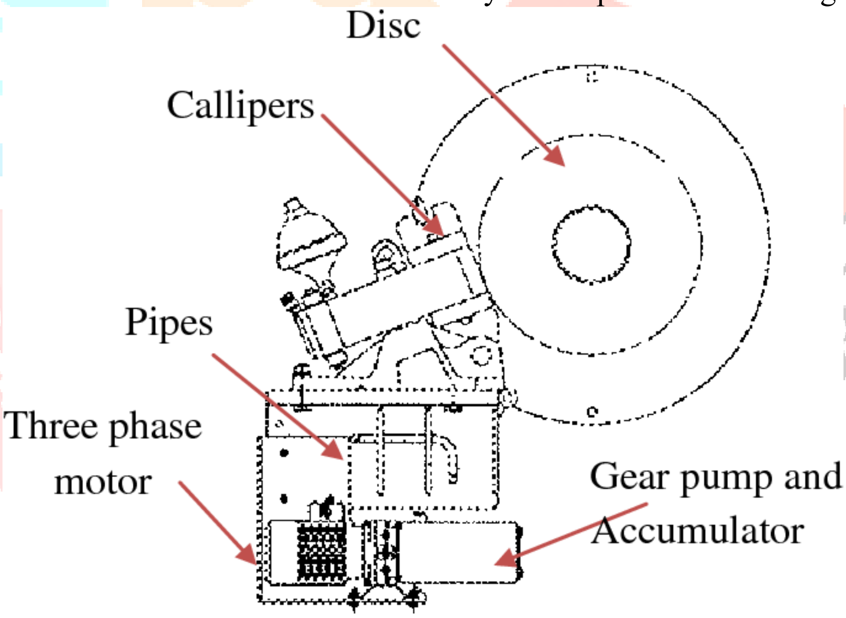

Figure.13: Mechanical braking system

YAW Mechanism

This mechanism is used in most horizontal axis wind turbines. Its purpose is to turn the head of the turbine according to the change in the direction of the wind's blow and to ensure that the turbine gets better wind. Generally, two electric motors help the working mechanism and the head is turned over the yaw bearing.

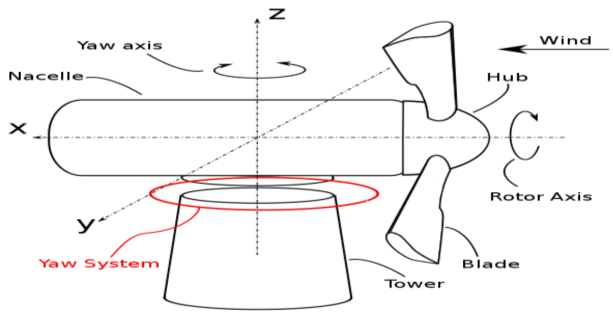

Figure.14: YAW Mechanism

Figure.15: YAW Mechanism

Component	% of Machine Weight	% of Machine Cost [5]
Rotor	10-14	20-30
Nacelle and machinery, less	25-40	25
Gearbox and drivetrain	5-15	10-15
Generator systems	2-6	5-15
Weight on Top of Tower	35-50	N/A
Tower	30-65	10-25

Table: Components of Wind Turbine

Materials of Wind Turbines

The importance of the material has been recognized very well in many machines and vehicles produced today. Material quality and properties have great importance in Wind Turbines. With the rapid development in the material technology recently, competition in the market has increased.

Both the aerodynamics and durability of the blades used in the Wind Turbine have great importance in their efficiency. Today, it is clear that the most suitable materials for wings are composite materials. However, many criteria are also being considered for the selection of composite materials. For example, economical, performance characteristics, values analysis, damage analysis and benefit analysis.

Composite Materials

These are obtained by combining materials with different properties in nature in different ways (granular, layered, etc.). The main purpose of composite materials is to combine materials that do not provide all of the desired properties (strength, aging resistance, fracture toughness, thermal properties, weight, etc.) by combining these properties.

Glass reinforced plastics are the most used composite materials in the wing structure of rotors in the Wind Turbine sector. In fact, the properties of composite materials with carbon fiber add much higher values, but their high cost is their biggest disadvantage.

CONCLUSION

Wind energy is very useful and clean energy. They have some little problems but it is not a big deal. All sides of seas and oceans have good wind potential. Also humanity, can build wind turbines in middle of oceans and seas. Thus, we can obtain a lot of energy from oceans and seas. Technology always progress. Clean and renewable energy systems will support us for protecting our planet.

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