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CHAPTER.3

WIND ENERGY

3.1. INTRODUCTION

The wind is a natural phenomenon on the earth which is been created by the difference of air density. It's in simple words 'an atmospheric air in motion'. Wind energy is a form of solar energy. Wind energy is generated by the movement of air relative to the earth's surface. Wind energy (or wind power) defines the process by which wind is utilized to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. In prehistoric times, the wind was used to move the sails of the ships. In this chapter, we will see how wind energy is used to generate electricity.

Wind energy captures the natural wind in our environment and translates the air's motion into mechanical energy. The wind is produced by differences in atmospheric pressure. Wind speeds differ founded on geography, landscape, and season. As an effect, there are some locations well-matched for wind energy production than others. In all-purpose, wind speeds are higher near the shoreline and offshore since there are rarer objects like vegetation, mountains, and buildings to slow them down.

The mechanism used to convert air motion into electricity is referred to as a turbine. A turbine is a large structure with several spinning blades. These blades are connected to an electromagnetic generator that generates electricity when the wind rotates the blades.

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A turbine translates the kinetic energy of the wind to beneficial mechanical energy. This energy could be used in mechanical form or turn generator turbines and deliver electricity. Fair like in the hydropower systems, wind energy is harnessed through the conversion of the wind kinetic energy into mechanical energy. Wind power generation means getting the electrical energy by converting wind energy into the rotating energy of the blades and converting that rotating energy into electrical energy by the generator. Wind energy increases with the cube of the wind speed; therefore, wind turbine generators (WTGs) should be installed in the higher wind speed area.

The inventors keep developing electronic devices including controlling systems with knowledge and technologies cultivated from the thermal and hydraulic power plant. The wind turbines are largely classified into two types- horizontal axis wind turbines and vertical axis wind turbines. Large areas installed with wind turbines, that is, wind farms are increasingly emerging today. The first known wind turbine used to produce electricity is built in Scotland in 1887. The wind turbine is formed by Prof James Blyth of Anderson's College, Glasgow (now recognized as Strathclyde University). Wind energy offers numerous advantages, which clarifies why it's one of the fastest-growing energy sources in the world.

3.2. WIND POWER PRODUCTION

The terms "wind energy" and "wind power" both describe the procedure by which the wind is used to produce mechanical power or electricity. This mechanical power can be used for specific tasks such as crushing grains or pumping water or a generator can convert this mechanical power into electricity. Wind turbines based on a simple principle that, instead of using electricity to make wind-like a fan, conversely wind turbines use the wind to produce electricity. The wind turns the propeller-like blades of a turbine around a rotor, which spins a generator, which creates electricity. The wind is a form of solar energy caused by a combination of three concurrent events:

(a) The sun disproportionately heating the atmosphere

(b) Anomalies of the earth's surface

(c) The revolution of the earth.

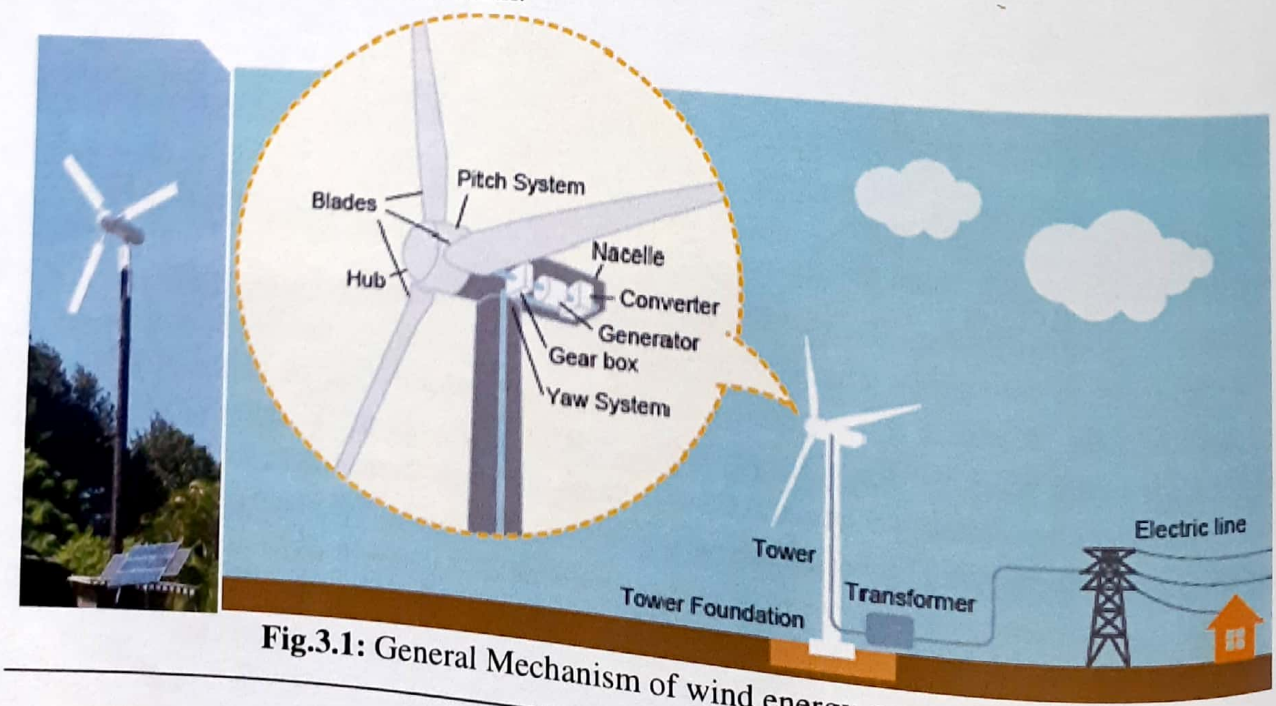

Fig.3.1: General Mechanism of wind energy generation

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Wind flow designs and speeds differ significantly across the Windy regions (like the United States) and are modified by bodies of water, vegetation, and changes in topography. Humans use this wind flow, or motion energy, for many purposes: flying a kite, sailing, also even for producing electricity.

Fig.3.1 shows the general working mechanism of the production of wind energy. A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade. When wind flowing across the blade, the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade creates both lift and drag. The force of the lift is stronger than the drag and this reasons the rotor to spin. The rotor attaches to the generator, either directly (if it's a direct drive turbine) or through a shaft and a series of gears (a gearbox) that speed up the rotation and permit for a physically smaller generator. This translation of aerodynamic force to rotation of a generator creates electricity that can be used for numerous purposes.

3.3. WIND CHARACTERISTICS

There are general characteristics of wind while others are more precise to the place. Some of the site-specific characteristics include:

1. **Mean wind speed**: This evaluates the annual wind yield though it does not give the distributions.
2. **Wind speed distribution**: There are three aspects namely annual, diurnal, and seasonal characteristics. Understanding the wind speed variations and the spread is necessary when choosing a site.
3. **Turbulence**: This is the chaotic movement of wind in unpredictable patterns. Turbulence results from continuously changing properties of wind motion that impact on energy production and fatigue on blades.
4. **Long term fluctuation**: Irregular wind causes unpredictable energy supply. Before a wind turbine is set, the area should be studied for a constant wind flux.
5. **Distribution of wind direction**: This is more significant in the positioning of the blades especially for horizontal axis types.
6. **Wind shear**: Shear is changed in wind direction, speed, or the height at which the maximum velocity occurs.

3.4. WIND SPEED PATTERNS

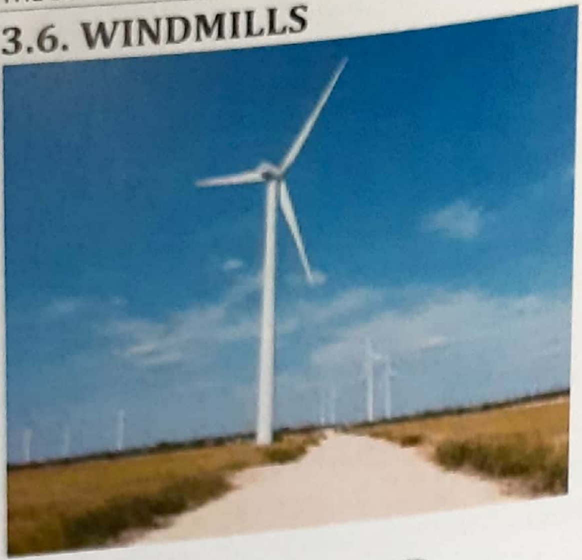
Wind patterns are important and are often analyzed using a wind spectrum. A high value of the wind spectrum represents a large change in the wind speed at the given time interval. If represented on a graph, the peaks depict turbulences that occur with time.

3.5. WIND SPEED DISTRIBUTION

There are three types of distributions:

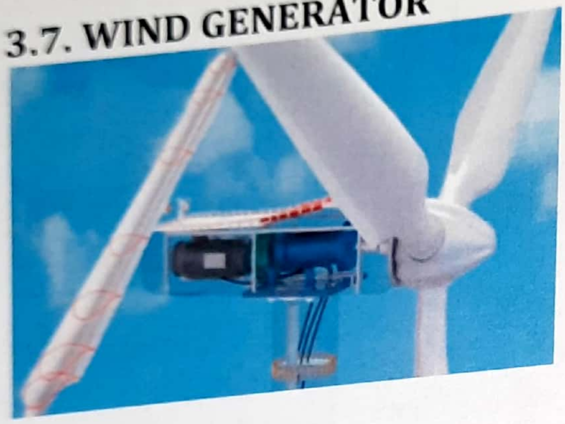
1. **Diurnal**: Caused by the difference between temperatures during the day and at night.
2. **Depressions**: Occur with four-day intervals along the coastal region.
3. **Annual**: Distribution is latitude dependent.

3.6. WINDMILLS



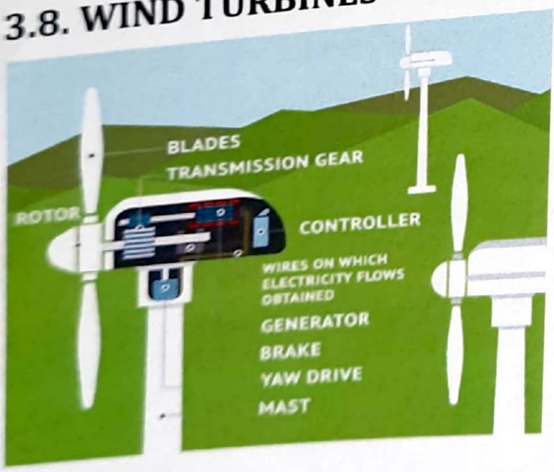
If the mechanical energy is used directly by machineries, such as a pump or grinding stones, the machine is usually called a windmill. The wind flows over windmill blades that are mounted on a rotor, which causes them to lift or turn like an airplane propeller. The blades are connected to a drive shaft that turns a generator to make electricity. This process converts the kinetic energy of the wind into electrical power. For utility-scale wind energy, large numbers of wind turbines are close together to form a wind farm.

3.7. WIND GENERATOR



If the mechanical energy is then converted to electricity, the machine is called a wind generator. There are many different types of generators used today in wind turbines, but the most common types are asynchronous generators. The two types mostly used are the squirrel cage induction generator & the wound rotor induction generator- also known as a doubly-fed induction generator.

3.8. WIND TURBINES



Windmills and wind turbines are different. They both use wind as a resource, but wind turbines are used to generate electricity. A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Turbines and generators are equally used in the production of electric power; nevertheless, the turbine converts available energy forms into the rotation while the generator converts rotation into electricity. Two types of modern wind turbines generate electricity

3.8.1. Types of wind turbines

Wind turbines are classified into two general types:

1. Horizontal axis wind turbines (HAWTs) and
2. Vertical axis wind turbines (VAWTs).

A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground. There are several available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are accessible commercially.

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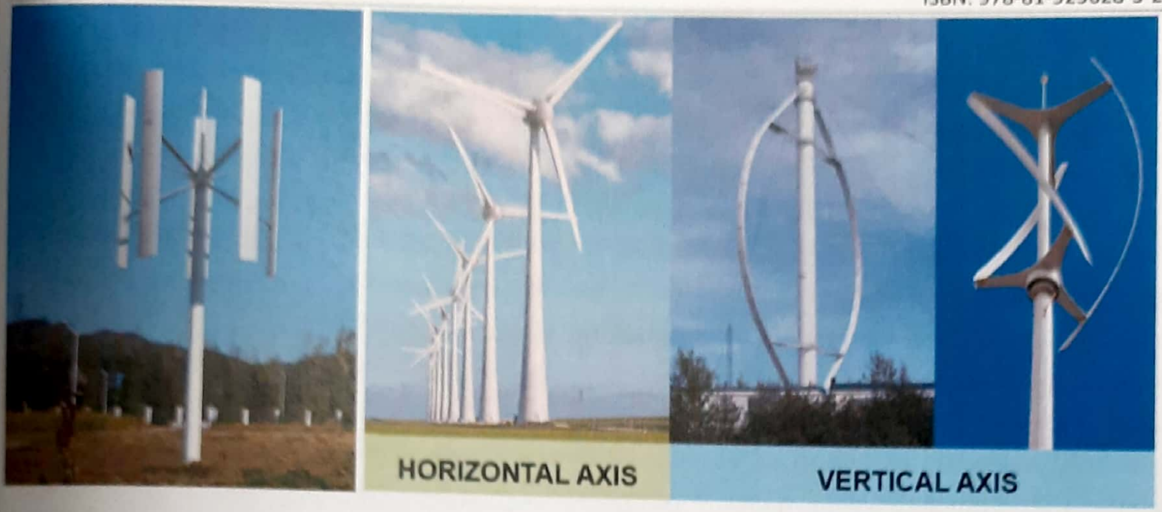

3.8.2. Components of a wind turbine

1. The nacelle contains the key components of the wind turbine, including the gearbox, and the electrical generator.
2. The tower of the wind turbine carries the nacelle and the rotor. Usually, it is an advantage to have a high tower, since wind speeds increase farther away from the ground.
3. The rotor blades capture wind energy and transfer its power to the rotor hub.
4. The generator converts the mechanical energy of the rotating shaft to electrical energy
5. The gearbox increases the rotational speed of the shaft for the generator.

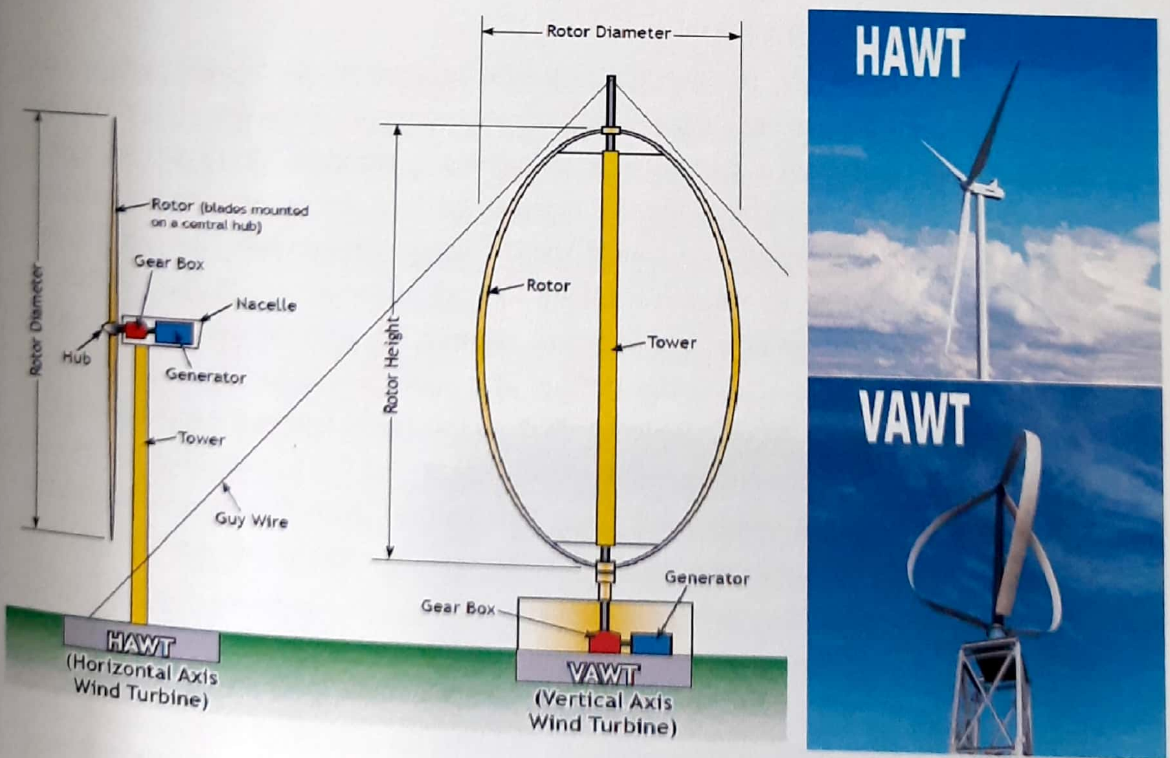

Fig.3.2: Schematics of HAWT and VAWT

Though vertical axis wind turbines have existed for centuries, they are not as common as their horizontal counterparts. The main cause for this is that they do not take benefit of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines.

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HAWTs are the most commonly used type, and each turbine possesses two or three blades or a disk containing many blades (multibladed type) attached to each turbine. VAWTs can harness wind blowing from any direction and are usually made with blades that rotate around a vertical pole (**Fig.3.2**).

HAWTs are characterized as either high or low solidity devices, in which solidity refers to the percentage of the swept area comprising solid material. High-solidity HAWTs comprise the multibladed types that cover the total area swept by the blades with solid material to maximize the total amount of wind coming into contact with the blades. An example of the high-solidity HAWT is the multibladed turbine used for pumping water on farms, often seen in the landscapes of. Low-solidity HAWTs most often use two or three long blades and resemble aircraft in appearance. Low-solidity HAWTs have a low proportion of material within the swept area, which is compensated by a faster rotation speed used to fill up the swept area. Low-solidity HAWTs are the most commonly used commercial wind turbines as well as the type most often represented through media sources. Those HAWTs offer the greatest in electricity generation and, therefore, are among the most cost-efficient designs used. The Darrieus VAWT, which uses curved blades in a curved arch design, became the most common VAWT in the early 21st century. H-type VAWTs use two straight blades attached to either side of a tower in an H-shape, and V-type VAWTs use straight blades attached at an angle to a shaft, forming a V-shape. Most VAWTs are not economically competitive with HAWTs, but there is continuing interest in of VAWTs, particularly for building wind energy systems.

3.9. ESTIMATING GENERATION

Rendering to Betz's law, the maximum amount of power that a wind turbine can generate cannot exceed 59 percent of the wind's kinetic energy. Given that limitation, the expected power generated from a particular wind turbine is estimated from a wind speed power curve derived for each turbine, usually represented as a graph showing the relation between power generated (kilowatts) and wind speed (meters per second). The wind speed power curve varies according to variables unique to each turbine such as the number of blades, blade shape, rotor swept area, and speed of rotation. To determine how much wind energy will be generated from a particular turbine at a specific site location, the turbine's wind speed power curve needs to be coupled with the wind speed frequency distribution for its site. The wind speed is representing wind speed classes and the frequency of hours per year that are expected for each wind speed class. The data for those histograms are usually provided by wind speed measurements collected at the site and used to calculate the number of hours observed for each wind speed class.

A rough estimate of annual electric production in kilowatt-hours per year at a site can be calculated from a formula multiplying average annual wind speed, swept area of the turbine, the number of turbines, and a factor estimating turbine performance at the site. However, additional factors may decrease annual energy production estimates to varying degrees, including loss of energy because of the distance of transmission, as well as availability (that is, how reliably the turbine will produce power when the wind is blowing). By the early 21st century most commercial wind turbines functioned at over 90 percent availability, with some even functioning at 98 percent availability.

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3.10. ADVANTAGES OF WIND ENERGY

1. It's a fresh fuel source. Wind energy doesn't pollute the air like power plants that depend on the combustion of fossil fuels, such as coal or natural gas. It is far more eco-friendly than the burning of fossil fuels for electricity. Wind turbines don't produce atmospheric emissions that cause acid rain or greenhouse effect.
2. Wind turbines can be constructed on existing farms. This significantly benefits the economy in rural areas, where most of the best wind sites are found. Farmers and planters can continue to work the land since the wind turbines use only a fraction of the land. Wind power plant owners make rent payments to the farmers for the use of the land providing landowners with extra income.
3. Wind power is cost-effective. Because the electricity from wind farms is sold at a fixed price over a long period (20+ years) and its fuel is free, wind energy mitigates the price uncertainty that fuel costs add to traditional sources of energy.
4. Wind creates jobs. The wind sector employs several workers and wind turbine technicians for manufacturing, installation, maintenance, and supporting services are one of the fastest-growing jobs across the globe.
5. The wind is a domestic source of energy. Over the past ten years, the wind power capacity of the world has grown 15%/year, & wind is now the largest source of renewable power.
6. It's sustainable. The wind is a form of solar energy. Winds are caused by the heating of the atmosphere by the sun, the rotation of the earth, and the earth's surface irregularities.

3.11. DISADVANTAGES OF WIND ENERGY

1. Constructing turbines and wind facilities is extremely expensive.
2. Some wind turbines cause to generate a lot of noise which can be unpleasant. Two kinds of noise associated with turbines are mechanical noise, which is produced by its equipment such as its gearbox, and aerodynamic noise, which is produced from the movement of air over the blades.
3. Though, this may be an advantage that placing wind turbines in desolate areas, far away from people, but it may also be a disadvantage. The cost of travel and maintenance on the turbines increases and is time-consuming. Offshore wind turbines require boats and can be dangerous to accomplish.
4. The turbine blades may damage local wildlife. Sometimes birds have been killed by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly setting wind plants.

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