Renewable Energy (EE7601)

Unit-3: Wind Energy

By Dr. Trilochan Penthia
EE Dept., NIT Patna

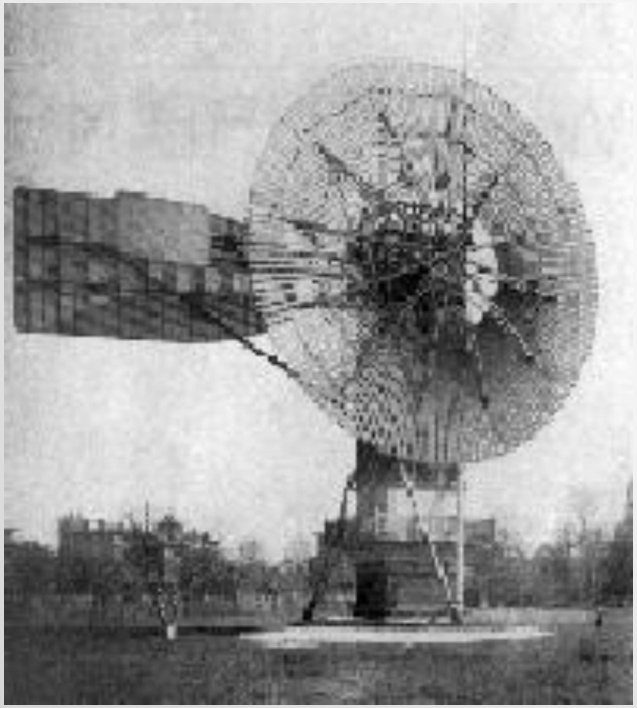
Contents of Unit-3

- Introduction of Wind energy
- Wind energy conversion
- Classification of wind turbines/WECS
- Basic components of WECS
- Electric generation schemes using synchronous generator and induction generator
- Wind energy storage
- Application of Wind energy (onshore/offshore)

Wind Power Generation

- Wind power generation means getting the electrical energy by converting wind energy into rotating energy of the blades and converting that rotating energy into electrical energy by the generator.
- The terms "wind energy" and "wind power" both describe the process by which the wind is used to generate mechanical power or electricity. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.
- Wind turns the propeller-like blades of a turbine around a rotor, which spins a generator, which creates electricity.

Wind Power Generation



- Wind energy increases with the cube of the wind speed, therefore WTGs should be installed in the higher wind speed area.
- Grain grinding and water pumping
- The first use of a large windmill to generate electricity was a system built in Cleveland, Ohio, in 1888 by Charles F. Brush.

Modern Wind Turbine

- Commercial wind energy is one of the most economical sources of new electricity available today.
- Wind turbines can be set up quickly and cheaply compared with building new coal-fired generating stations or hydroelectric facilities.

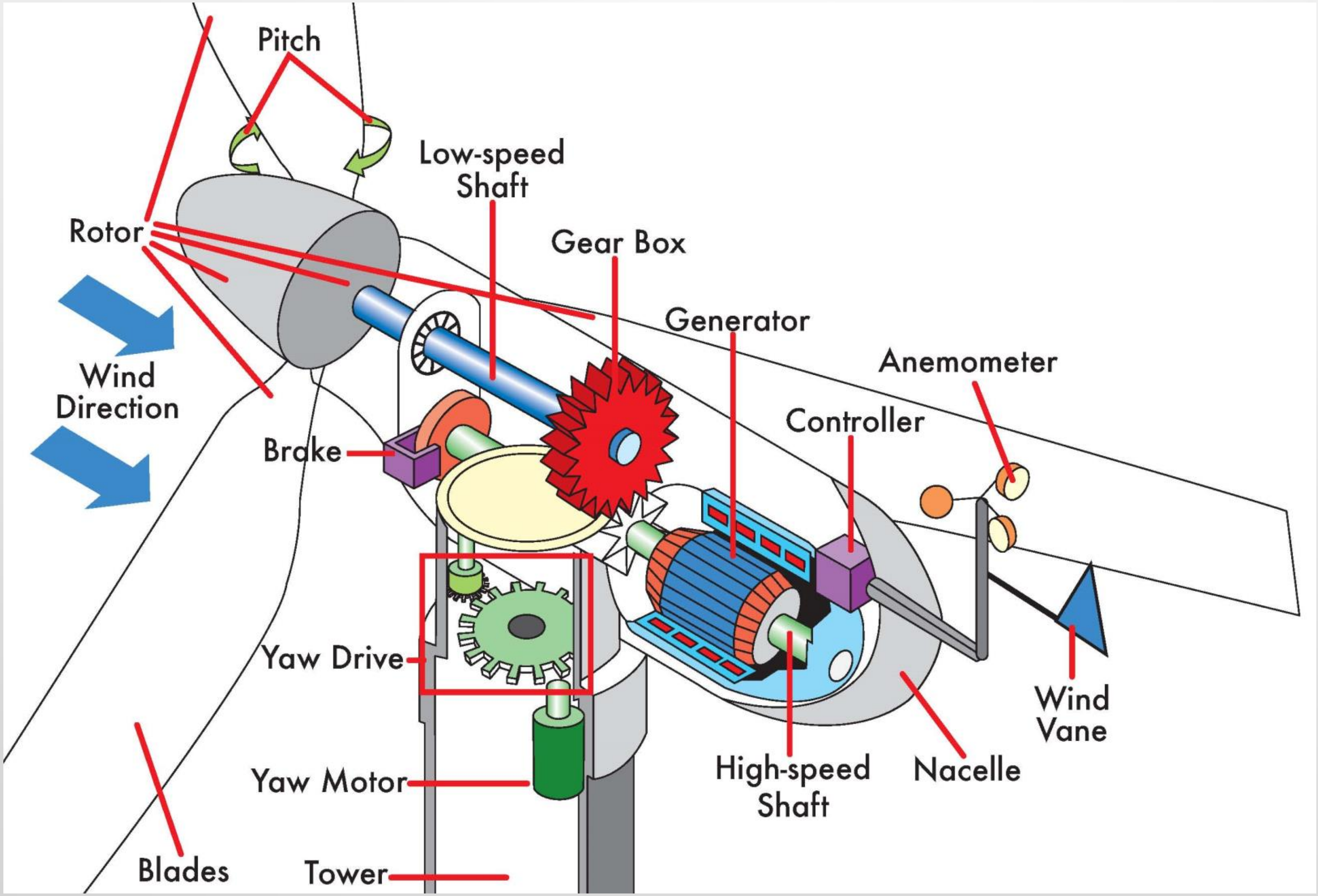
Modern Wind Turbine

- Commercial wind energy is one of the most economical sources of new electricity available today.
- Wind turbines can be set up quickly and cheaply compared with building new coal-fired generating stations or hydroelectric facilities.
- Modern wind generating equipment is efficient, highly reliable, and becoming cheaper to purchase.
- The environmental impact of large wind turbines is negligible compared with an open pit coal mine or a reservoir, and during their operation produce no air pollution.
- Because of these factors, wind energy is recognized as the world's fastest-growing new energy source.

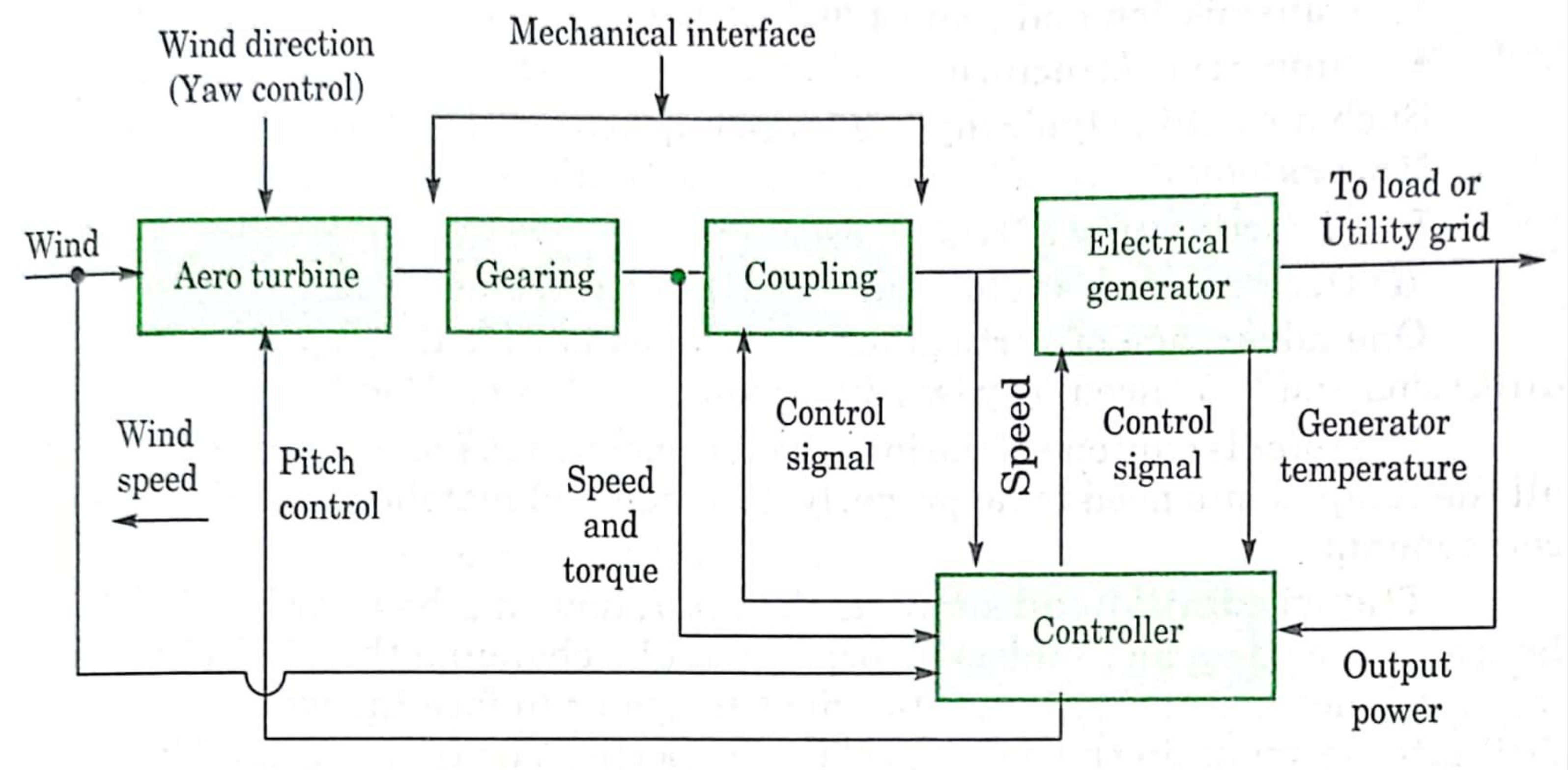
How does a Wind Turbine Work?

- Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.
- Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind.
- Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid (shown here) for more widespread electricity distribution.

How does a Wind Turbine Work?



Block diagram of a wind-electric conversion system (WECS)



Components of a Wind Turbine

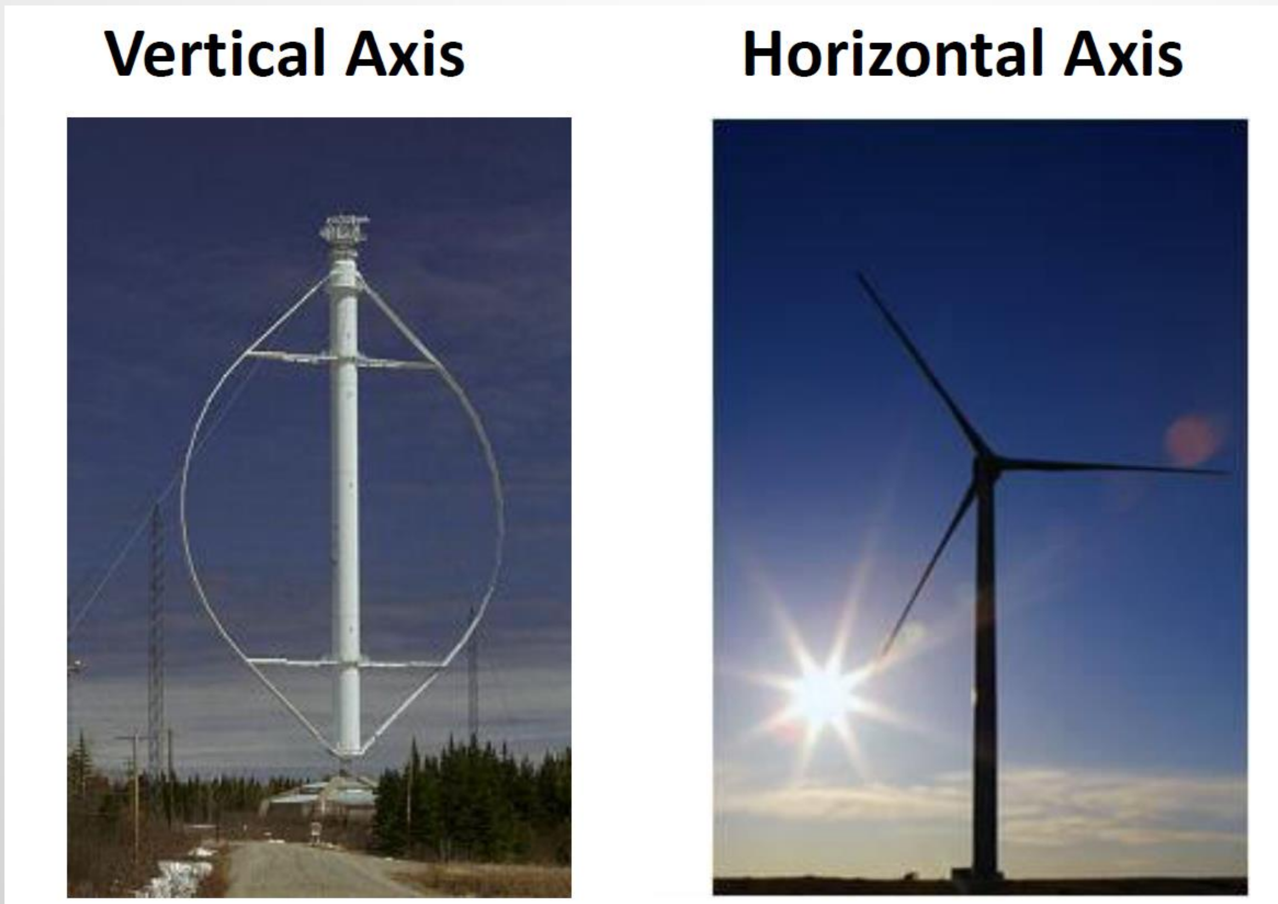
- **Anemometer**: Measures the wind speed and transmits wind speed data to the controller.
- **Blades**: Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.
- **Brake**: A disc brake, which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.
- **Controller**: The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they might be damaged by the high winds.
- **Gear box**: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.
- **Generator**: Usually an off-the-shelf induction generator that produces 60-cycle AC electricity. High-speed shaft: Drives the generator. Low-speed shaft: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Components of a Wind Turbine

- **Nacelle**: The nacelle sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough for a helicopter to land on.
- **Pitch**: Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor from turning in winds that are too high or too low to produce electricity.
- **Rotor**: The blades and the hub together are called the rotor.
- **Tower**: Towers are made from tubular steel (shown here), concrete, or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.
- **Wind direction**: This is an "upwind" turbine, so-called because it operates facing into the wind. Other turbines are designed to run "downwind," facing away from the wind.
- **Wind vane**: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.
- **Yaw drive**: Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.
- **Yaw motor**: Powers the yaw drive.

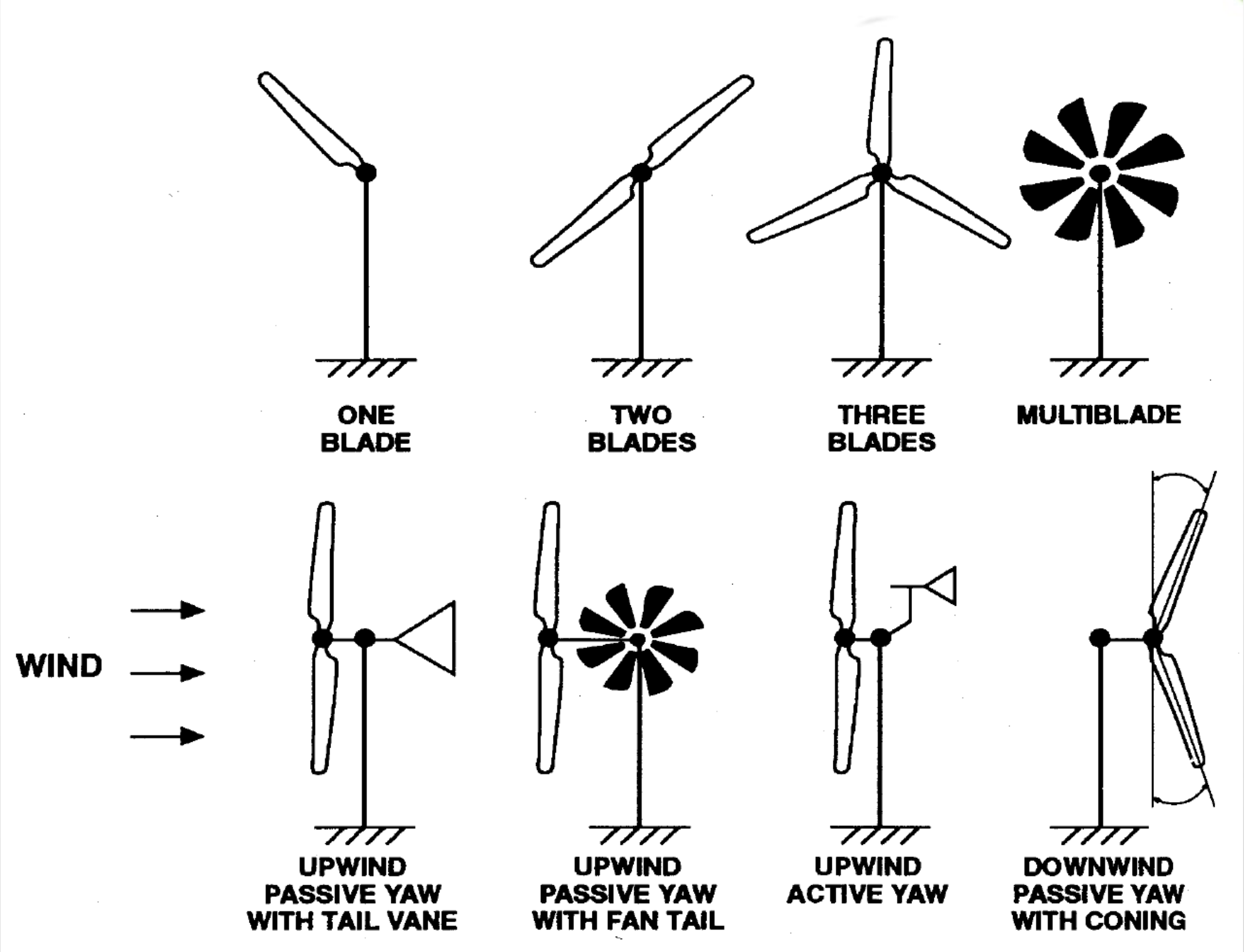
Orientation of wind turbines

- Turbines can be categorized into two overarching classes based on the orientation of the rotor:



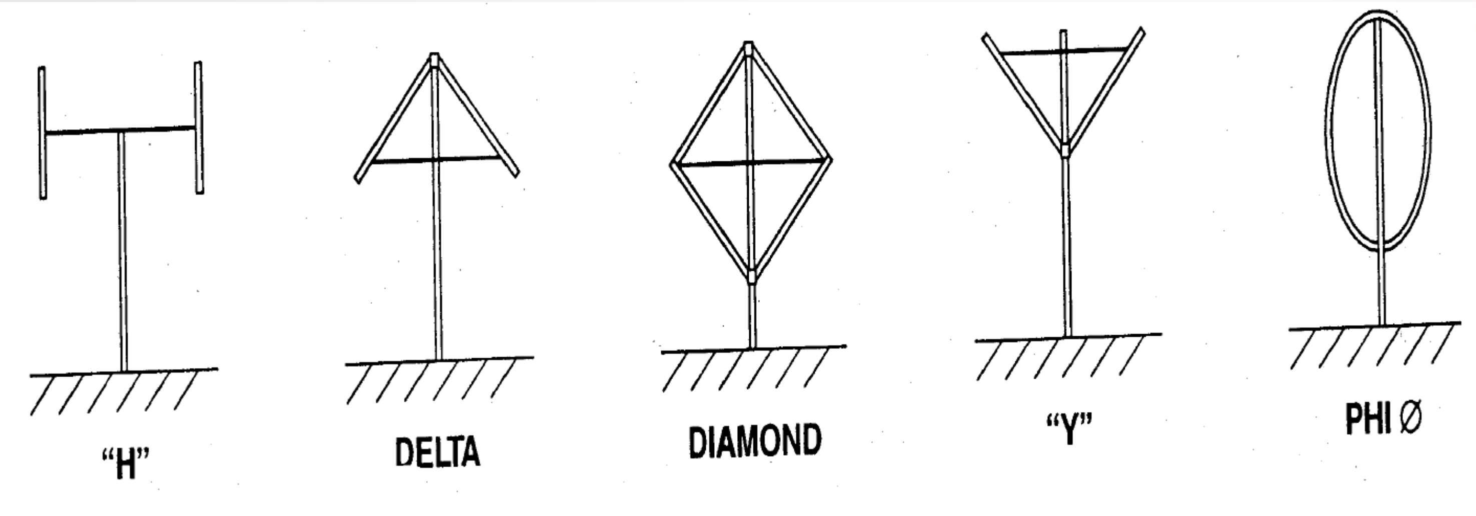
Types of Wind Turbine Generators (WTG)

1. Horizontal Axis wind turbines (HA-WTs)



Types of Wind Turbine Generators (WTG)

2. Vertical Axis wind turbines (VA-WTs)

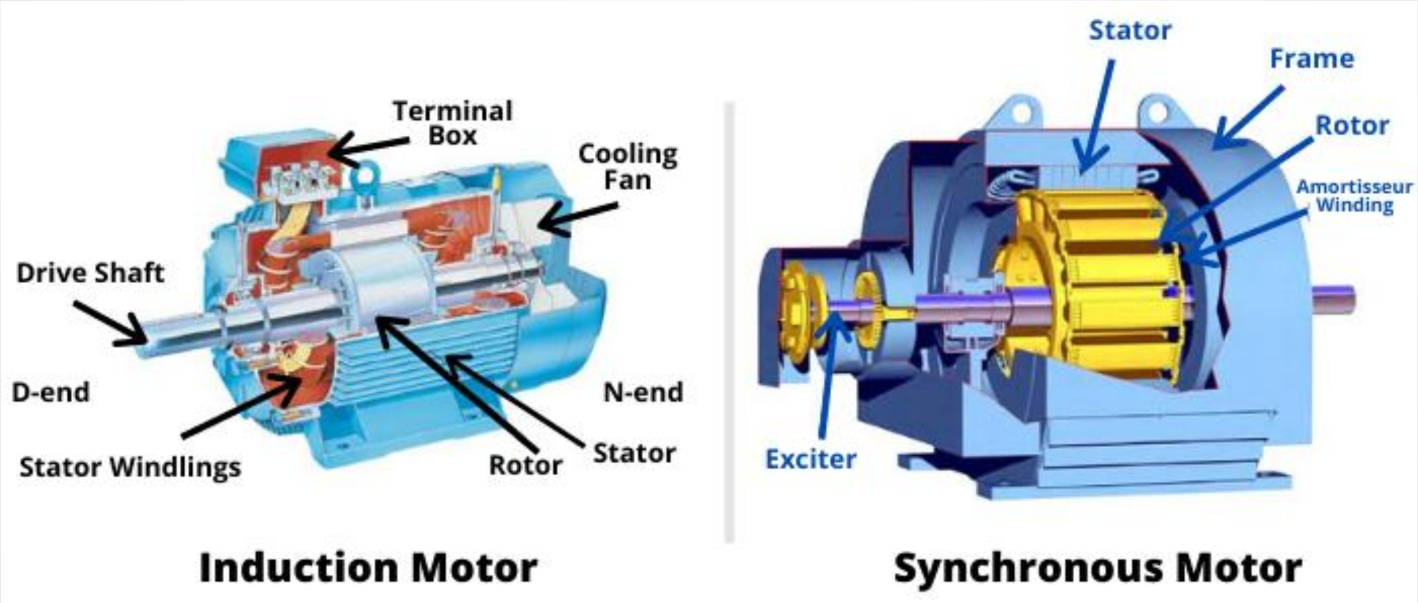


Comparison of Wind Turbines

Items	HA-WTs	VA-WTs
Output power	Wide range	Narrow range
Starting	Self starting	Need starting means
Efficiency	Higher	Lower
Cost	Lower	Higher
Rotor shaft	Runs horizontally	Runs vertically
Wind direction	Need redirected when the Wind change its direction	Does not needs redirected into the wind direction
Wind speed	Operate fine in moderate to high wind speed	Can operate even in low wind speed
Generator and gear box	At the top of the tower	At the ground level
Maintenance	Difficult	Easy

Synchronous and Induction Generators in WECS

- The AC generators used in WECS are categorized into two:
  a) Synchronous generators (commonly referred as alternators) and
  b) Induction generators (or asynchronous generators)



Synchronous and Induction Generators in WECS

- The AC generators used in WECS are categorized into two:
  a) Synchronous generators (commonly referred as alternators) and
  b) Induction generators (or asynchronous generators)
- Generally, there are two types of induction generators widely used in wind power systems – Squirrel-Cage Induction Generator (SCIG) and Doubly-Fed Induction Generator (DFIG).
- SCIG is widely accepted in fixed-speed applications whereas, DFIG preferred in variable-speed applications.

Synchronous vs. Induction generators

Synchronous generators	Induction generators
1. The AC generator which runs at synchronous speed is known as synchronous generator.	1. It runs at speed higher than the synchronous speed is known as Induction generator.
2. It is one type of machine whose rotor speed and stator magnetic field speed are the same.	2. It is an electrical machine whose rotor spins higher than the synchronous speed.
3. In case of synchronous motor, there is no slip.	3. There is a slip in an induction generator whose value ranges from 0 to 1.
4. DC supply is given to the rotor of the synchronous generator.	4. AC supply (in wound type rotor) is fed to the rotor circuit.
5. Synchronous generators are more efficient	5. It has comparably less efficiency.

Site selection criteria for wind turbines

- When selecting a site for wind turbines, several factors should be considered to ensure the turbines operate efficiently and reliably. Here are some common site selection criteria for wind turbines:
- **Wind resource**: The primary criterion for selecting a site for wind turbines is the availability of wind. The wind speed and direction should be measured and analyzed to determine the site's potential wind energy production.
- **Land use**: Wind turbines require large areas of open land, typically farmland or open plains. The site should be free from obstructions such as trees, buildings, and other structures that could interfere with wind flow. The land should also be suitable for construction and provide access to roads for transporting equipment and materials.
- **Environmental considerations**: Wind turbines can have significant impacts on the environment, including noise, visual impact, and potential harm to wildlife. Thus, these studies should be conducted to ensure compliance with local regulations and minimize potential impacts on nearby residents.

Site selection criteria for wind turbines

- **Grid connection**: Wind turbines require a connection to the power grid to transport electricity to consumers. The site should be located near existing transmission lines or have the potential for a cost-effective connection to the grid.
- **Social considerations**: Wind turbines can have significant impacts on local communities. The site should be located away from sensitive areas such as schools and hospitals.
- **Economic considerations**: The site's economic viability is also an important consideration. The cost of building, operating, and maintaining the wind turbines should be evaluated to ensure that the project is financially feasible.
- **Accessibility**: The site should be easily accessible to accommodate construction equipment, personnel, and maintenance vehicles.

Overall, site selection for wind turbines requires a comprehensive evaluation of multiple criteria.

Wind energy storage

- Wind energy storage refers to the ability to store excess energy generated by wind turbines for later use when the wind is not blowing.
- Energy storage is essential for integrating wind energy into the electrical grid.
- There are several ways to store wind energy, including:
- **Battery storage:** This involves storing excess energy in batteries for later use. Batteries can be charged when wind output is high and discharged when needed, providing a reliable and flexible source of electricity.
- **Pumped hydro storage:** This involves pumping water uphill into a reservoir when wind output is high and using it to generate electricity later by releasing the water through turbines.

Wind energy storage

- **Compressed air energy storage**: This involves compressing air and storing it in underground reservoirs or tanks. The compressed air can then be released to power turbines and generate electricity when needed.
- **Flywheel storage:** This involves storing energy by spinning a large wheel at high speeds. The energy can then be released by slowing down the wheel and using the kinetic energy to generate electricity.
- **Thermal storage:** This involves using excess energy to heat or cool materials, such as water or rocks, which can then be used to generate electricity later.

Wind energy storage is still a developing technology, and the most common methods of storage are currently battery storage and pumped hydro storage.

Application of Wind energy

- Wind energy has a wide range of applications and can be used in many different ways. Some of the most common applications of wind energy include:
- **Electricity generation:** Wind turbines can be used to generate electricity for homes, businesses, and communities. Large-scale wind farms are often connected to the electrical grid, while smaller turbines can be used to power individual homes or buildings.
- **Water pumping:** Wind turbines can be used to pump water from wells or other sources for irrigation, livestock, and other agricultural applications.
- **Transportation:** Wind energy can be used to power vehicles, such as sailboats, and can also be used to charge electric vehicles.
- **Off-grid power:** Wind turbines can be used to provide electricity to remote or off-grid locations, such as islands or rural communities, where traditional power sources may be unavailable or expensive.

Application of Wind energy

- **Mechanical power:** Wind energy can be used to power mechanical devices, such as water pumps, gristmills, and sawmills. This application of wind energy was common in the past, and there are still many historic windmills in operation around the world.
- **Disaster relief:** Wind turbines can be used as part of disaster relief efforts to provide power in areas that have been affected by natural disasters or other emergencies.
- **Industrial applications:** Wind energy can be used in industrial applications, such as powering factories, manufacturing plants, and other industrial facilities.

As wind energy technology continues to improve, new applications for wind energy are likely to emerge, making it an even more important part of our energy mix.

End of Unit-3