WIND TURBINES

The purpose of this presentation is to present and analyze the main components of state-of-the-art Wind Turbine Generators.

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WIND TURBINES:

❖ Introduction: One

- ❖ 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 sizes, with either horizontal or vertical axes.
- ❖ Multi-turbine installations are referred to as wind farms.
- ❖ Advances in Semiconductor technologies of high voltages have played a significant role in the rise of wind and photovoltaic (PV) power systems.
- ❖ In these types of systems power electronics is used to convert the electric power generated by wind turbine generators to the form required by the electric grid operators and the associated regulatory Agencies responsible for the stability of the Grid.

WIND TURBINES:

❖ Introduction: Two

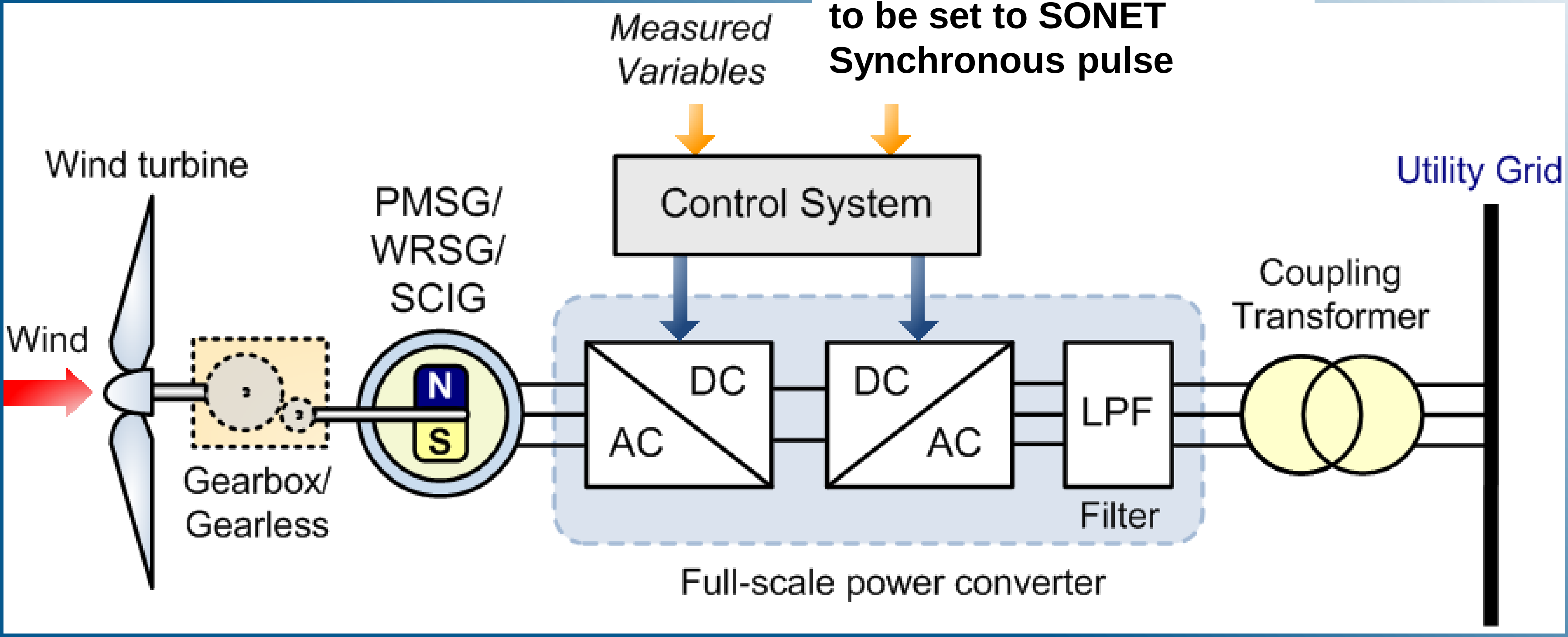
WIND TURBINES:

❖ Introduction: Three

WIND TURBINES: #5

- Electrical Generation Schematic

Note: Reference frequency in Synchronization Project to be set to SONET Synchronous pulse

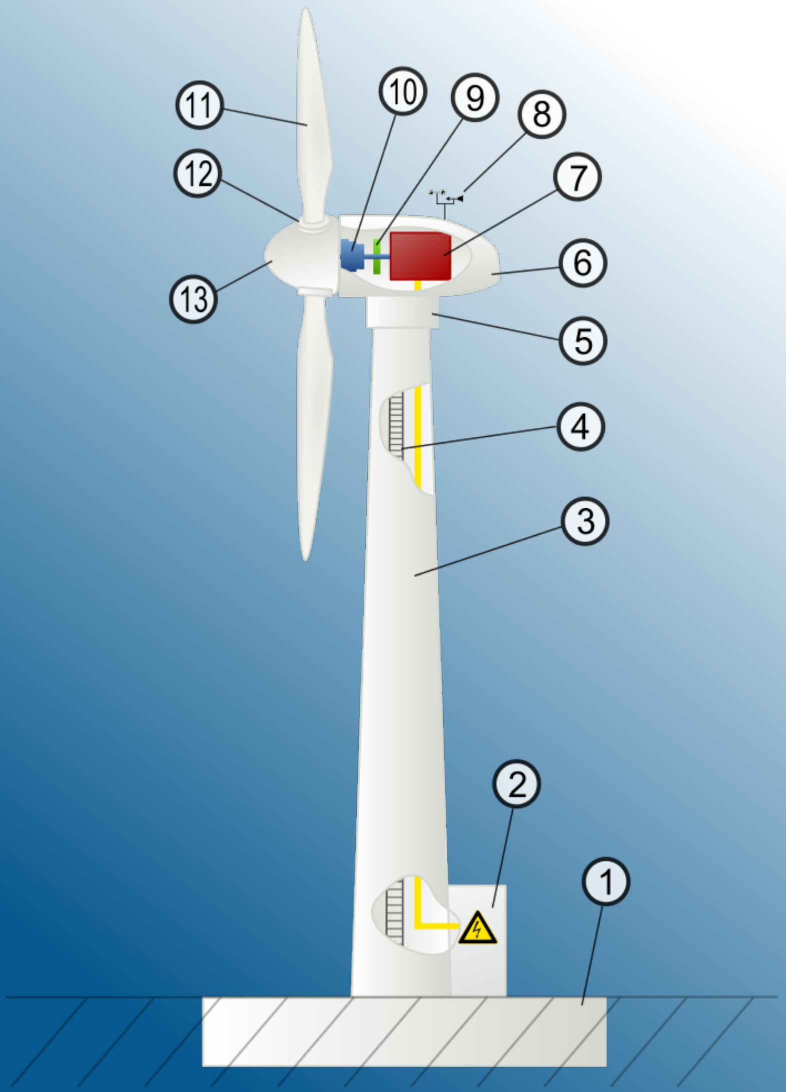


WIND TURBINES:

❖ Turbine Components

Wind turbine components :

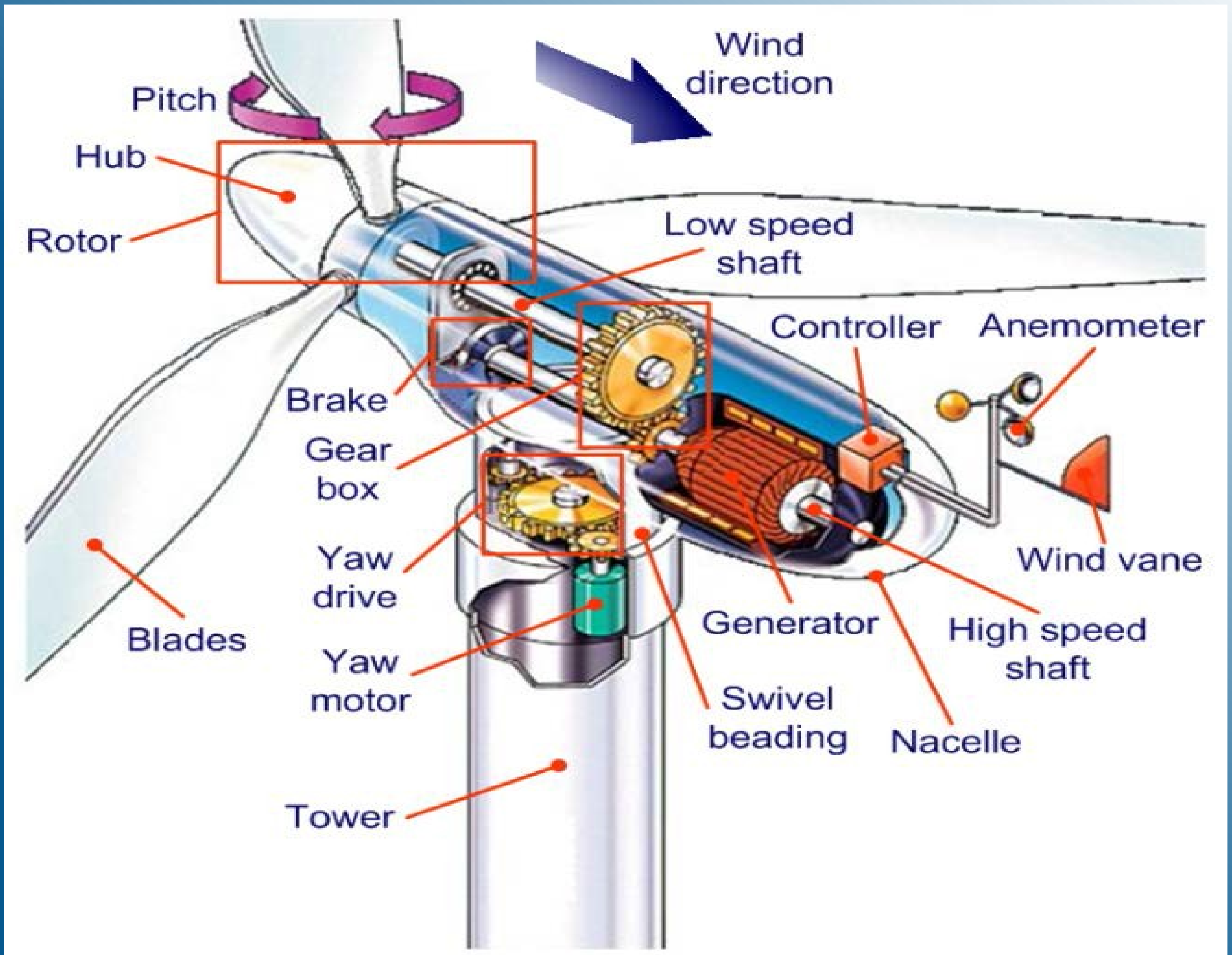
1. Foundation
2. Connection to the electric grid
3. Tower
4. Access ladder
5. Wind orientation control (Yaw control)
6. Nacelle
7. Generator
8. Anemometer
9. Electric or Mechanical Brake
10. Gearbox
11. Rotor blade
12. Blade Pitch Control
13. Rotor Hub



WIND TURBINES:

❖ Turbine Cross-Section

Wind turbine generator (WTG)
Components



WIND TURBINES:
❖ Turbine Components

Wind turbine generator (WTG) has three major systems:

1. **Rotor system**. This includes blades that capture energy and a rotor hub that connects the blades to the shaft, along with pitch mechanism that assists in efficient capture of energy.

2. **Nacelle**. This contains all the components that sit on top of the tower, except the rotor system. It includes main shaft, gearbox, generator, brake, bearings, nacelle frame, yaw mechanism, auxiliary crane, hydraulic system, and cooling system.

3. **Tower and foundation**. These structural elements carry all the forces and moments to the ground

WIND TURBINES:
❖ Turbine Components

1. Rotor System

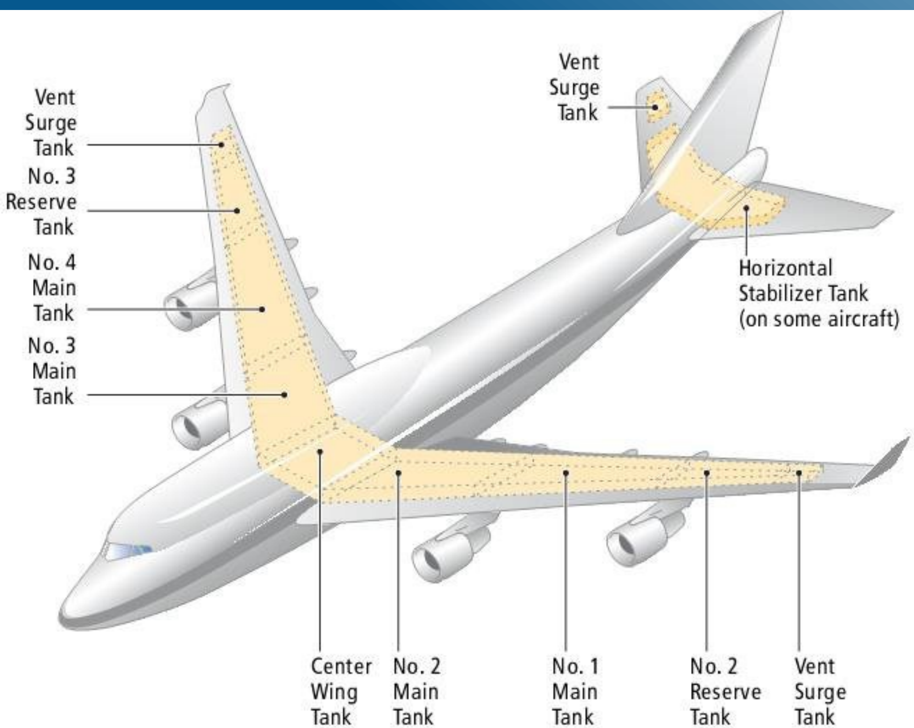
The rotor system captures wind energy and converts into rotational kinetic energy. This is accomplished through :

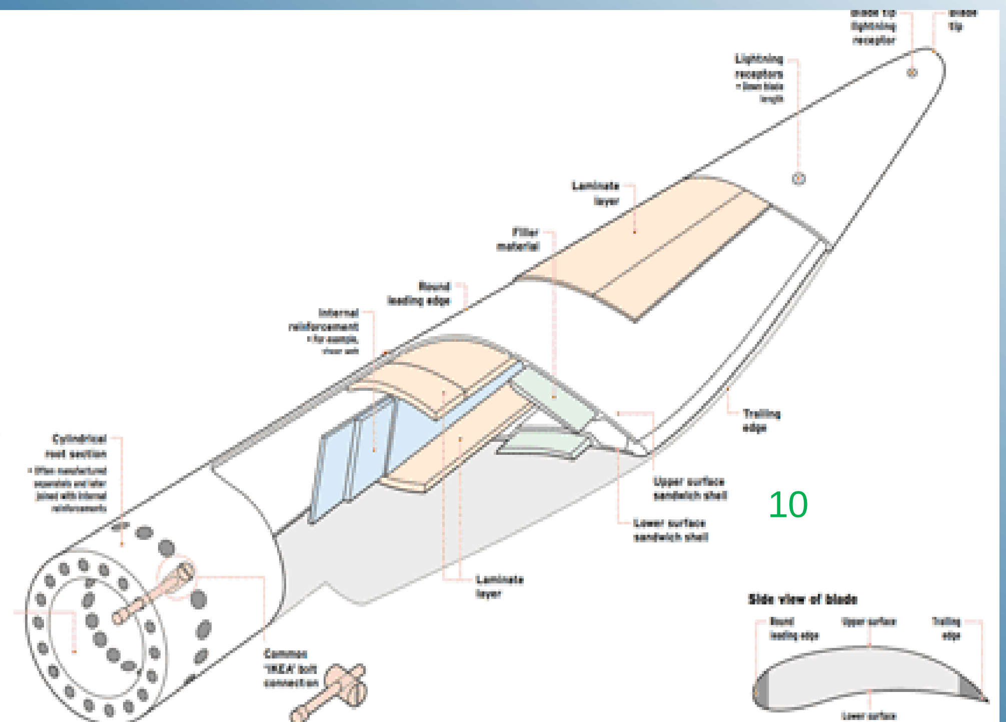
1. **blades**
2. **rotor hub** that is connected to the main shaft. In large utility-scale turbines, the rotor hub has **mechanisms to pitch** the blade, that is, rotate along the longitudinal axis of the blade.

WIND TURBINES:
❖ Turbine Components

1.1 Blades

turbine blades are, in principle, similar to airplane wings in terms of generating lift.



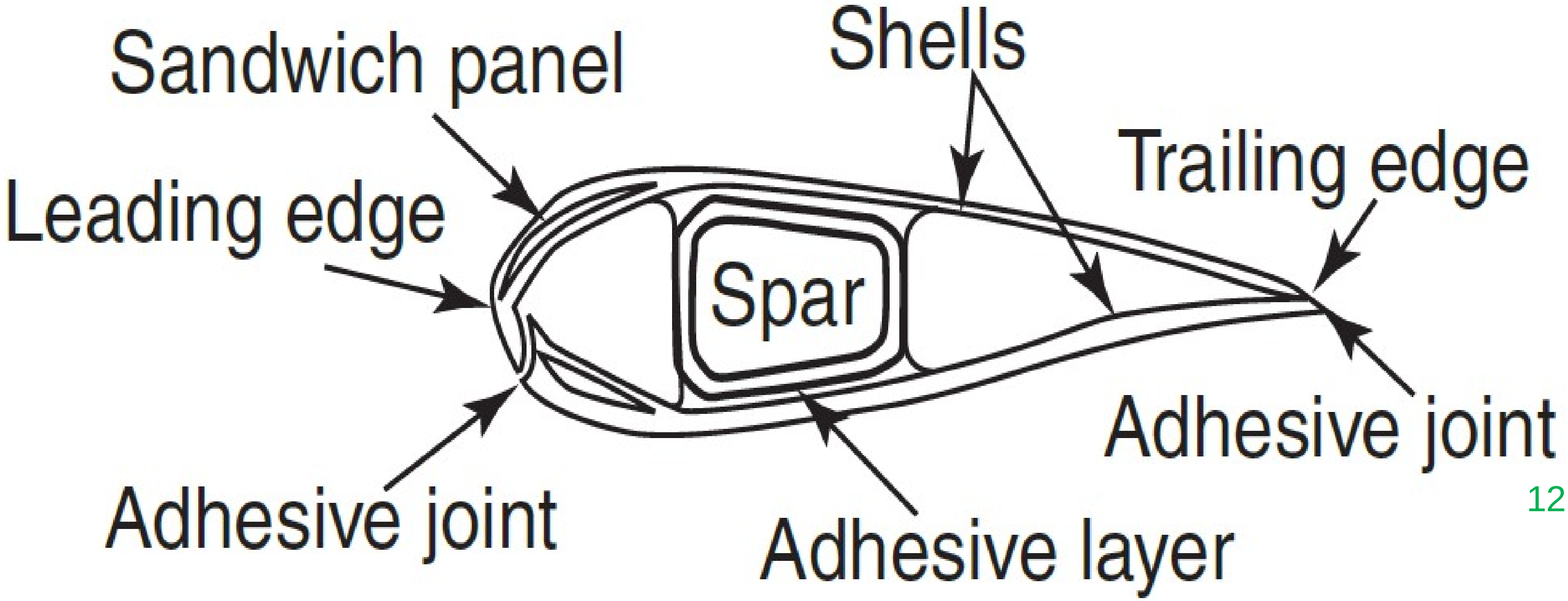


WIND TURBINES:

❖ Turbine Components

1.1 Blades (Cont.)

The cross section of a turbine blade is shown on the figure below



WIND TURBINES:
❖ Turbine Components

1.1 Blades (Cont.)

The components of a blade are:

- The **core** of the blade is made of balsa wood or foam; the core gives the blade its shape. This is also called the spar, which is like a long tubular beam along the length of the blade.
- Upwind and downwind **aerodynamic shell** made of fiberglass and epoxy resins. These two are glued at the leading and at the trailing edge. The shells are glued to the spar with an adhesive.
- **Root** of the blade is a metallic cylinder with bolts to connect the blade to the rotor hub.
- **Sensors** in the blade to monitor stress, strain, acoustic emissions and other signals

WIND TURBINES:
❖ Turbine Components

1.1 Blades (Cont.)

Blade materials should meet the following criteria:

- wide availability and easy processing to reduce cost and maintenance
- low weight or density to reduce gravitational forces
- high strength to withstand strong loading of wind and gravitational force of the blade itself
- high fatigue resistance to withstand cyclic loading
- high stiffness to ensure stability of the optimal shape and orientation of the blade and clearance with the tower
- high fracture toughness
- the ability to withstand environmental impacts such as lightning strikes, humidity, and temperature

WIND TURBINES:
❖ Turbine Components

1.1 Blades (Cont.)

Options

- ❖ Metals: vulnerability to fatigue.
- ❖ Ceramics: have low fracture toughness, which could result in early blade failure.
- ❖ Traditional polymers: are not stiff enough to be useful, and
- ❖ wood has problems with repeatability, especially considering the length of the blade.

That leaves fiber-reinforced composites, which have high strength and stiffness and low density, as a very attractive class of materials for the design of wind turbines.

WIND TURBINES:
❖ Turbine Components

1.1 BLADES (Cont)

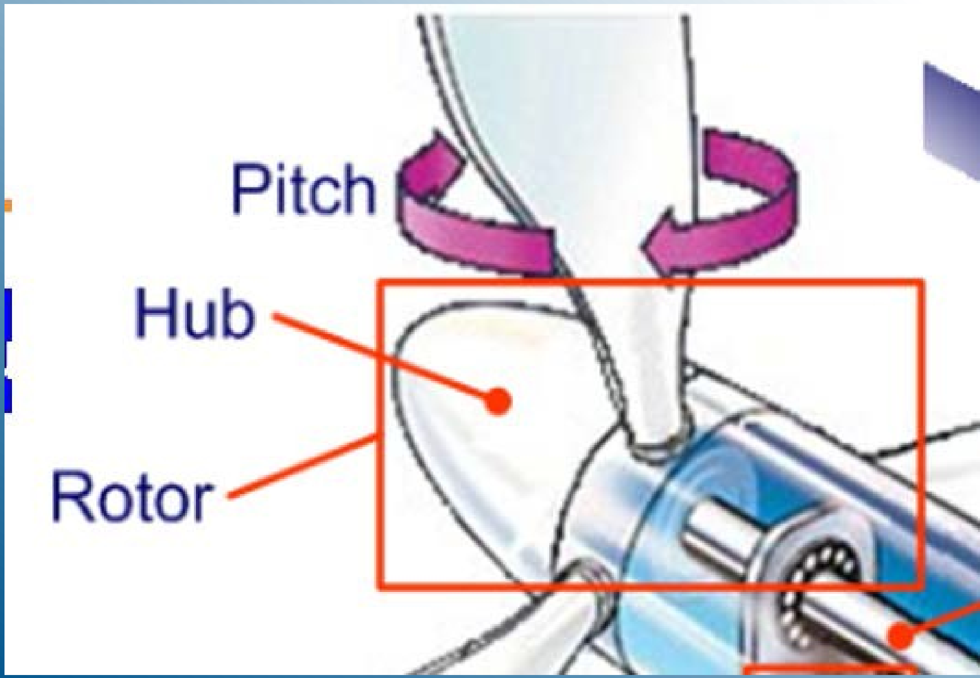
Fiberglass-reinforced epoxy blades of Siemens SWT-2.3-101 wind turbines. The blade size of 49 meters

WIND TURBINES:

❖ Turbine Components

1.2 Rotor Hub

Blades are radially bolted to the hub. On the axial end, the rotor hub is connected to the drive train. The hub is made of high-quality cast iron. It transfers load from the blades to the nacelle frame and to the drive train. The manner of transferring loads from the hub to rest of the components in the nacelle depends on the turbine configuration-direct drive or with the gearbox in the nacelle depends on the turbine configuration: direct drive or with gearbox.



WIND TURBINES:
❖ Turbine Components

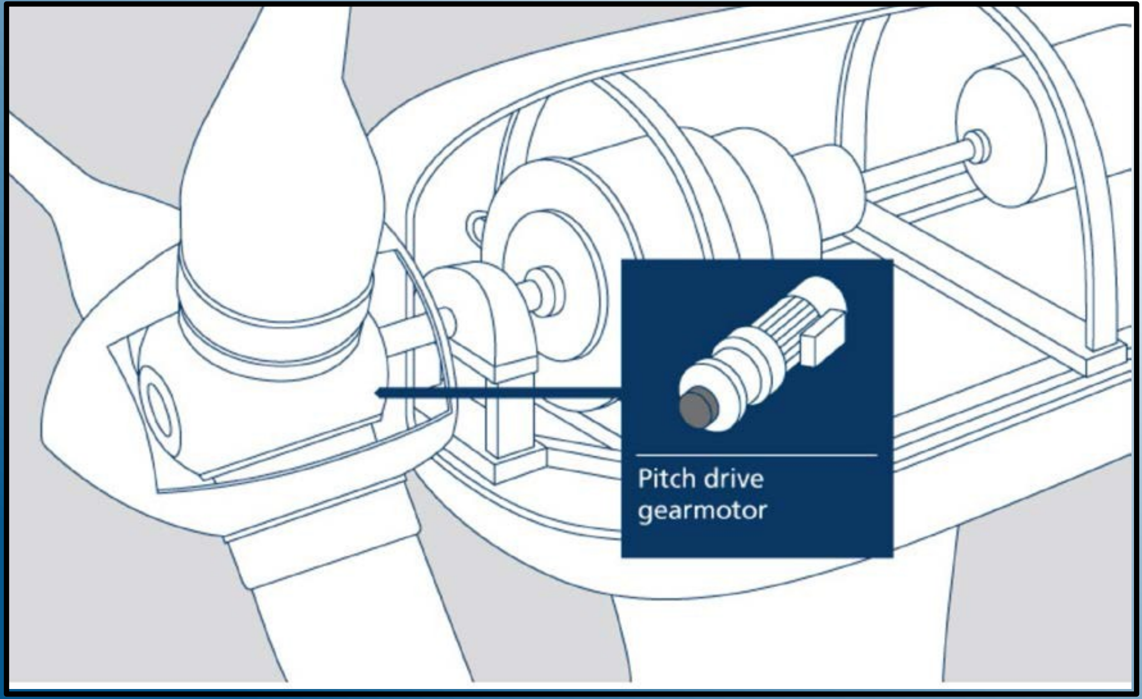
1.2 Rotor Hub

- In other more sophisticated designs, they are bolted to the pitch bearing, which adjusts their angle of attack with the help of a pitch system according to the wind speed to control their rotational speed.
- The pitch bearing is itself bolted to the hub. The hub is fixed to the rotor shaft which drives the generator directly or through a gearbox.

WIND TURBINES:
❖ Turbine Components

1.3 Pitch Control

Pitch control gearboxes serve the essential purpose of setting wind turbine blades at the best angle to the wind to turn the rotor.

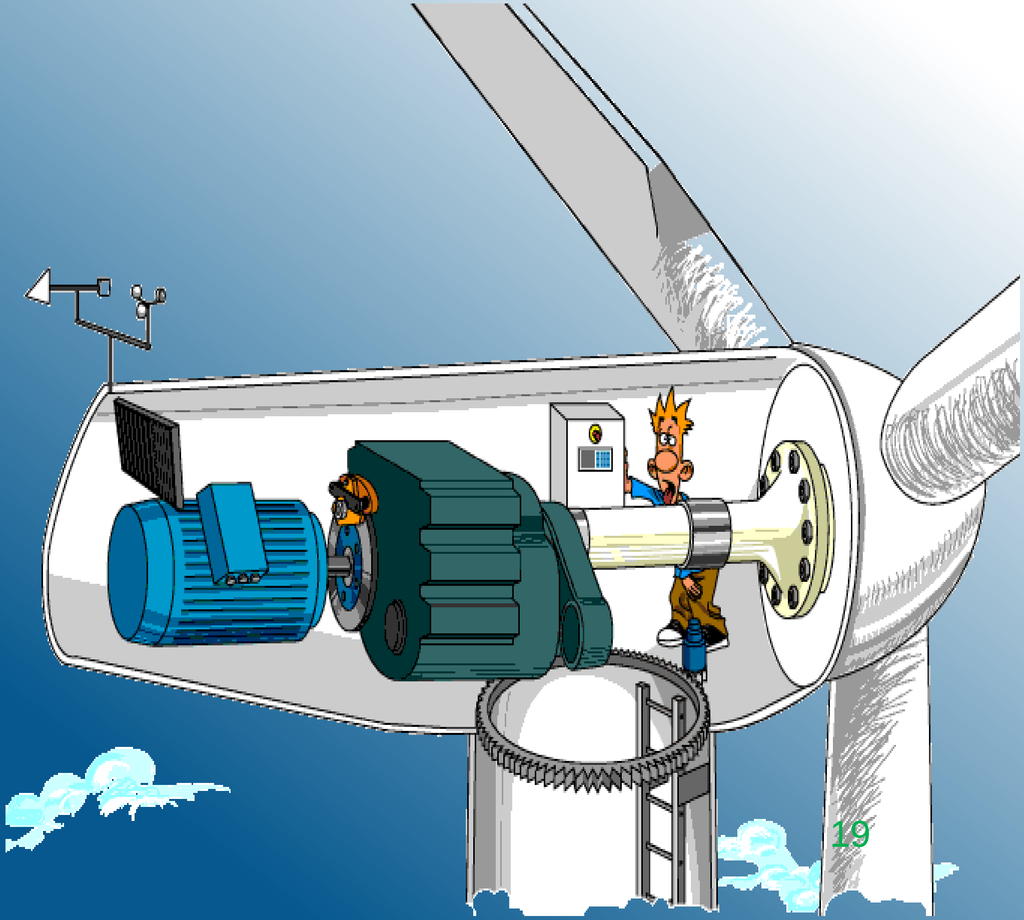


WIND TURBINES:

❖ Turbine Components

2. Nacelle

- The nacelle is a housing for the gearbox and generator
- It connects the tower and rotor
- Sensors detect the wind speed and direction, and motors turn the nacelle .
- Other components inside the nacelle are brake, nacelle frame, hydraulic systems for brakes and lubrication, and cooling system
- The nacelle is also the housing for the electrical generation equipment

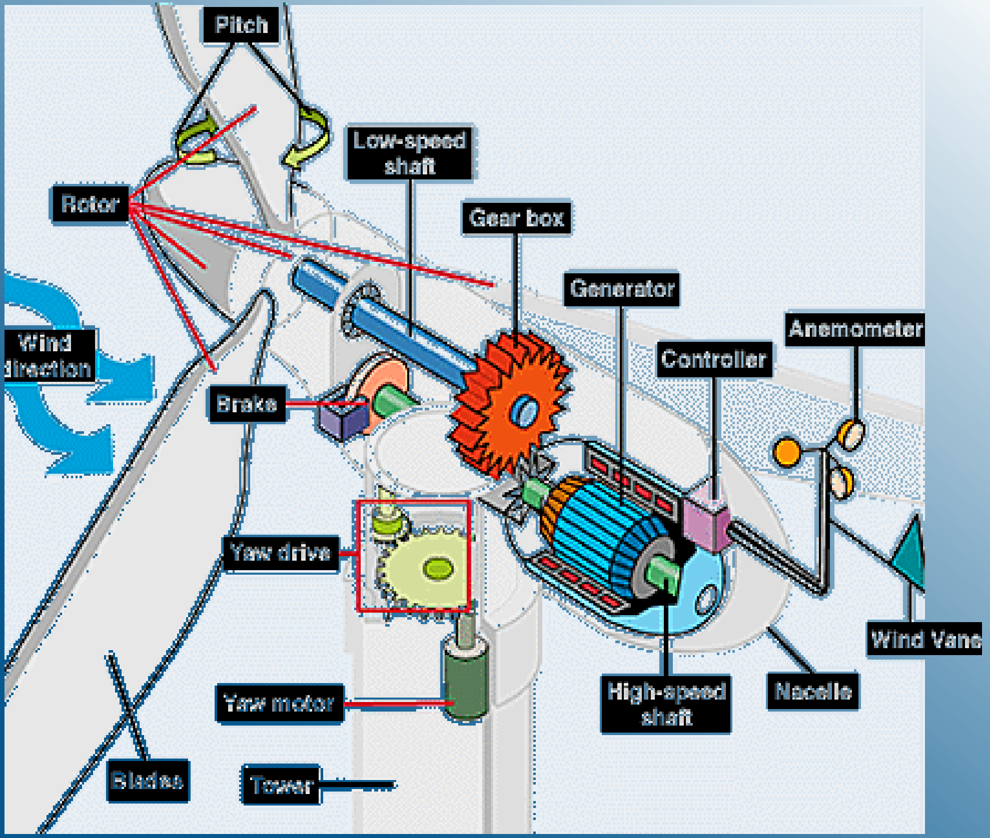


WIND TURBINES:

❖ Turbine Components

2.1 Gearbox

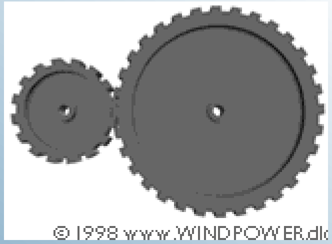
In conventional wind turbines, the blades spin a shaft that is connected through a gearbox to the generator. The gearbox converts the turning speed of the blades 15 to 20 rotations per minute for a large, one-megawatt turbine into the faster 1,800 revolutions per minute that the generator needs to generate electricity.



WIND TURBINES:

❖ Turbine Components

2.1 Gearbox (Cont.)



- ❖ A gearbox is typically used in a wind turbine to increase rotational speed from a low-speed rotor to a higher speed electrical generator. A common ratio is about 90:1, with a rate 16.7 rpm input from the rotor to 1,500 rpm output for the generator.
- ❖ The multiple wheels and bearings in a gearbox suffer tremendous stress because of wind turbulence and any defect in a single component can bring the turbine to a halt. This makes the gearbox the highest-maintenance part of a turbine

WIND TURBINES:

❖ Turbine Components

2.2 Electrical Generator

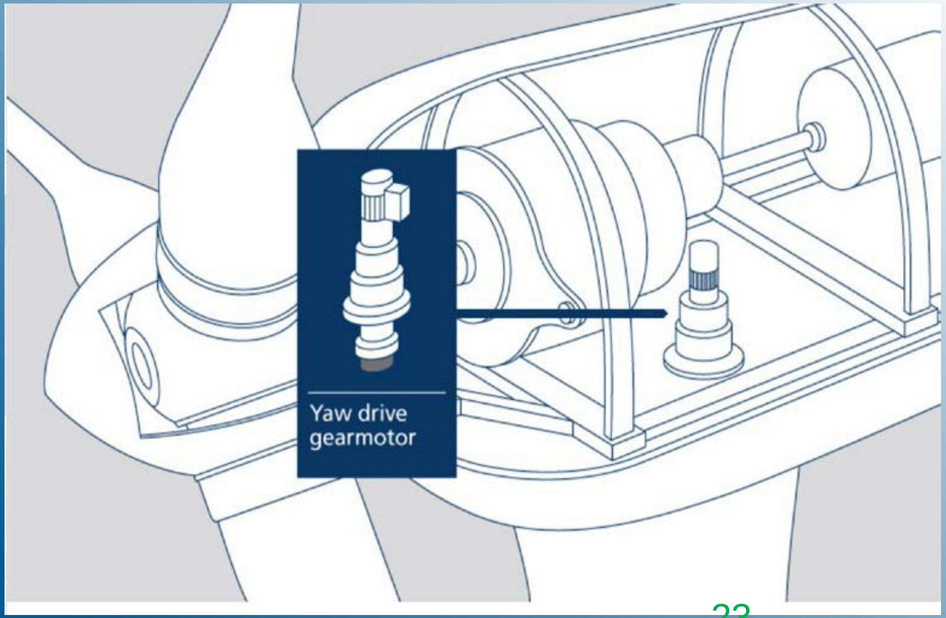
The electrical generator is mounted inside the nacelle at the top of a tower, behind the hub of the turbine rotor. Usually the rotational speed of the wind turbine is slower than the equivalent rotation speed of the electrical network: typical rotation speeds for wind generators are 5–20 rpm while a directly connected machine will have an electrical speed between 750 and 3600 rpm. Therefore, a gearbox is inserted between the rotor hub and the generator. This also reduces the generator cost and weight.

WIND TURBINES:

❖ Turbine Components

2.3 Yaw Control

- Yaw is the angle of rotation of the nacelle around its vertical axis. Efficient yaw control is essential to ensure that wind turbines always face directly into the wind.
- Modern large wind turbines are typically actively controlled to face the wind direction measured by a wind vane situated on the back of the nacelle.



WIND TURBINES:

❖ Turbine Components

2.3 Yaw Control (Cont.)

Smaller turbines (and some older large turbines) use **a passive yaw**, which are of two types: Tail vane to orient the plane of rotation and downwind turbine where the wind flows over the nacelle before turning the blades.

WIND TURBINES:
❖ Turbine Components

THE TOWER

- The tower of the wind turbine carries the nacelle and the rotor.
- Towers for large wind turbines may be either:
  - Tubular steel towers,
  - Lattice towers, or
  - Concrete towers.
  - Guyed tubular towers are only used for small wind turbines (battery chargers etc.)

WIND TURBINES:

- Turbine Components

THE TOWER

Tubular steel tower | Tubular concrete | Lattice tower | Three-legged tower | Guy-wired pole tower

WIND TURBINES:
❖ Turbine Components

3. Towers (Cont.)

Tubular Steel Towers

Most large wind turbines are delivered with tubular steel towers, which are manufactured in sections of 20-30 metres with flanges at either end, and bolted together on the site. The towers are conical (i.e. with their diameter increasing towards the base) in order to increase their strength and to save materials at the same time.

WIND TURBINES:
❖ Turbine Components

3. Towers (Cont.)

Lattice towers

Lattice towers are manufactured using welded steel profiles. The basic advantage of lattice towers is cost, since a lattice tower requires only half as much material as a freely standing tubular tower with a similar stiffness. The basic disadvantage of lattice towers is their visual appearance . For aesthetic reasons lattice towers have almost disappeared from use for large, modern wind turbines.

WIND TURBINES:

❖ Turbine Components

3. Towers (Cont.)

Guyed Pole Towers

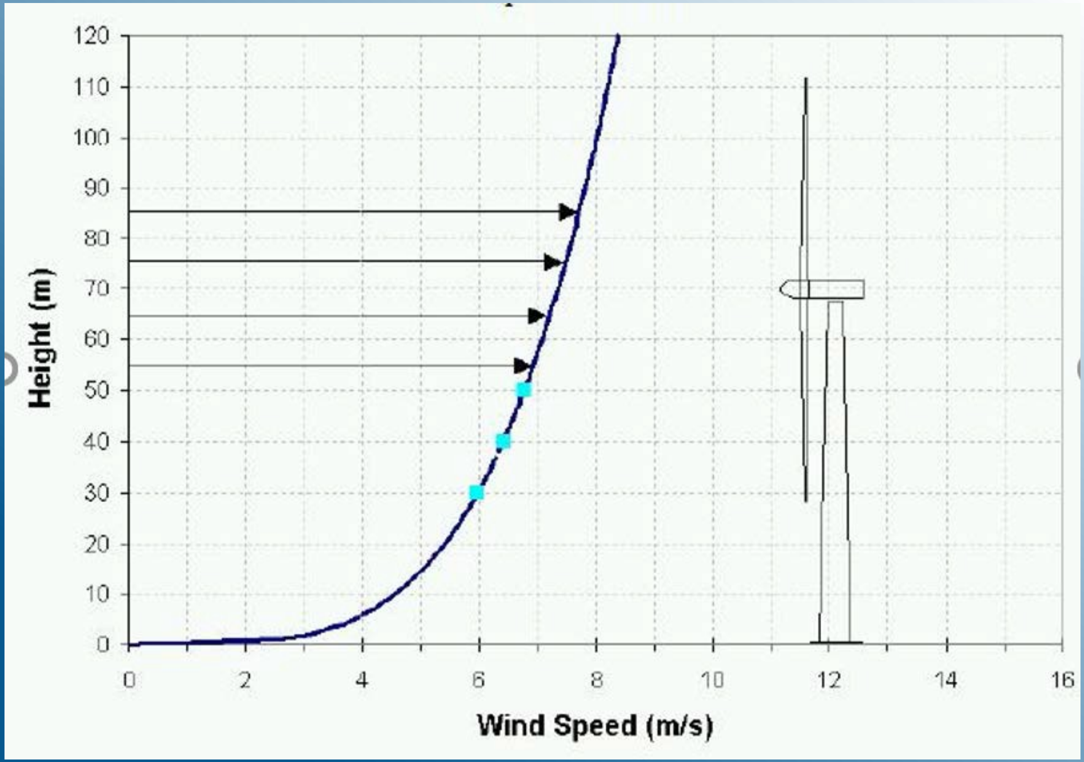
Many small wind turbines are built with narrow pole towers supported by guy wires. The advantage is weight savings, and thus cost. The disadvantages are difficult access around the towers which make them less suitable in farm areas. Finally, this type of tower is more prone to vandalism, thus compromising overall safety.

WIND TURBINES:
❖ Turbine Components

3. Towers (Cont.)

Tower height

Wind velocities increase at higher altitudes due to surface aerodynamic drag and the viscosity of the air.
The variation in velocity with altitude, called **wind <u>shear</u>**



WIND TURBINES:

❖ Turbine Components

3. Towers (Cont.)

Tower materials

- Higher grade S500 **steel** costs 20%-25% more than S335 steel but it requires 30% less material because of its improved strength. Therefore, replacing wind turbine towers with S500 steel would result in a net savings in both weight and cost.
- A hybrid of **prestressed concrete** and steel has shown improved performance over standard tubular steel at tower heights of 120 meters. Concrete also gives the benefit of allowing for small precast sections to be assembled on site, avoiding the challenges steel faces during transportation.

WIND TURBINES:
❖ Turbine Components

4. Foundations

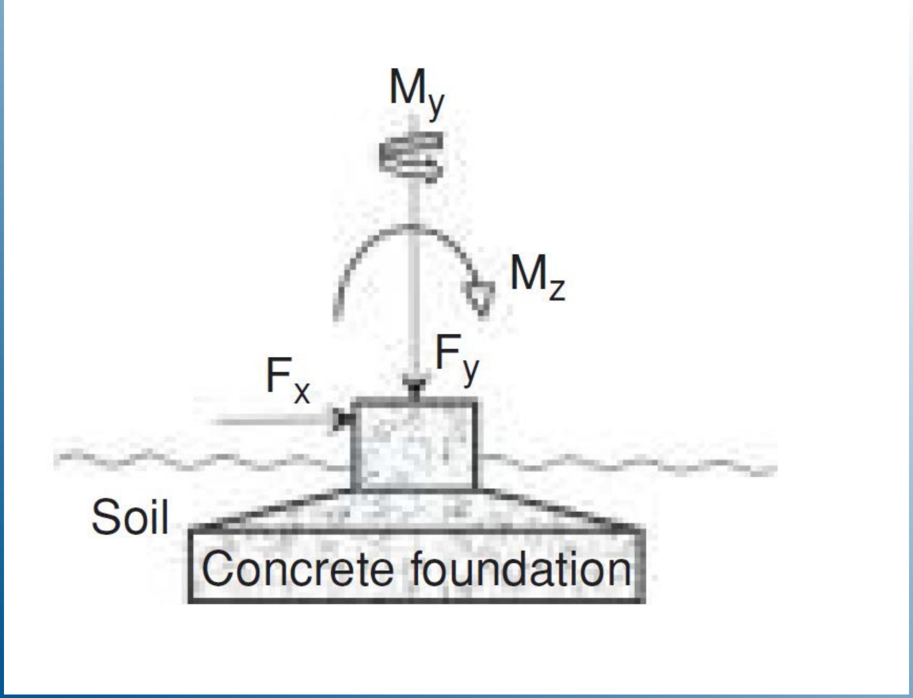
Wind turbines, by their nature, are very tall slender structures, this can cause a number of issues when the structural design of the foundations are considered.

WIND TURBINES:

❖ Turbine Components

4. Foundations (Cont.)

Weight of the structure is the largest force that must be overcome by foundation. The bending moment because of thrust force applied at the hub height is a large moment that must be overcome. The bending moment acts to overturn the entire turbine; the foundation provides the necessary resistance. This bending moment causes the upwind side of the foundation to be tension and the downwind side to be in compression.



WIND TURBINES:
❖ Turbine Characteristics

- ❖ Rotor diameter – up to 120 m
- ❖ Hub height – up to 120 m
- ❖ Peak electrical power output – up to 6 MW now, up to 15 MW foreseen (offshore)
- ❖ Cut-in wind speed (typically 3-4 m/s)
- ❖ Rated wind speed (typically 15 m/s)
- ❖ Cut-out wind speed (typically 25 m/s)

WIND TURBINES:

❖ Turbine: Power Capacity

- ❖ Onshore – typically 2 MW, some up to 4 MW, but restricted due to the logistical difficulties of transporting blades by road
- ❖ Offshore – many 6-7 MW turbines are available, the largest currently available is the 9.5 MW Vestas V-164, and 15 MW turbines are currently envisaged
- ❖ Building larger turbines for offshore is regarded as one of the keys to reducing the still high unit cost of offshore wind energy

WIND TURBINES:

- ❖ Turbine: Size Progression