Energy and Environment Science

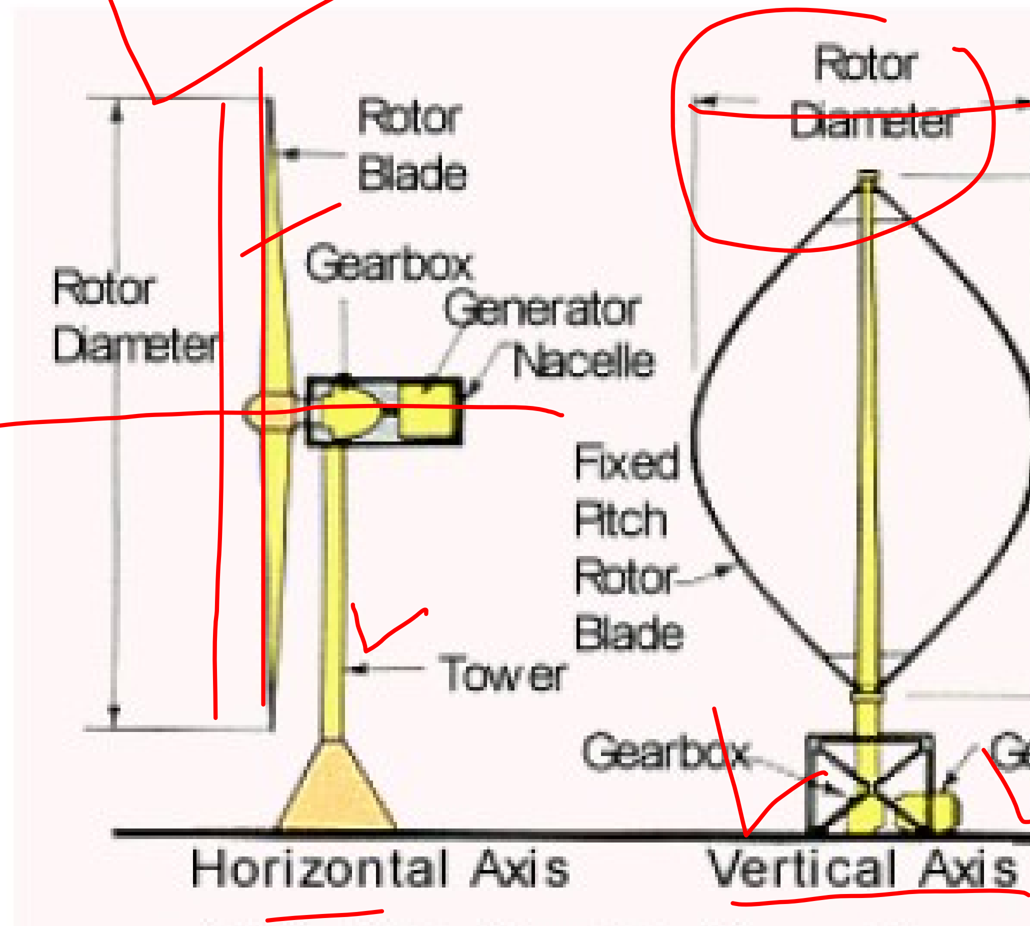
Unit – 3 : Wind Energy Syllabus:

i. Power and energy from wind turbines
ii. Wind energy theory and Fundamentals
iii. **Types of wind turbines**
iv. **Offshore Wind energy**
v. India’s wind energy potential
vi. Environmental benefits and impacts.

Types of Wind Mill and Classification

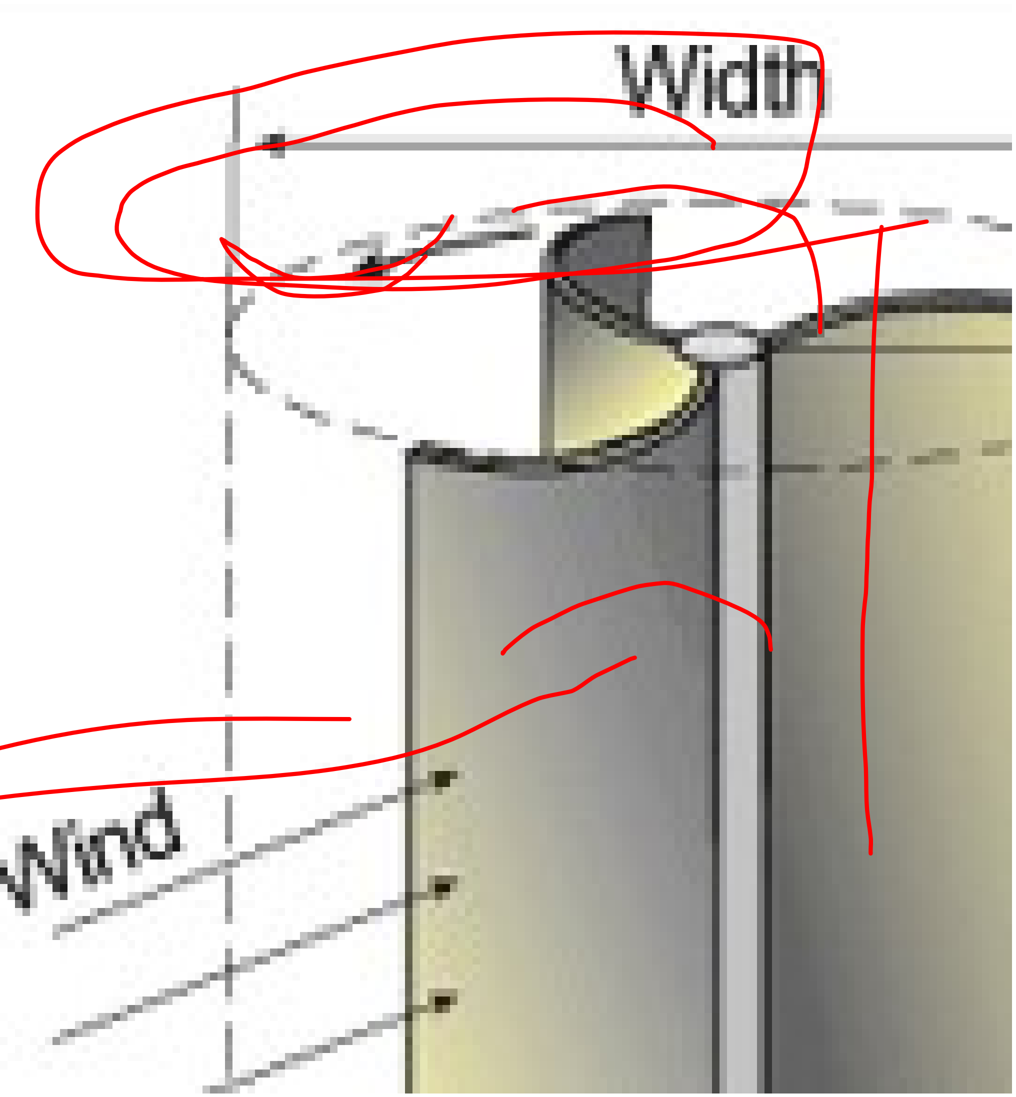
Wind Energy Design

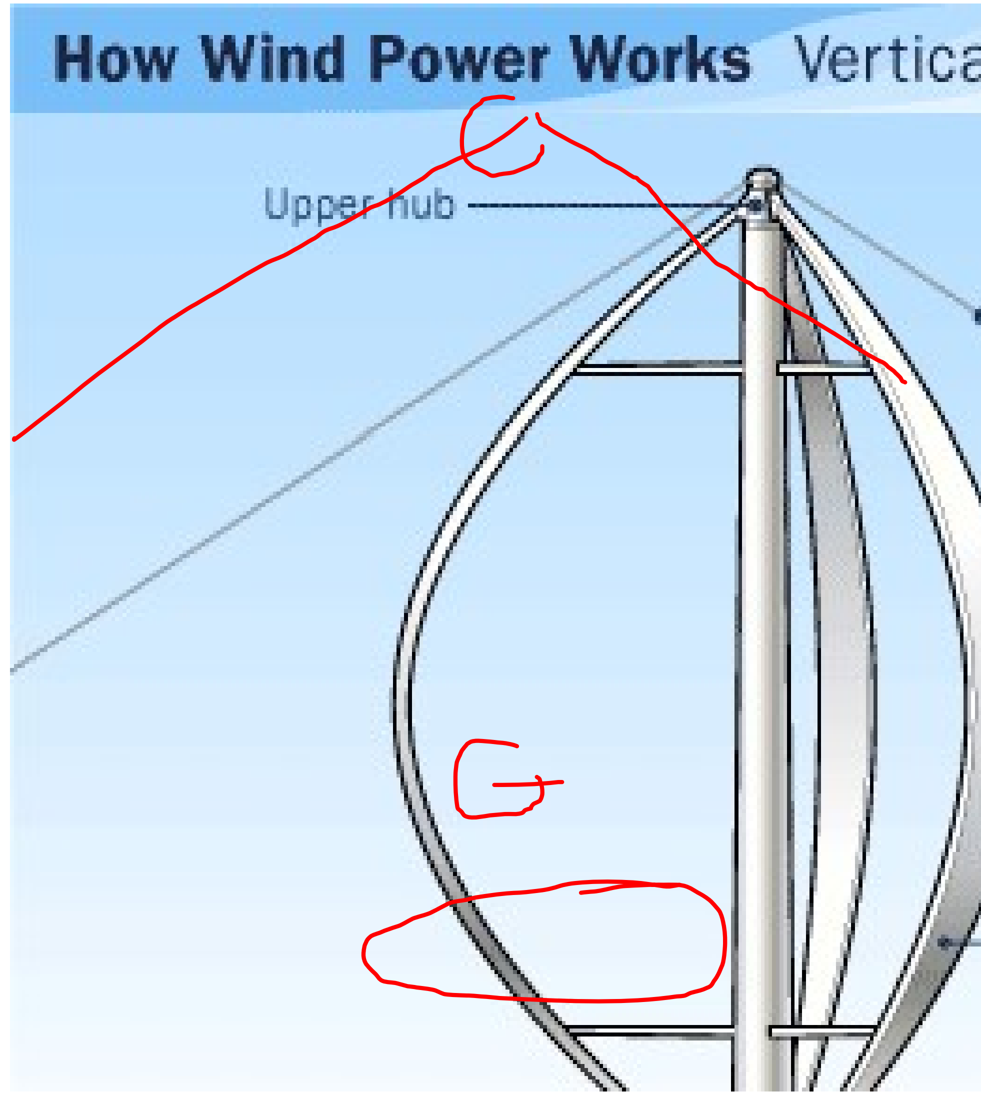
re are two basic designs wind electric turbines: **ical-axis, or "egg-beater" e, and horizontal-axis chines**. Horizontal-axis d turbines are most mon today.



Wind Turbine Configurations

2.3.2.Wind energy- Classification





Vertical wind mill (Darrieus rotar)

WIND TURBINE TYPES AND THEIR CONSTRUCTION

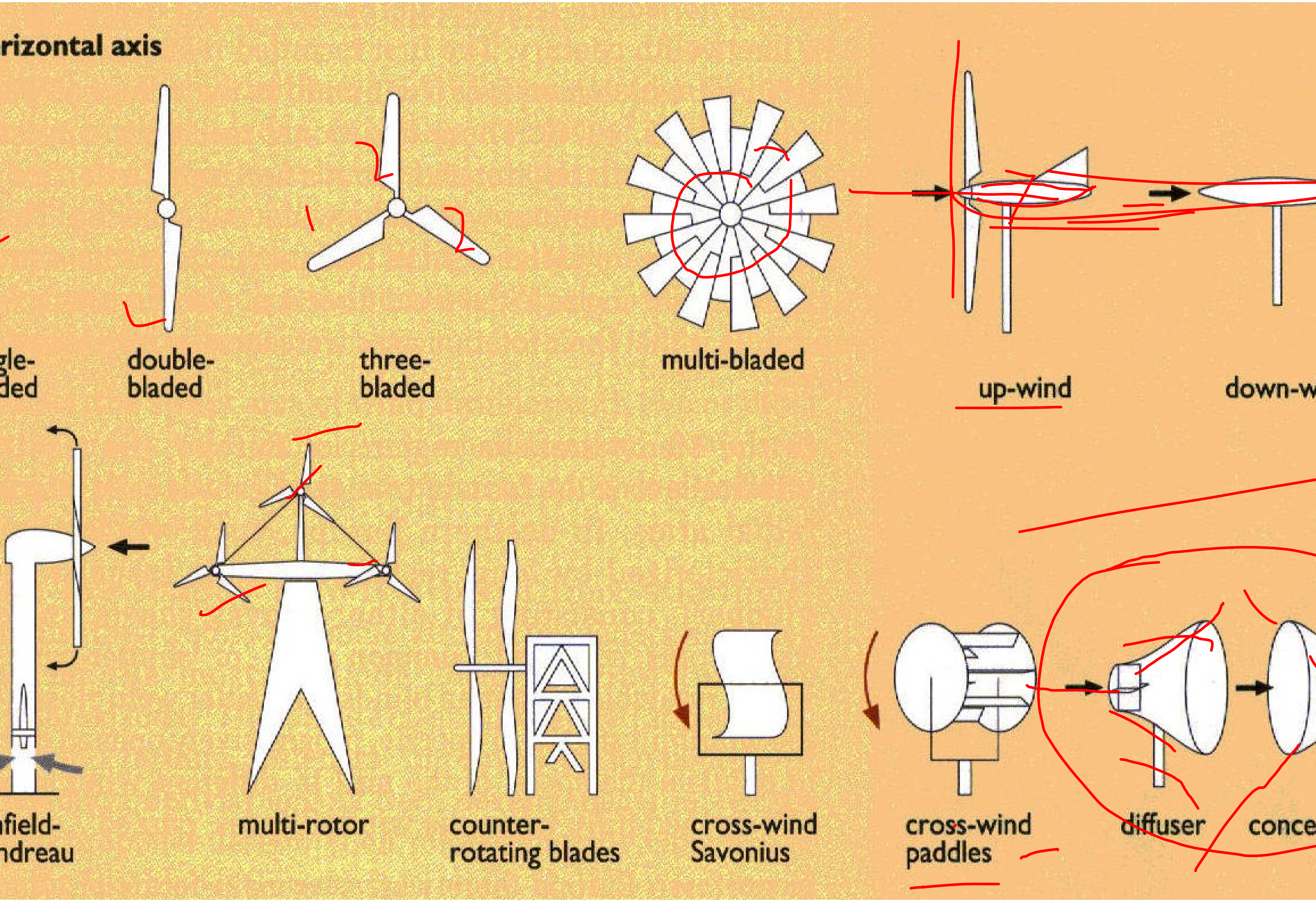
Wind turbines are broadly classified into two categories.

1. **Horizontal Axis Wind Turbine (HAWT),**
2. **Vertical Axis Wind Turbine (VAWT).**

When the axis of rotation is **parallel** to the air stream (i.e. horizontal), the turbine is said to be a **Horizontal Axis Wind Turbine (HAWT), A horizontal axis machine has its blades rotating on an axis parallel to the ground**

When it is **perpendicular** to the air stream (i.e. vertical), it is said to be a **Vertical Axis Wind Turbine (VAWT).**

A vertical axis machine has its blades rotating on an axis perpendicular to the ground.


rizontal axis
gle-
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multi-bladed
up-wind
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Savonius
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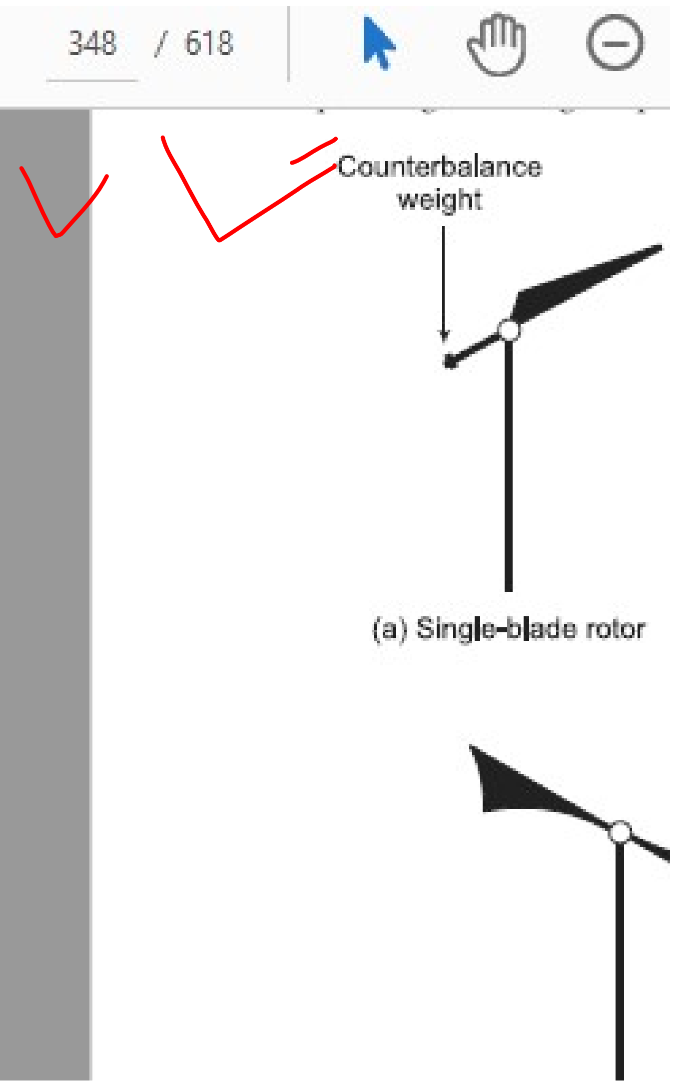
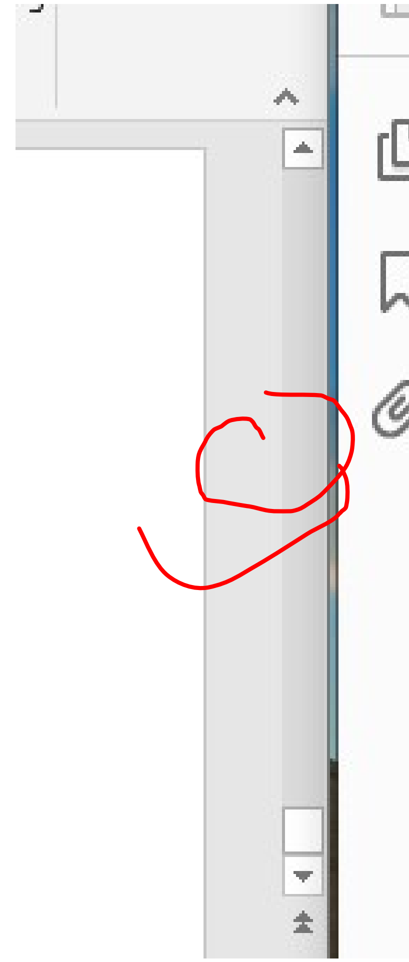
Horizontal Axis Wind Turbine (HAWT)

Types of Rotors



3. Teetering of Rotor

- As wind speed rises with height, the axial force on blade when it attains the upper position is significantly higher as compared to that when it is at lower position.
- For one and two blade rotors this causes cyclic (sinusoidal) load on a rigid hub leading to fatigue. This is greatly relieved by providing a teeter hinge (a pivot within the hub) that allows a see-saw motion to take place out of the plane of rotation



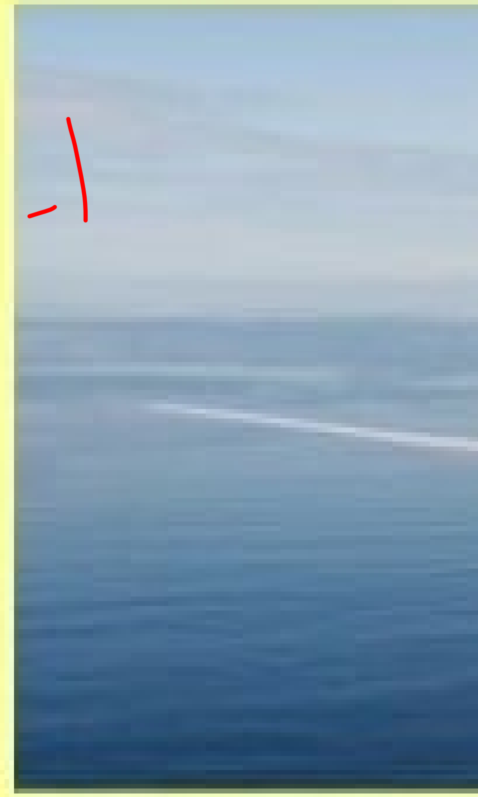
A teetered hub

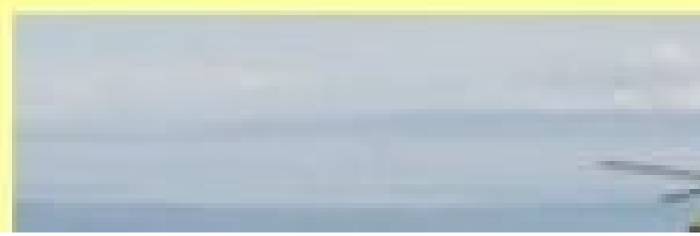
Number of Blades –

- Rotor must move more rapidly to capture same amount of wind
  - Gearbox ratio reduced
  - Added weight of counterbalance negates some benefits of lighter design
  - ~~Higher speed~~ means more noise, visual, and wildlife impacts
- Blades easier to install because entire rotor can be

Number of Blades -

- Advantages & disadvantages similar to one blade
- Need teetering hub and or shock absorbers because of gyroscopic imbalances
- Capture 5% less



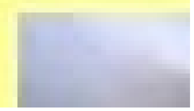


Number of Blades - T

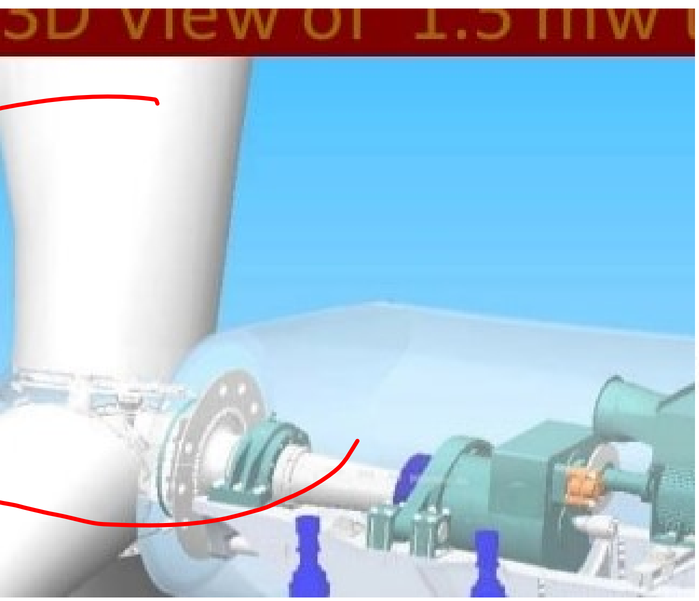
- Balance of gyroscopic forces
- Slower rotation
  - increases gearbox & transmission costs

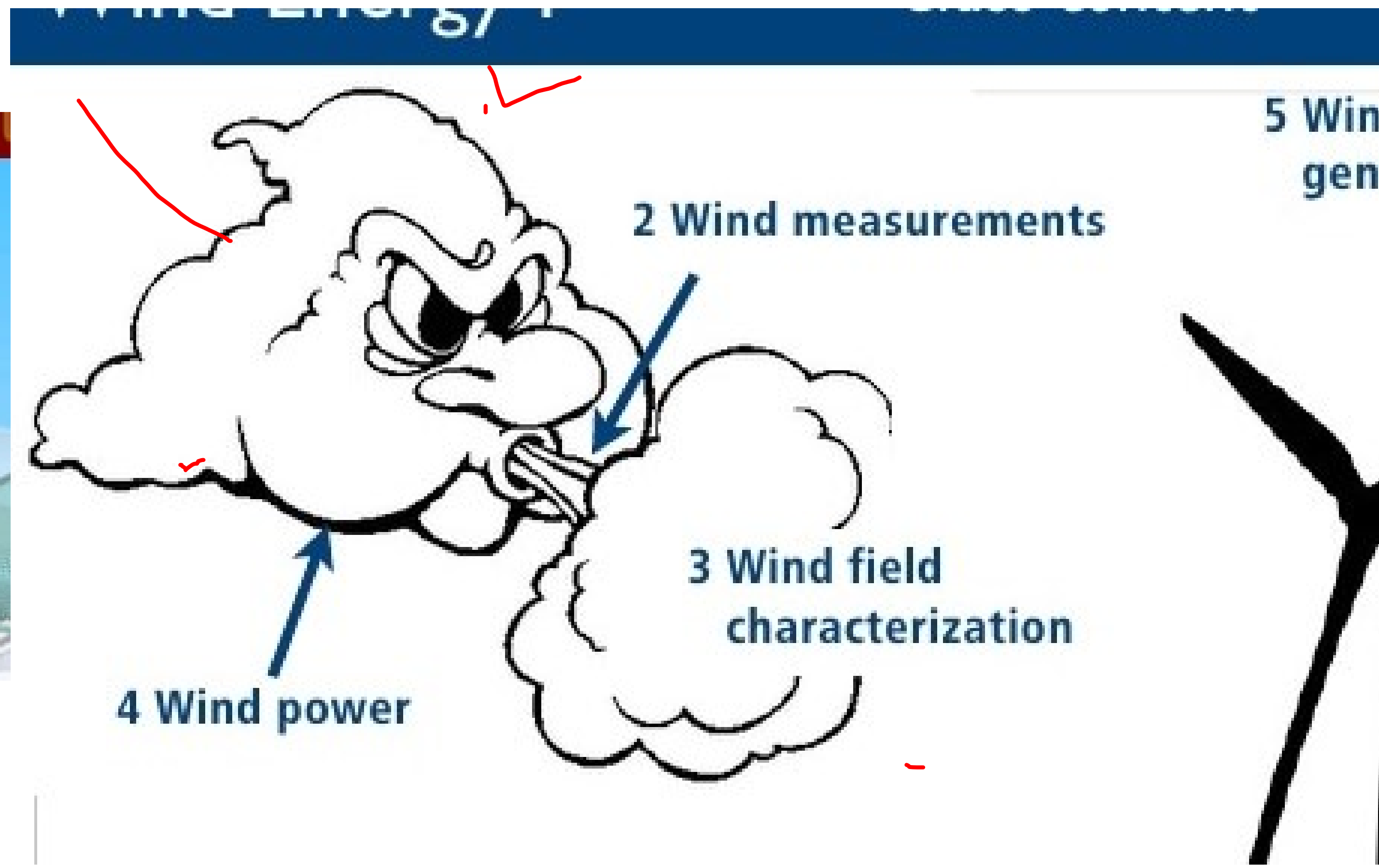
Blade Composition Metal

- Steel
  - Heavy & expensive
- Aluminum
  - Lighter-weight and easy

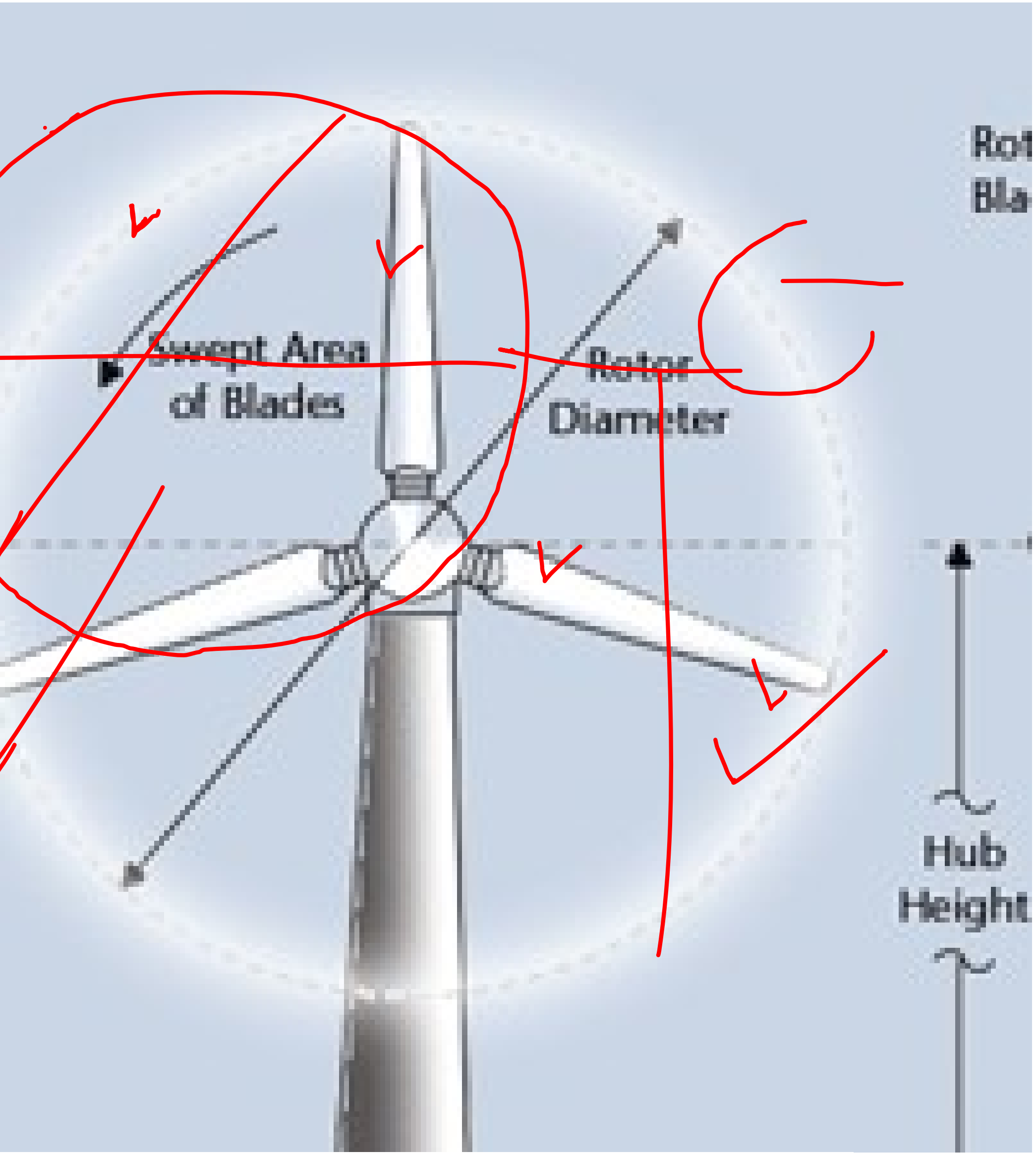


WIND MILL SYSTEMS & ITS COMPONENTS





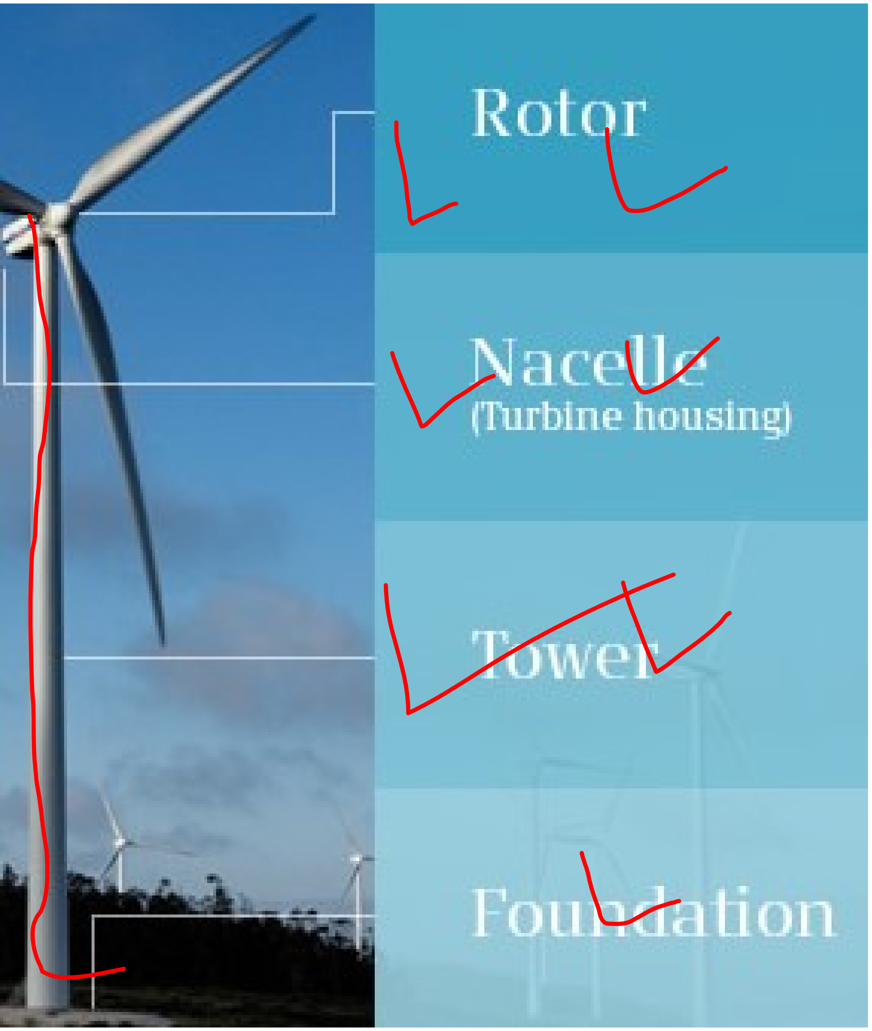
Horizontal-axis wind Mill



Rotor and Blades

Horizontal-axis wind turbi
which are the **most commo**
have the main rotor shaft
and electrical generator at t
top of a tower, and must be
pointed into the wind.

Major components of System



- **Rotor, or blades,** which **convert the wind's energy into rotational shaft energy.**
- **Nacelle (enclosure)** containing a dr train, usually including a **gearbox (S turbines operate without a gearbo and a generator.**
- **Tower,** to support the rotor and dri train; and
- **Electronic equipment** such as contr electrical cables, ground support equipment, and interconnection equipment.

Horizontal Axis Wind Turbine (HAWT)

in Components

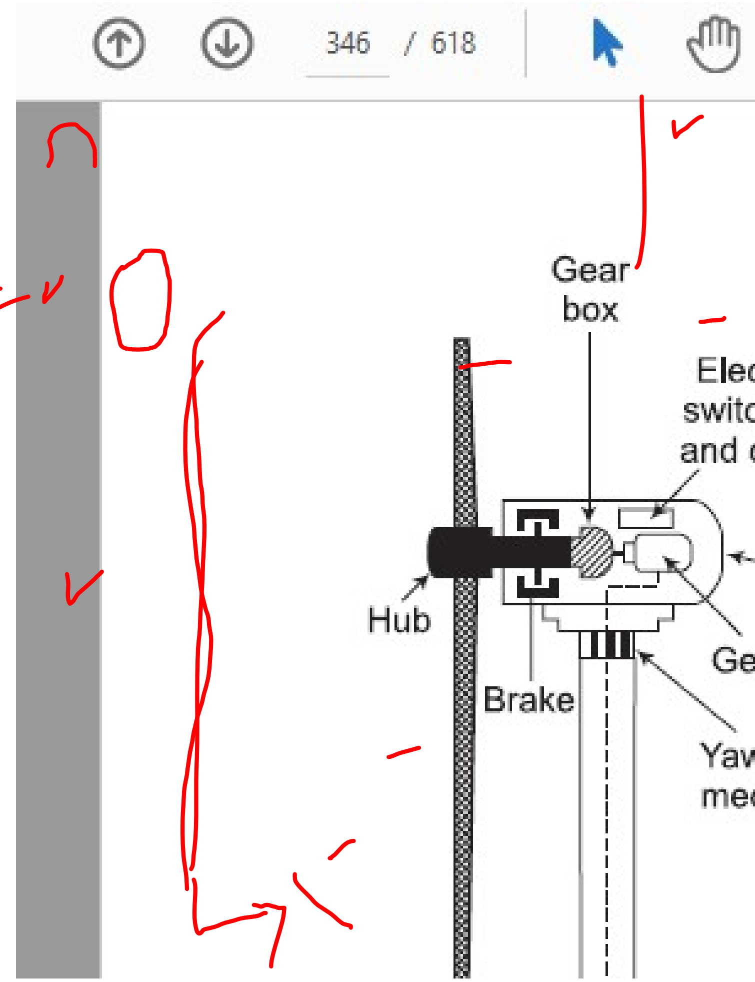
rbine Blades - Turbine blades are made of high-
ensity wood or glass fiber and epoxy
mposites. They have airfoil type cross-section.

ub - The central solid portion of the rotor wheel
known as hub.

acelle - The term nacelle is derived from the
me for housing containing the engines of an
rcraft. The rotor is attached to nacelle, mounted
the top of a tower.

w Control Mechanism - The mechanism to
ljust the nacelle around vertical axis to keep it
cing the wind is provided at the base of nacelle.

wer - Tower supports nacelle and rotor. For
edium and large sized turbines, the tower is
ghtly taller than the rotor diameter.



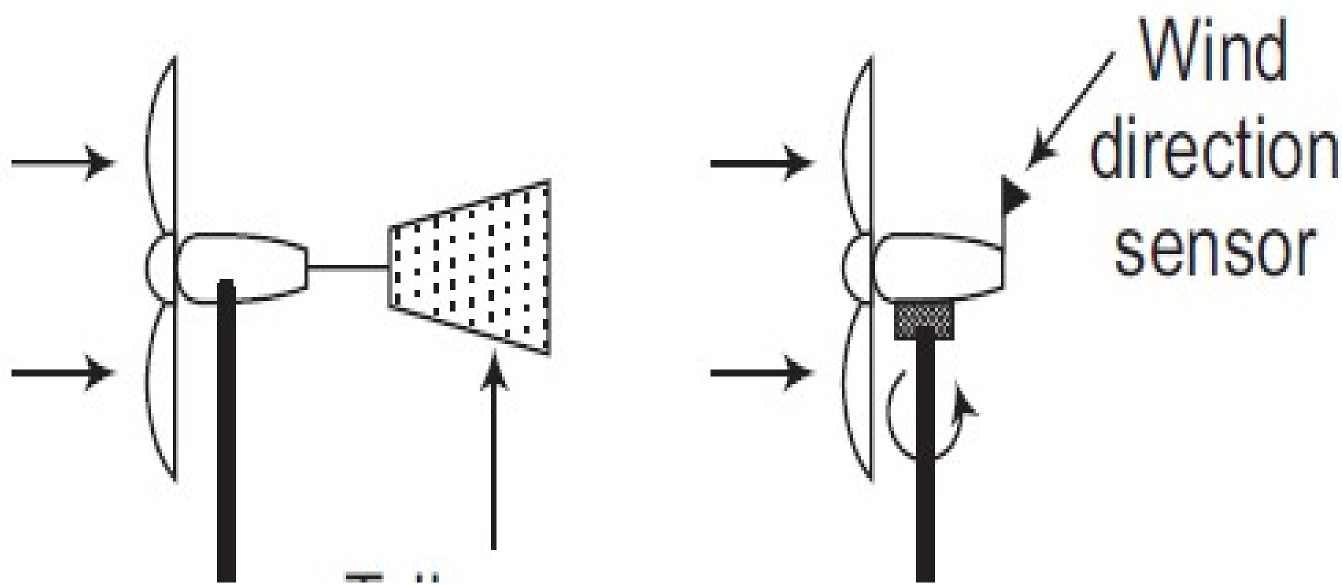
Horizontal Axis Wind Turbine (HAWT)

vind and Downwind Machines

In upwind machine, rotor is located upwind (in front) of the tower whereas in downwind machine, the rotor is located downwind of (behinc the tower

dangerous as it may excite any natural mode of t

harmonics.



Horizontal Axis Wind Turbine (HAWT)

'aw Control System

usting the nacelle
out vertical axis to
ng the rotor facing
wind is known as
v control.

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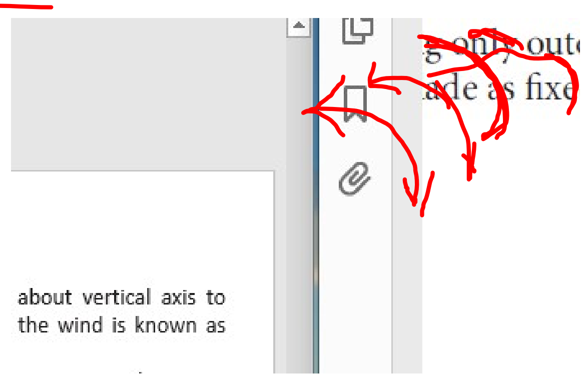
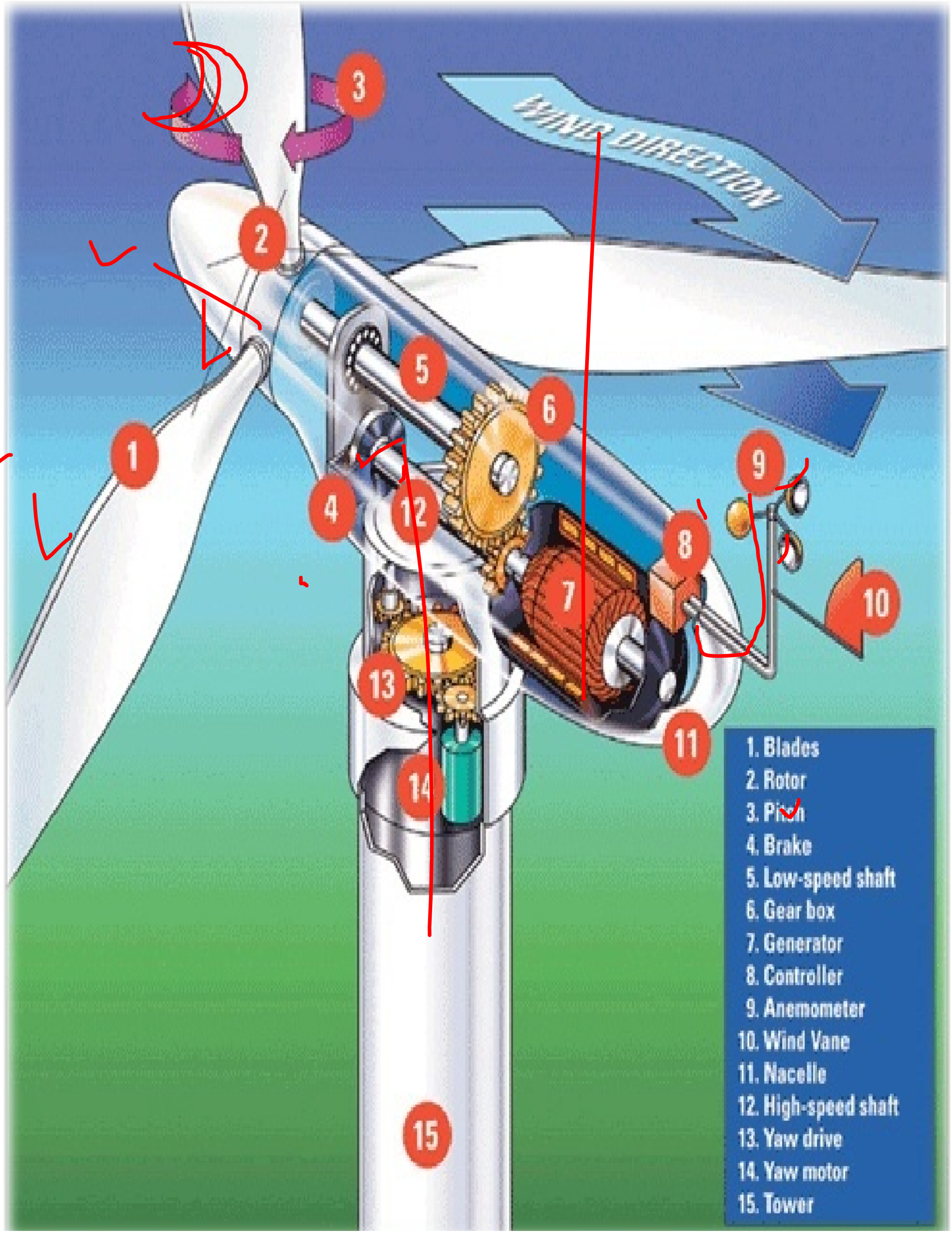
stem continuously
ents the rotor in the
ection of wind.



6. Pitch Control System

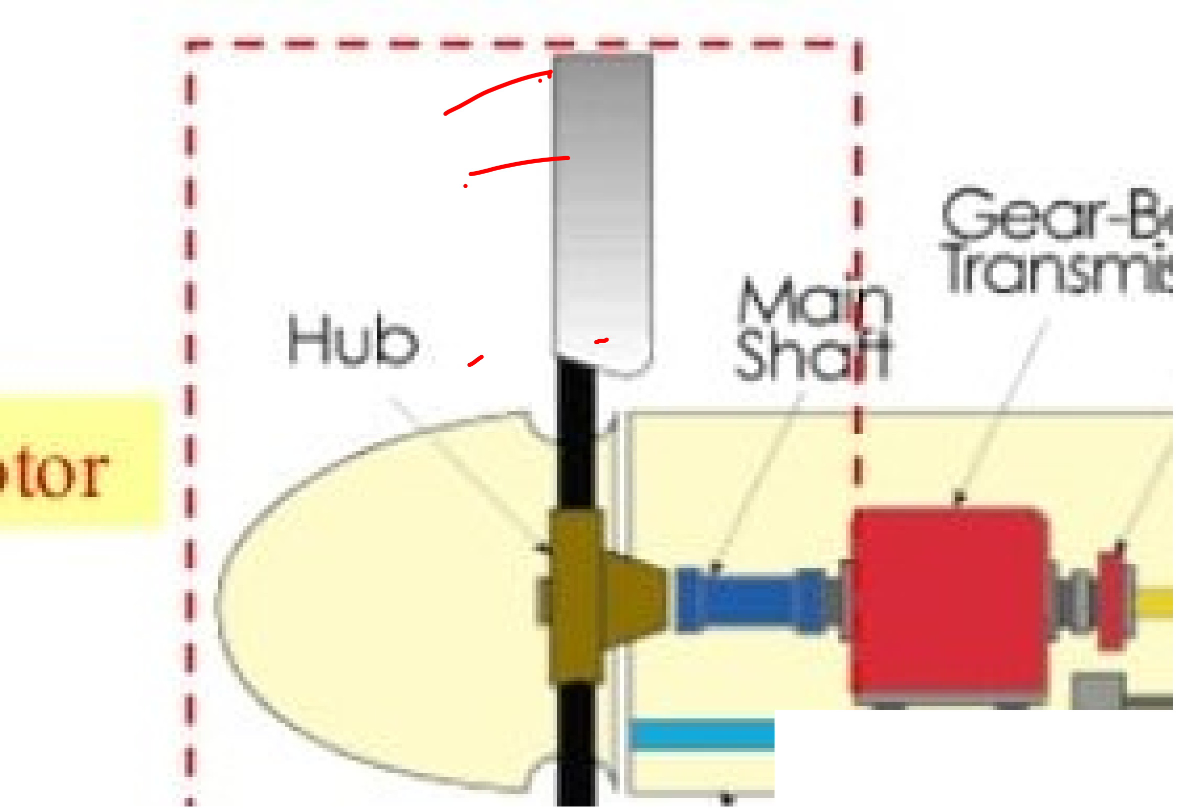
- Pitch contr
mechanism is provide
through the hub usin
hydraulic jack in th
nacelle.
- The control syste
continuously adjus
the pitch to obta
optimal performance.



Components of Wind Turbine

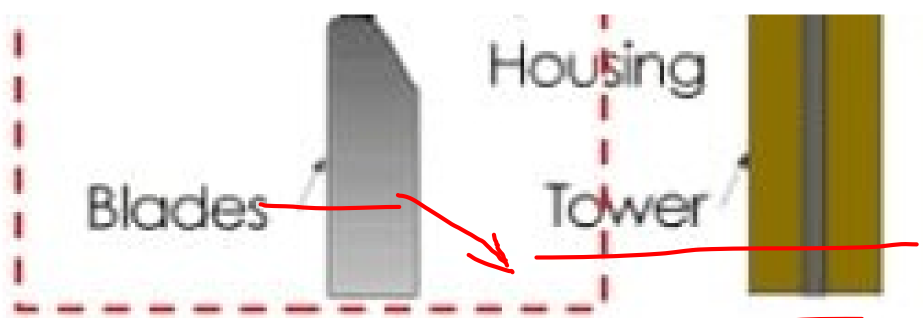
1. ROTOR
2. DRIVE TRAIN
3. TOWER
4. CONTROL SYSTEM
5. YAW SYSTEM
6. MAIN FRAME
7. NACELLE

Rotor



- **Two- and three-bladed rotors a commonly used for power generation.**

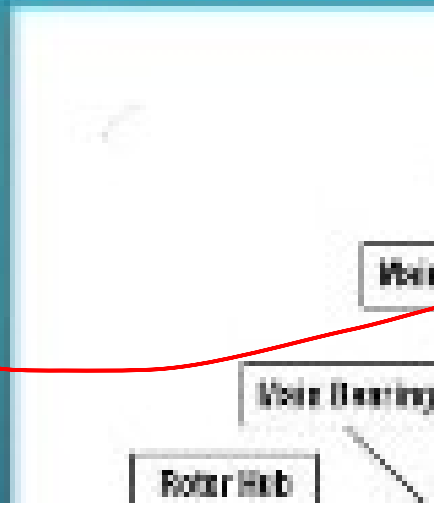
  Multi-bladed rotors have large starting torque in light winds and used for water pumping and low frequency mechanical power.

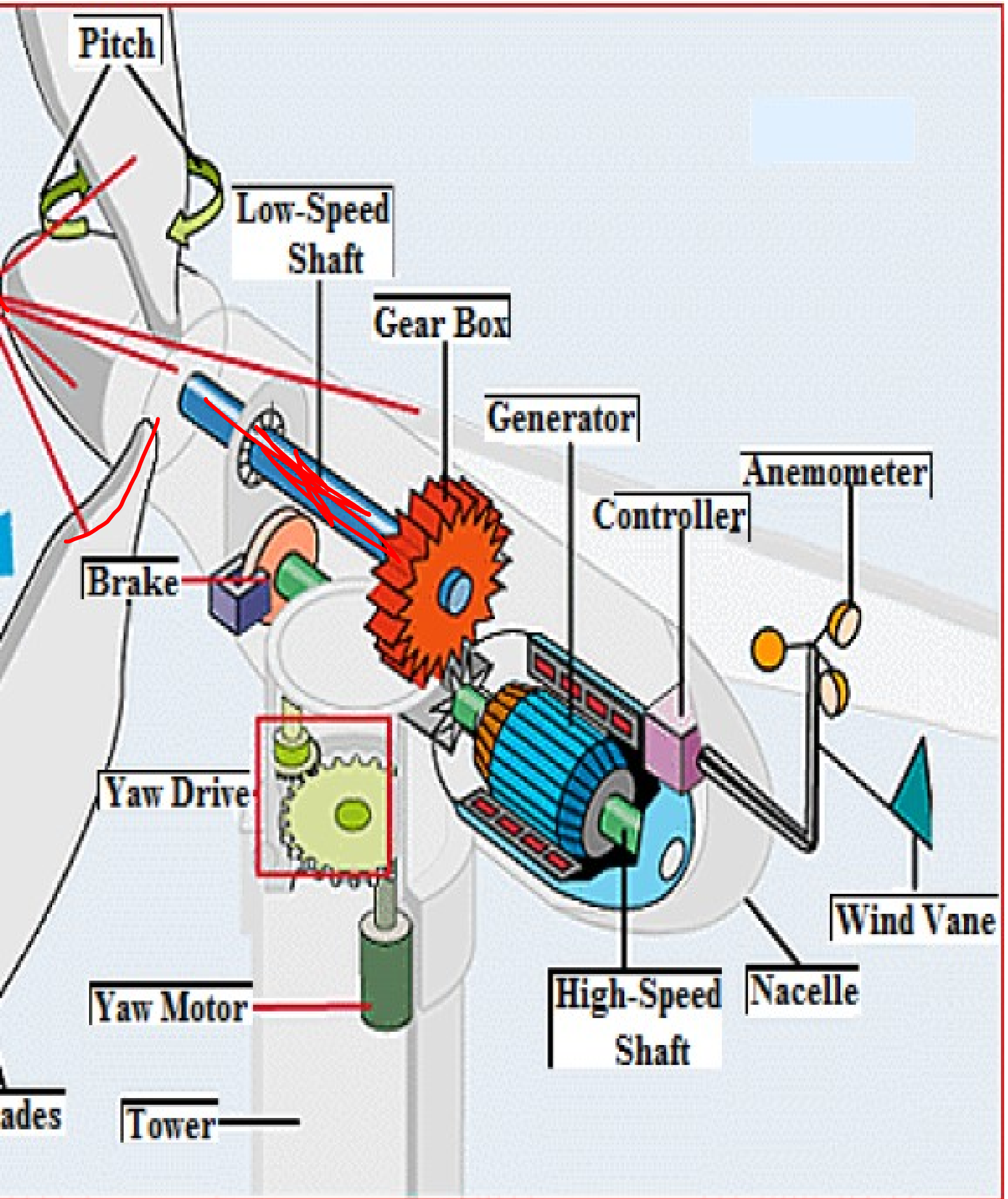


- **Blades are connected to a hub, whic**

NACELLE

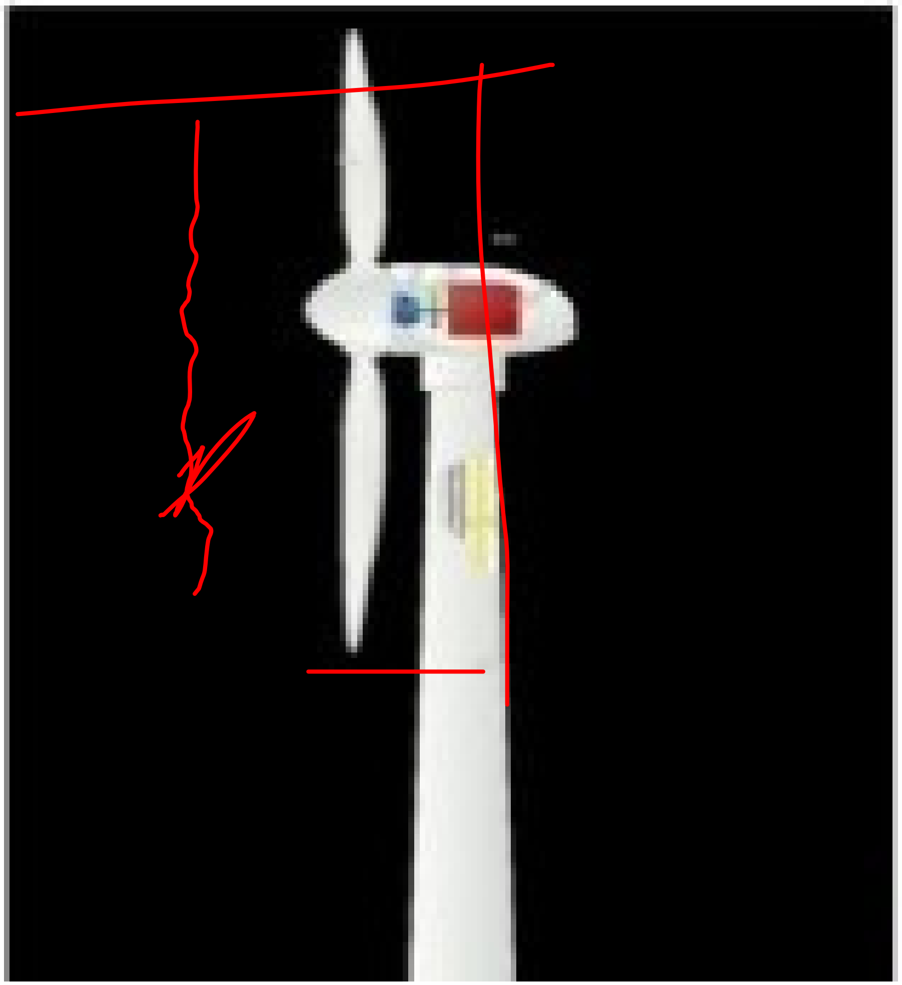
- The term nacelle is derived from the name for housing (casing) containing the engines of an wind turbine (Aerogenerator).
- The rotor is attached to the nacelle, and mounted at top of a

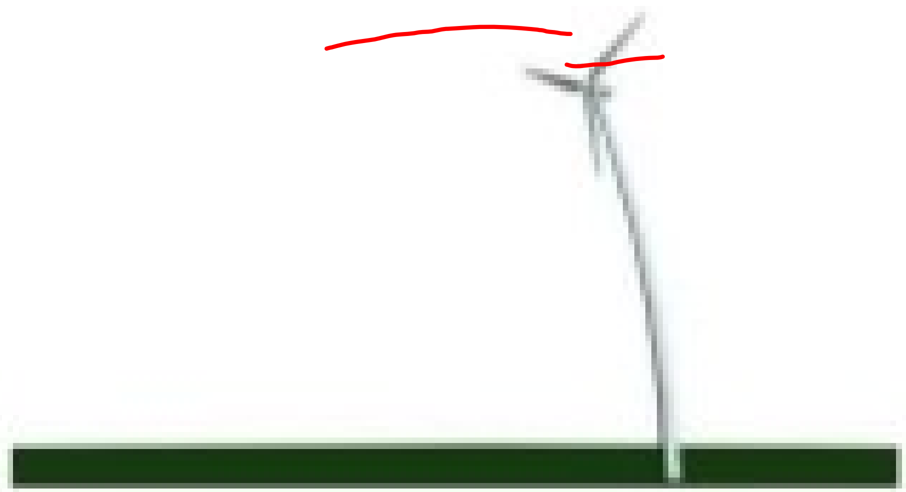




Nacelle Assembly: Nacelle is t part of wind turbine at top of tower housing containing gear box, gene assemblies and any control component.

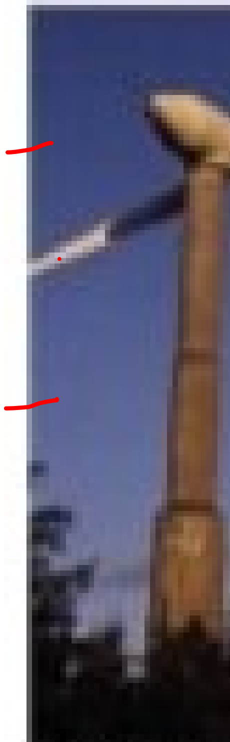
Low-speed shaft: The low-speed shaft, which is the main shaft, is connected directly to the rotor hub. rotor turns the low-speed shaft at a **30 to 60 rotations per minute.**





TYPES OF TOWERS

1. The reinforced concrete tower,
2. The pole tower,
3. The built up shell-tube tower, and



Features of major Compone

Tower

- Tubular Tower for be
- Designed stiffness to
- frequencies
- Designed to reduce th
- minimum
- Load Separation plate
- foundation for better
- distribution.
- Ergonomically design
- necessary safety equi
- Superior cable manag

Wind turbines: Components

lades	Most turbines have three blades. The turning of
ub	Centre of the rotor to which the rotor blades are
otor	Blades and hub referred together
ow-speed shaft	Turned by the rotor at about 30 to 60 rotations p
ears	Connects low-speed shaft to high-speed shaft a from about 30 to 60 rpm to about 1000 to 1800 r required by most generators to produce electrici
enerator	Produces electricity
igh-speed shaft	Drives generator
ontroller	Starts up and shuts off the machine
nemometer	Measures wind speed and transmits wind speec
Vind vane	Measures wind direction and communicates witl

Technical specifica

- Tower

Nominal Power -1500 k

Rotor dia

Hub height-

Rotor cone a

Swept area -5

Rotor speed (at rated p

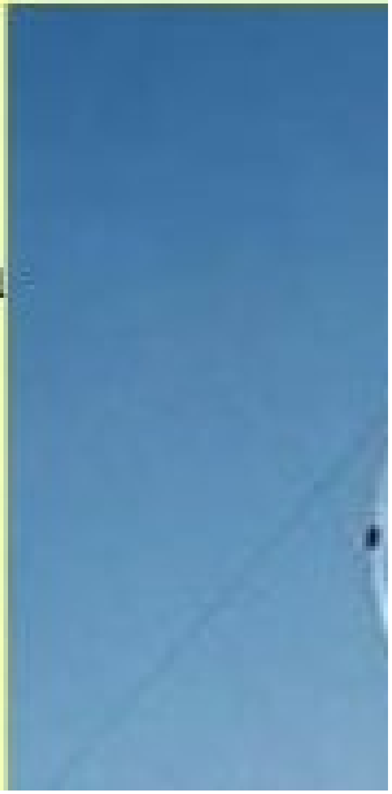
Rotational speed 1

Tip speed (at rated

Blade lengt

Vertical Axis Wind Turbin

- 1920 :Invented by G. M. Darrieus (French Engineer): Darrieus Rotor
- 500 kW, 34m long was undertaken in 1980 by Sandia national Lab, USA but leaving the business in 1997



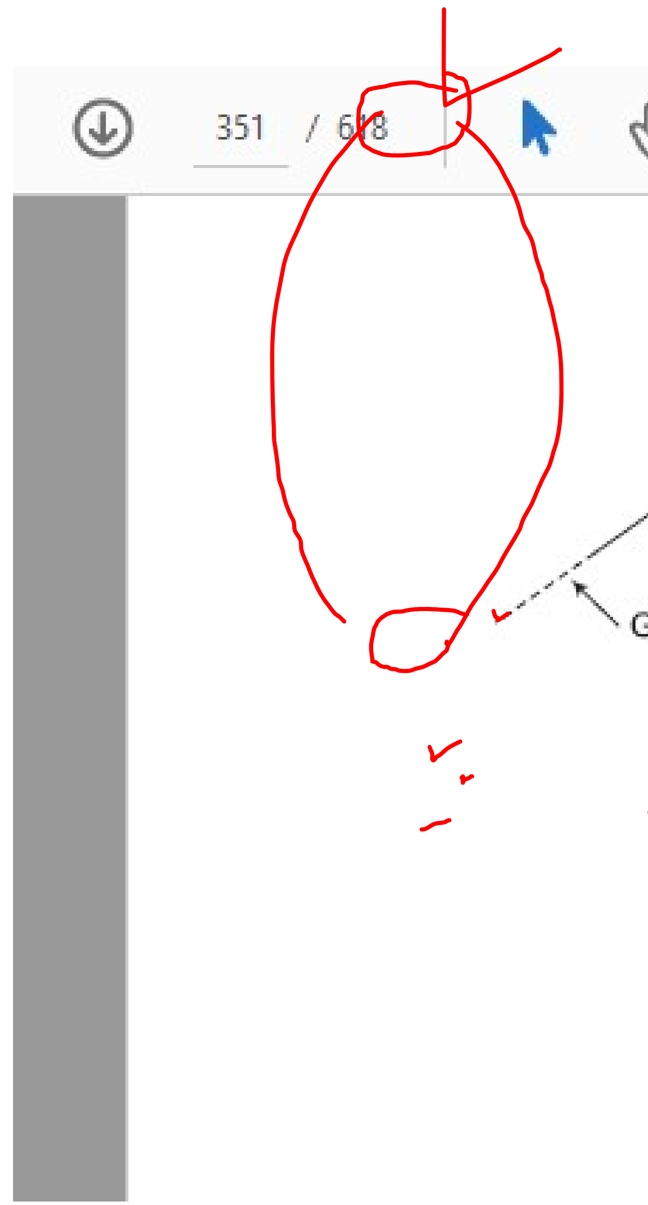
Vertical Axis Wind Turbine (VAWT)

. Main Components

Tower (or Rotor Shaft) - The tower is a hollow vertical rotor shaft, which rotates freely about vertical axis between top and bottom bearings. It is installed above a support structure.

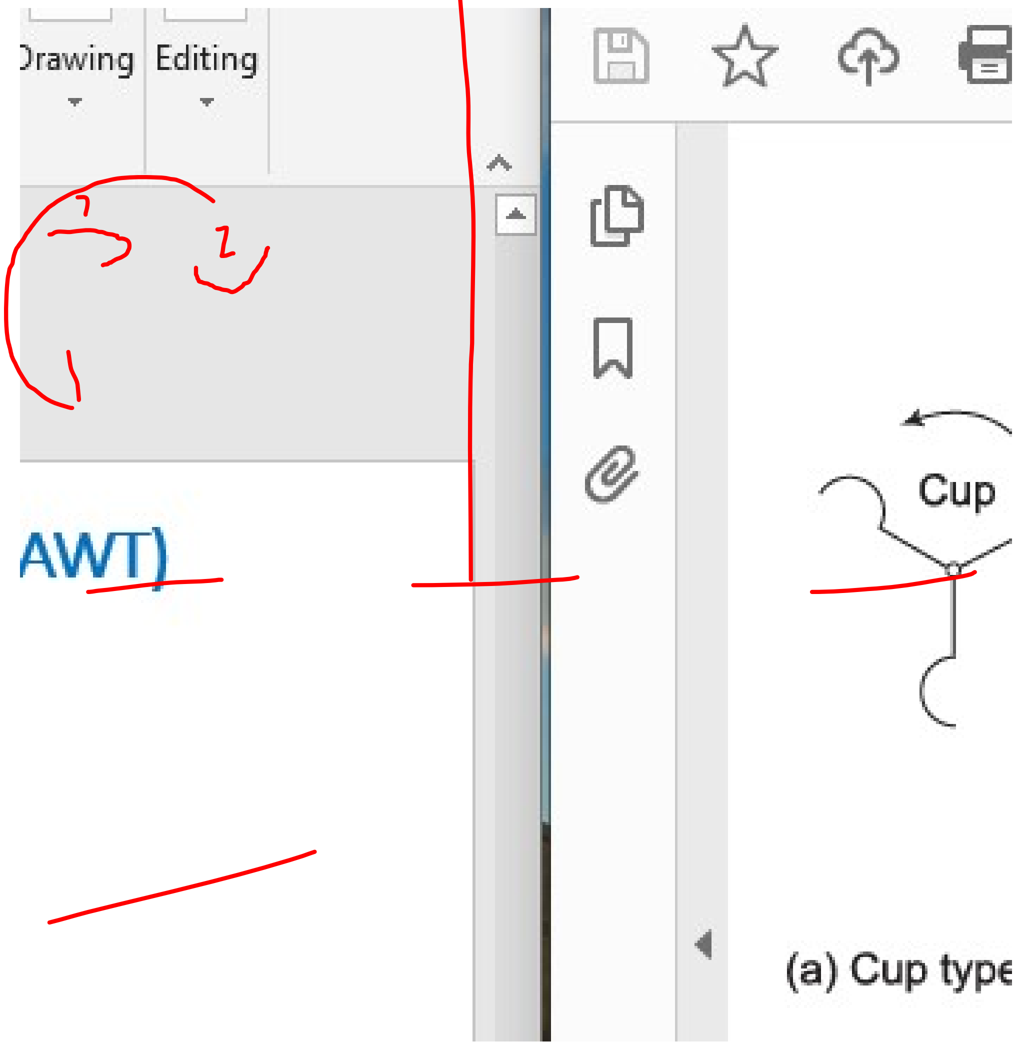
Blades - It has two or three thin, curved blades shaped like an eggbeater in profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces-the so-called 'Troposkien' profile. The blades have airfoil crosssection with constant chord length.

Support Structure - Support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.



Vertical Axis Wind Turbine (VAWT)

2. Types of Rotors



Types of WT contd..

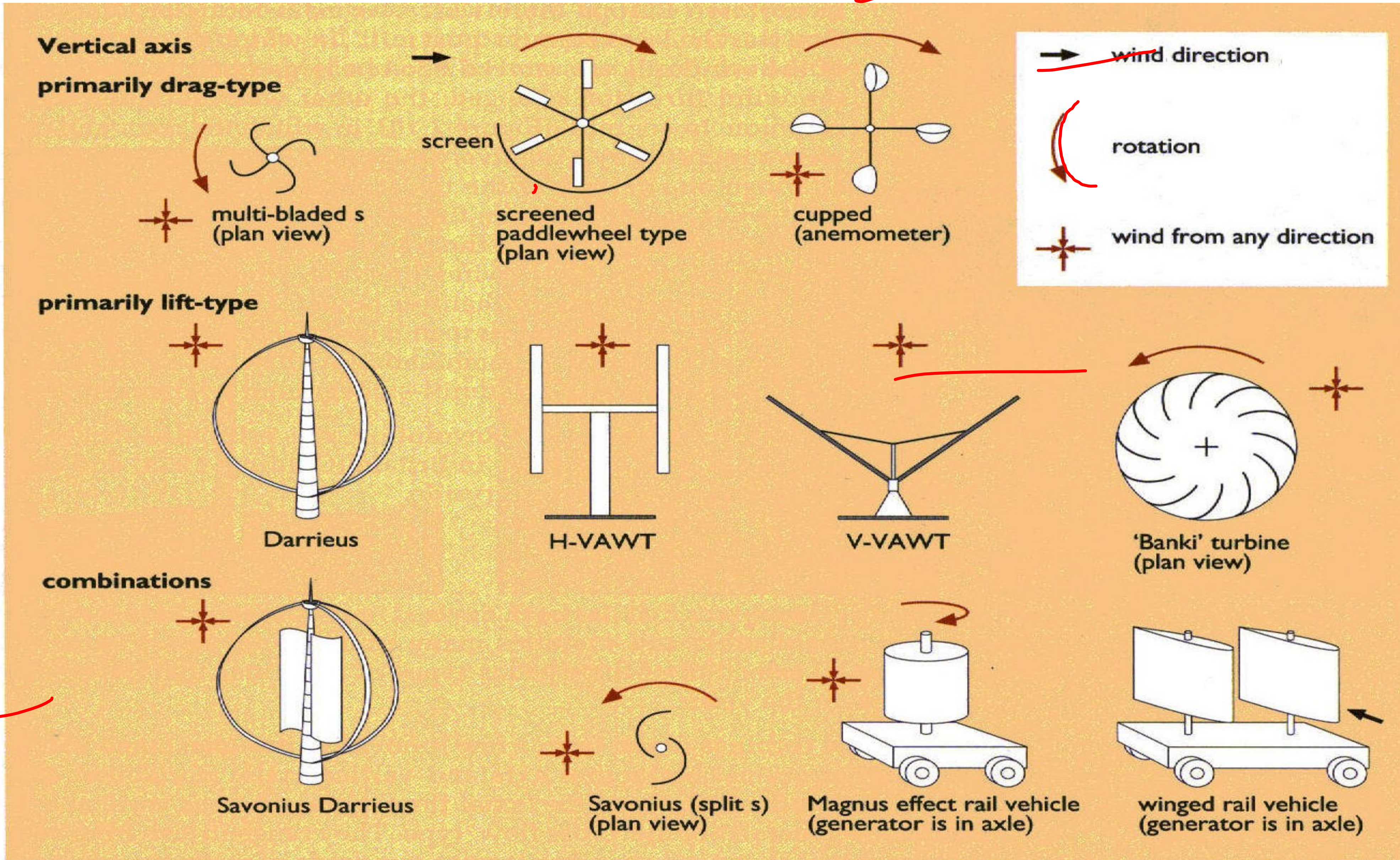


Figure 7.9 Some examples of the machines that have been proposed for wind energy conversion (source: adapted from Eldridge, 1975. For further information on these machines see Eldridge, 1975 and Golding, 1955)

TYPES OF WIND TU

- **1. Onshore:**
- Onshore wind turbines are placed in hilly and mountainous places and are at least three kilometers away from the nearest shore.

Near-shore win
within thr
nearest sh

Lift and Drag Type Machines

ind turbines make use of either lift force or drag force predominantly
use motion and accordingly known as **lift or drag type machines.**

lift devices the ratio of lift to drag forces may be as high as 30:1.

r the drag design, the wind literally pushes the blades out of the way.

ag devices are less efficient and turn slower than wind.

ey produce high torque and thus are suitable for pumping applicatio
high wind speeds they spill wind instead of producing more energy.

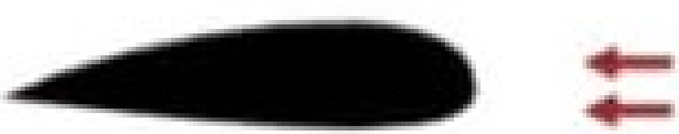
us they do not benefit from high energy density available in wind.

e lift blade design employs the same principle that enables aeroplanes
es and birds to fly.

e blade is essentially an airfoil, or wing. When air flows past the blade,
nd speed and pressure differential is created between the upper and
wer blade surfaces.

Lift & Drag Forc

The *Lift Force* is perpendicular to the direction of motion. We want to make this force BIG.



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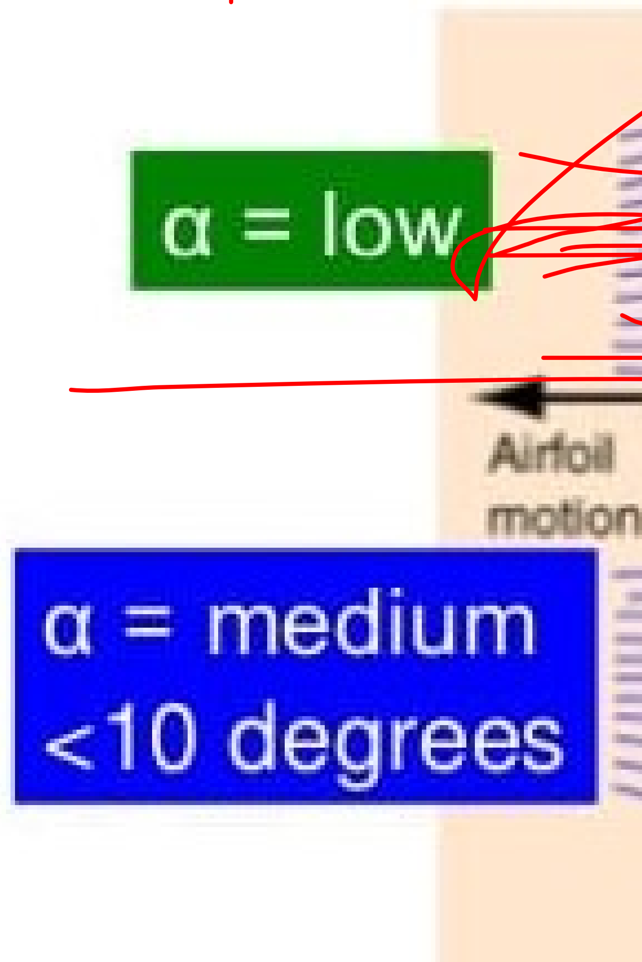
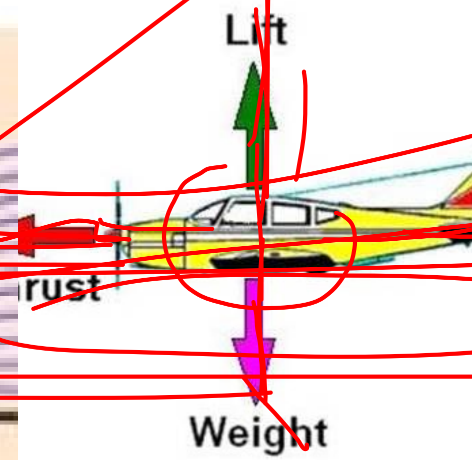
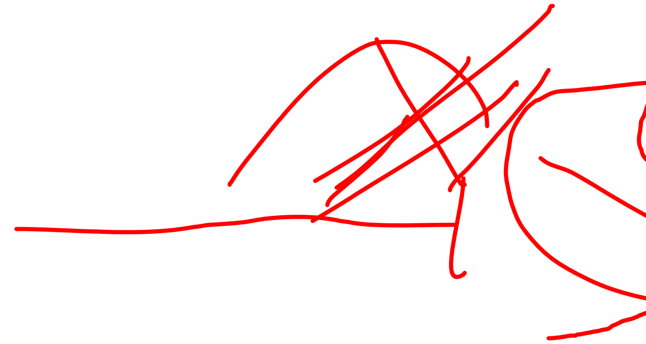




Effect of Solidity



High solidity rotors use drag force and turn slower.

Solidity of Savonious rotor is unity and that of American multi-blade rotor it is typically 0.7.

Low solidity rotors, on the other hand, use lift force.

Lift devices usually have solidity in the range of 0.01 to 0.1.

They have slender airfoil blades. When solidity is less than 0.1, the device will usually not start up without first being rotated to generate lift.

Horizontal Axis vs Vertical Axis Turbin

lost wind turbines, used at present are of horizontal axis type.
hey have been well researched and have gone through extensive field trial.
s a result, well-established technology is available for HAWTs.
ome advantages of VAWT have recently generated considerable interest in
ype of turbine.
hese are:
(i) it can accept wind from any direction without adjustment, which avoids th
cost and complexity of yaw orientation system,
(ii) gearing and generators, etc., are located at ground level, which simplifie
design of tower, the installation and subsequent inspection and maintenanc
and (iii) also they are less costly as compared to HAWTs.

Wind turbines: Types

- Depending on Capacity
  - Utility scale (900kW to 2MW per turbine): us
    generate bulk energy sold in power markets.
  - Industrial scale (50kW to 250kW per
    commercial/community power applications, typi
  - Residential Scale (400 watts to 50kW): used in
- Depending on operations at different wind spe

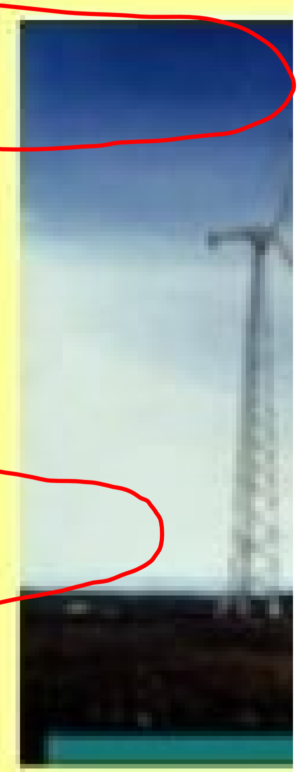
Variable speed	
Operates at a wider range of wind speeds	Attains peak

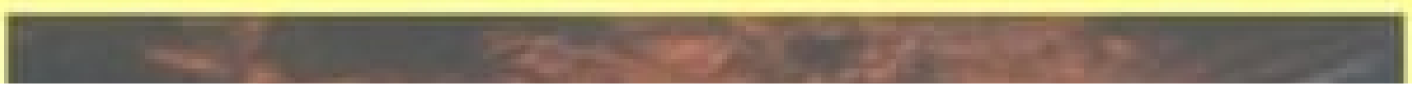
Turbines: Different Sizes an

Small (≤10 kW)

- Homes (Grid-connected)
- Farms
- Remote Applications

(e.g. battery changing, water pumping, telecom sites)



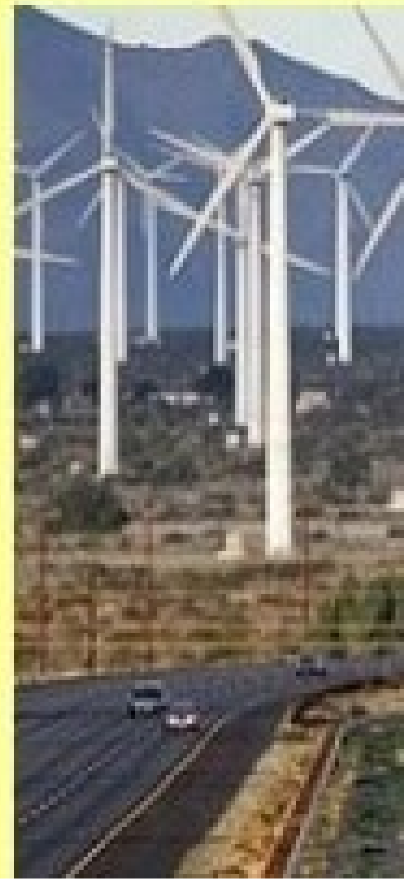


Wind Turbine Techn

Part 4

WIND FIRMS

Wind farms



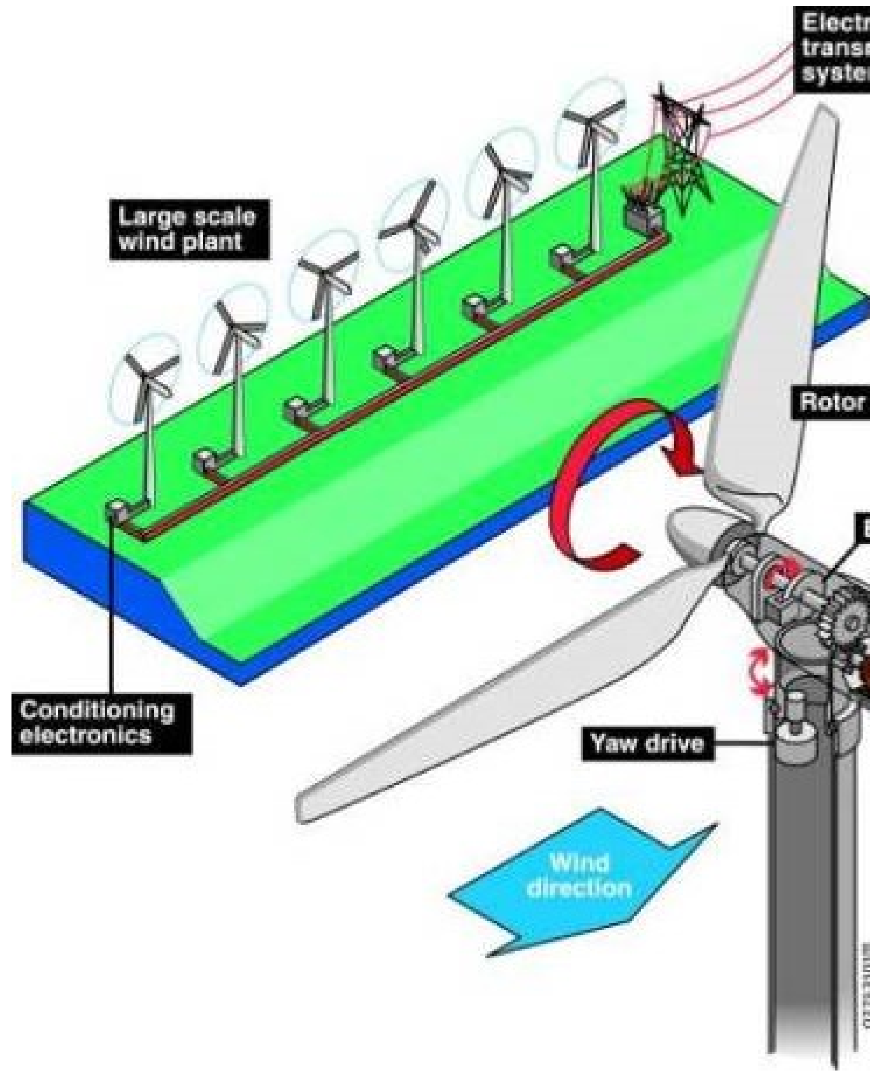
Wind farms

- Group of wind turbines operating in the same a
- Sizes range between 20 and 300MW
- Can be typically set up in a year
  - quicker than conventional energy plants

Inter-turbine and inter-row spacing varies as a function of rotor diameter and wind resource characteristics

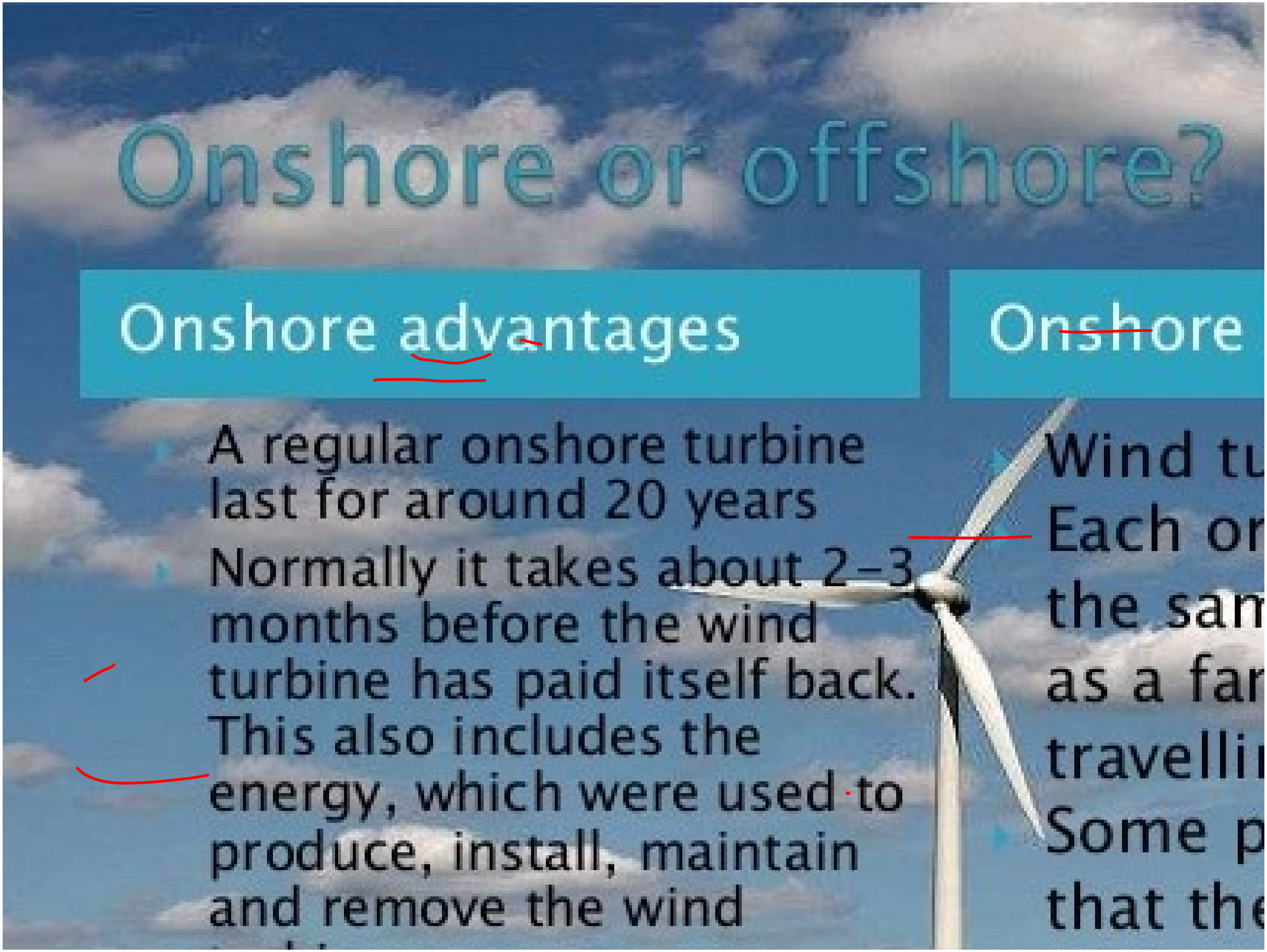
Wide spacing can maximize increase infrast off exists.

Large Wind Turbines / Wind Farms



Part 4

On shore off shore


Onshore or offshore?
Onshore advantages
A regular onshore turbine last for around 20 years
Normally it takes about 2-3 months before the wind turbine has paid itself back. This also includes the energy, which were used to produce, install, maintain and remove the wind
Onshore
Wind tu
Each or
the sam
as a fa
travelli
Some p
that the


Onshore or offsh
Offshore advantages
• A offshore wind turbine is stronger than a onshore turbine. It lasts around 25-30 years, and produces about 50 % more energy than a onshore turbine.
• When a strong wind blows, it produces around 3-5
Offshore
• More ex
• More di maintai

Speed Control Strategies for Wind Turbine

- Various options are available for speed control of a turbine. The particular control strategy depends on the size of the turbine.
- These methods may be grouped in the following categories:
    i. **No speed control at all**. Various components of the entire system are designed to **withstand extreme speed under gusty wind.**
    ii. **Yaw and tilt control**, in which the **rotor axis is shifted out of wind direction,** either by yaw control or by tilting the rotor plane with respect to normal vertical plane **when the wind exceeds the design limit.**
    iii. **Pitch control**, in which the pitch of the rotor blades is controlled **to regulate the speed**.
    iv. **Stall control**, in which the blades are shifted to a position such that they stall **when wind speed exceeds the safe limit**.

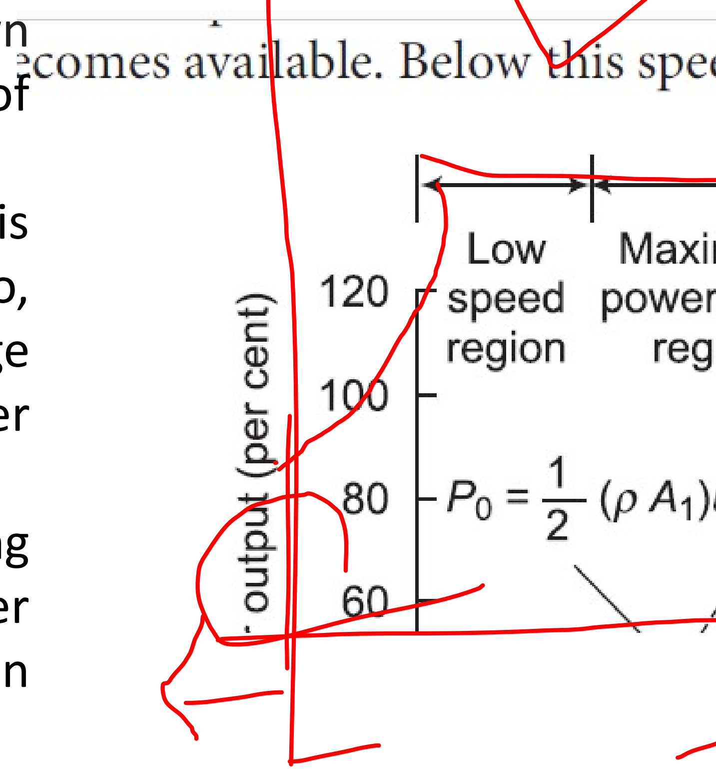
Wind Turbine Operation and Power versus Wind Speed Characteristics

Speed Region (Zero to Cut-in Speed) In this region, the turbine is in braked position till minimum wind speed (about 5 m/s), known t-in speed becomes available. Below this speed the operation of urbine is not efficient.

mum Power **Coefficient Region** In this region, rotor speed is d with wind speed so as to operate it at constant tip-speed ratio, esponding to maximum power coefficient, CP max. In this range nature of characteristics is close to that of maximum power able in the wind

tant Power Region (Constant Turbine Speed Region) During speed winds (above 12 m/s), the rotor speed is limited to upper issible value based on the design limits of system components. In egion the power coefficient is lower than CP max.

ng Speed Region (Cut-out Speed and Above) Beyond certain mum value of wind speed (around 25 m/s) rotor is shut down and er generation is stopped to protect the blades, generator and r components of the system.



Thank You

Save energy and water for Sustainable Life

Dr.P.Dharmalingam
Accredited Energy Auditor
Director, EnSave Academy
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https://ecourse.ensaveindia.in