INDUS UNIVERSITY

WIND ENERGY

Introduction

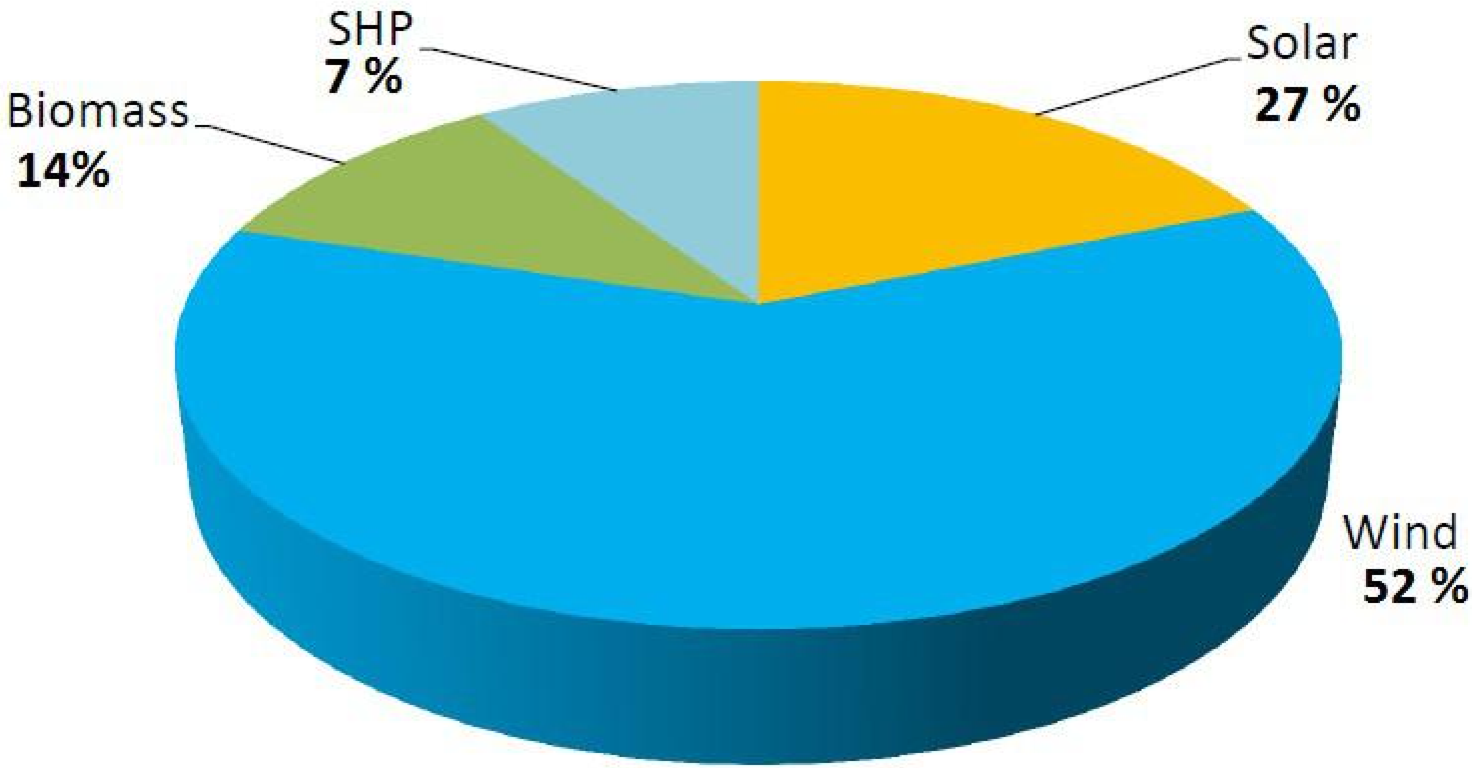
Why wind power??

→ Wind power has always given the necessary propulsive force to sailing ships and has been also used to run windmills.

→ However, the recent attention paid to climate changes ,the demand to increase the amount of green energy and fear of a decrease of oil fuel in the future have promoted a renewed interest in the production of electrical energy from renewable sources and also from the wind power.

→ The horizontal axis wind turbine (HAWT) with upstream three-blade rotor has resulted to be the most suitable typology and consequently has found a remarkable development, characterized both by a quick grown in size and power, as well as by a wide spread.

All India Total Installed Capacity- 62.8 GW

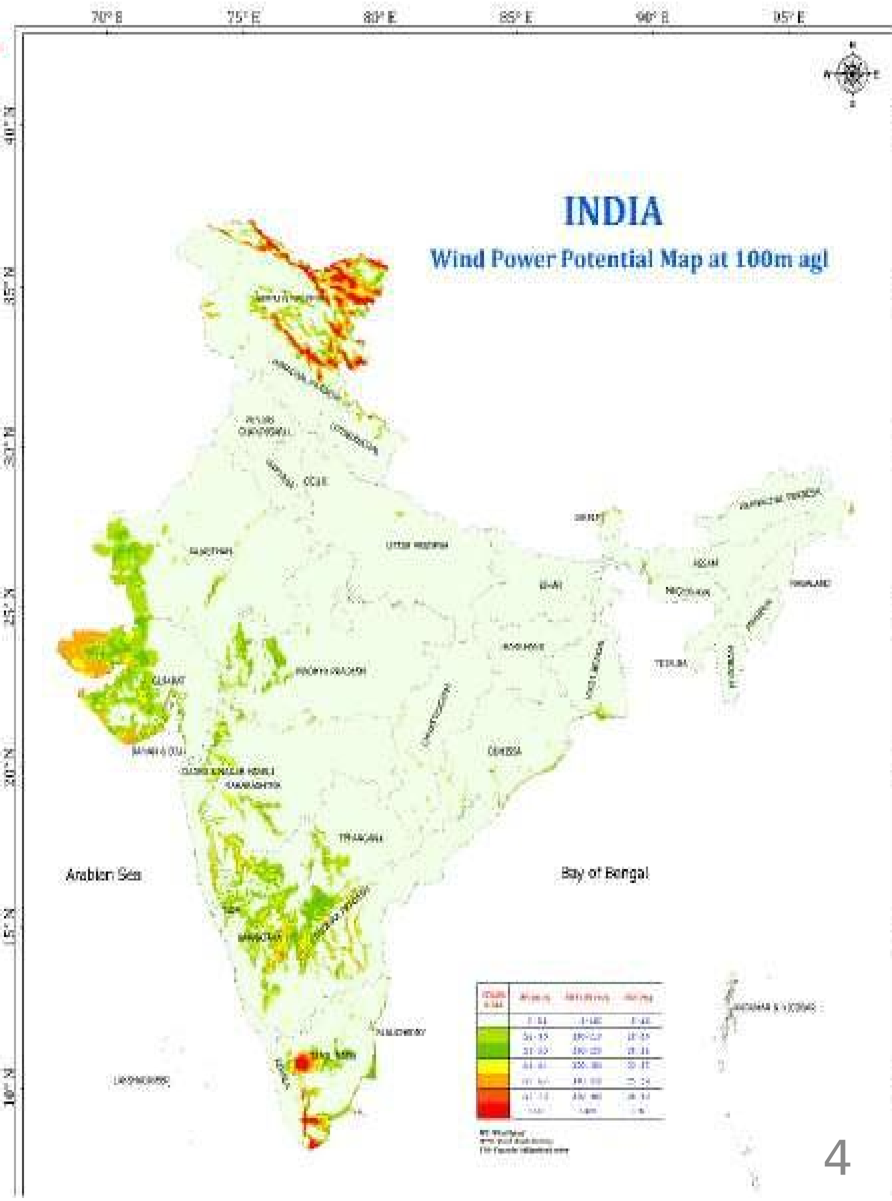


Wind	Solar	Biomass	SHP	Total
33 GW	17 GW	9 GW	4.4 GW	62.8 GW

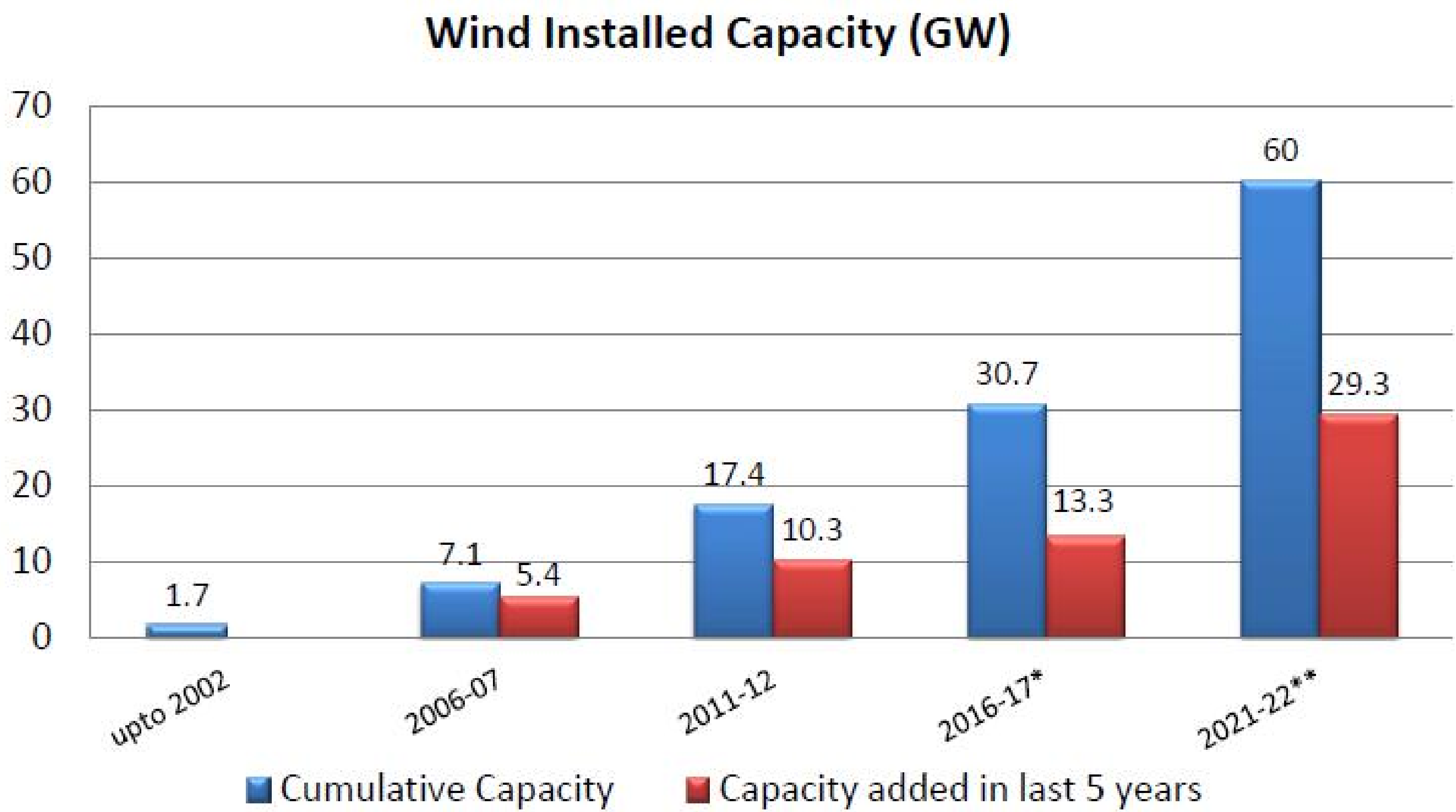
Source: MNRE 31.12.2017

Onshore Wind Potential

Wind Power Potential in India at 100 meter above ground level (GW)		
S. No.	State	Wind Power Potential at 100 mtr in GW
1	Andhra Pradesh	44.23
2	Gujarat	84.43
3	Karnataka	55.86
4	Madhya Pradesh	10.48
5	Maharashtra	45.39
6	Rajasthan	18.77
7	Tamil Nadu	33.80
8	Telangana	4.24
	Total (8 windy States)	**297.21**
9	Other States	5.04
	All India Total	**302.25**



Growth of Indian Wind Power



* Estimated -28.3 GW already achieved

**Targeted

(As on 31.01.2018)

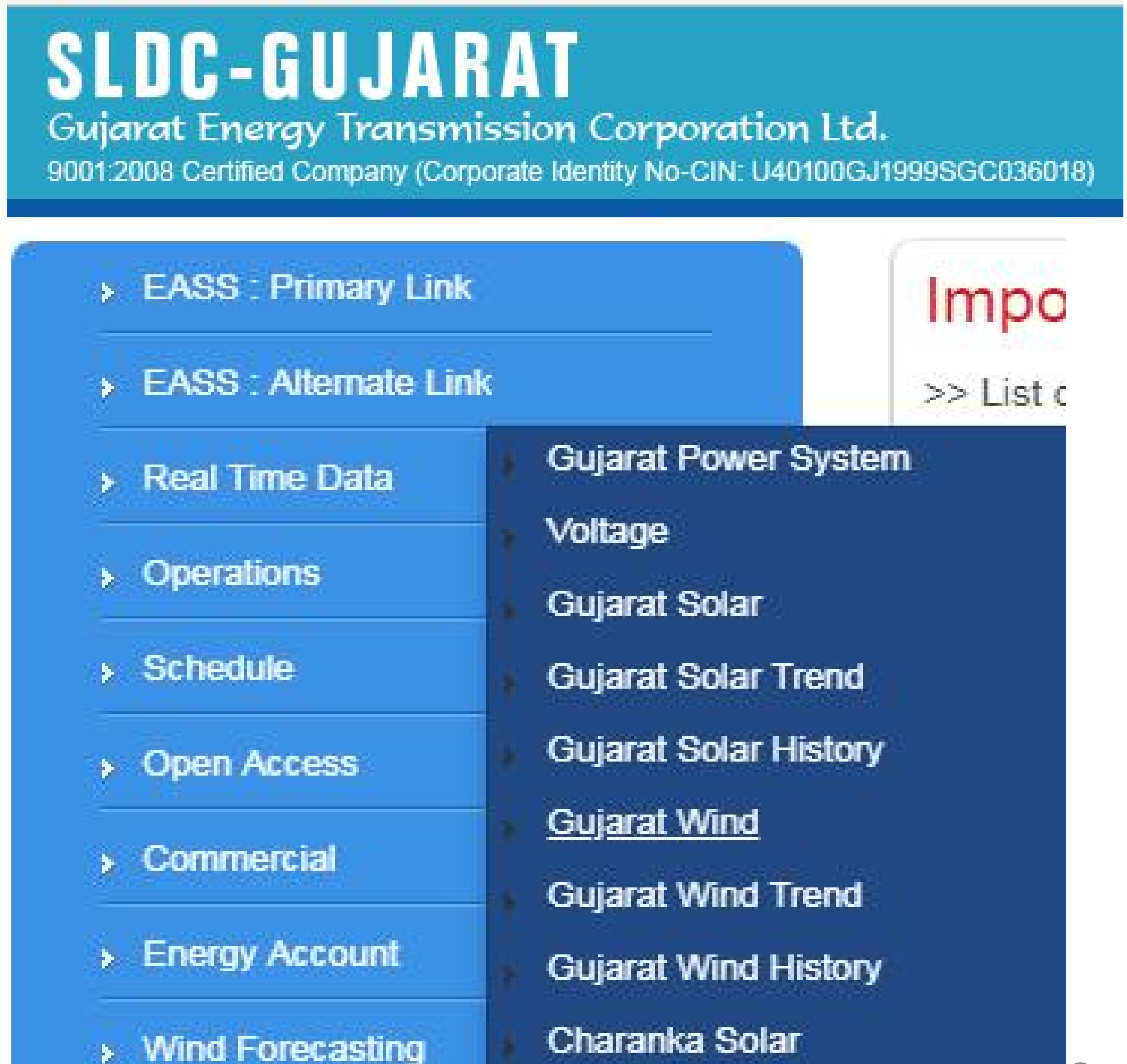
State	Ownership/ Sector	Modewise breakup							Grand Total
		Thermal				Nuclear	Hydro (Renewable)	RES (MNRE)	
		Coal	Gas	Diesel	Total				
Gujarat	State	4750.00	2177.82	0.00	6927.82	0.00	772.00	8.00	7707.82
	Private	7765.67	3960.00	0.00	11725.67	0.00	0.00	6727.41	18453.08
	Central	3012.09	424.00	0.00	3436.09	559.00	0.00	238.30	4233.39
	Sub-Total	**15527.76**	**6561.82**	**0.00**	**22089.58**	**559.00**	**772.00**	**6973.71**	**30394.29**

Gujarat total wind plant installed capacity (As on Jan-2018): 5339 MW

TOTAL PLANT : 69

YOU CAN SEE ALL PLANT IN

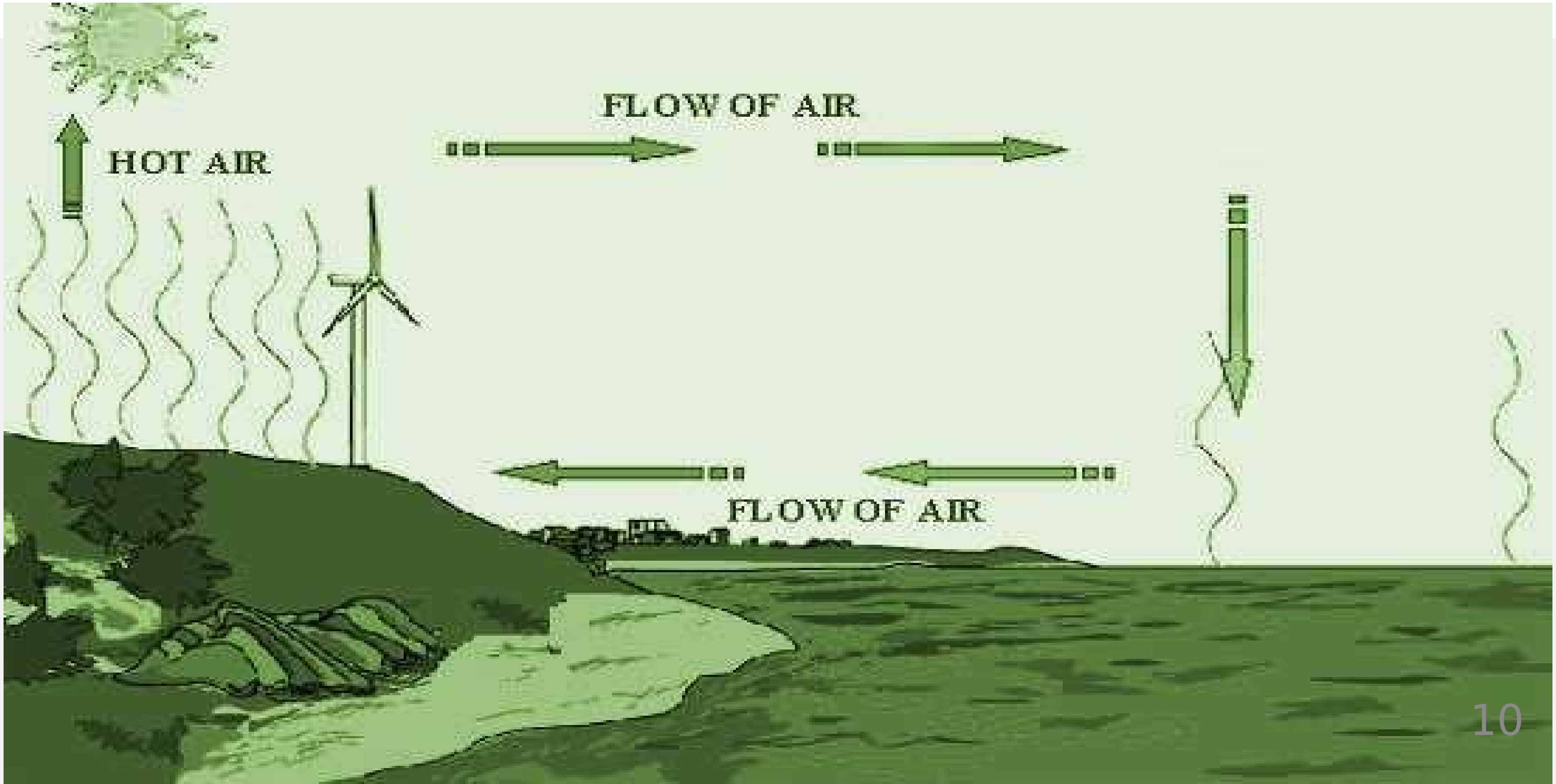
STATION
MUNDRA
OKHA
KANDLA
JAKHAU
SUTHRI
JAMNAGAR
PORBANDAR



Types of wind plant

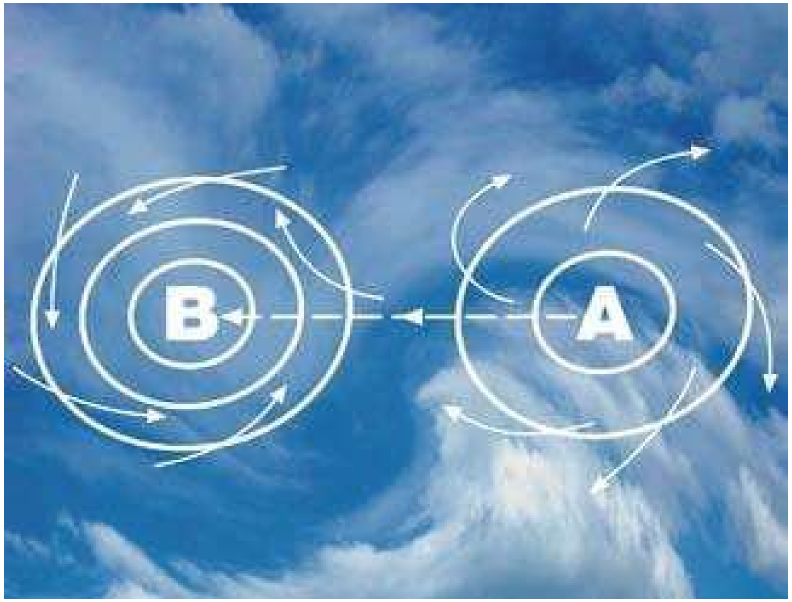
Introduction to wind energy

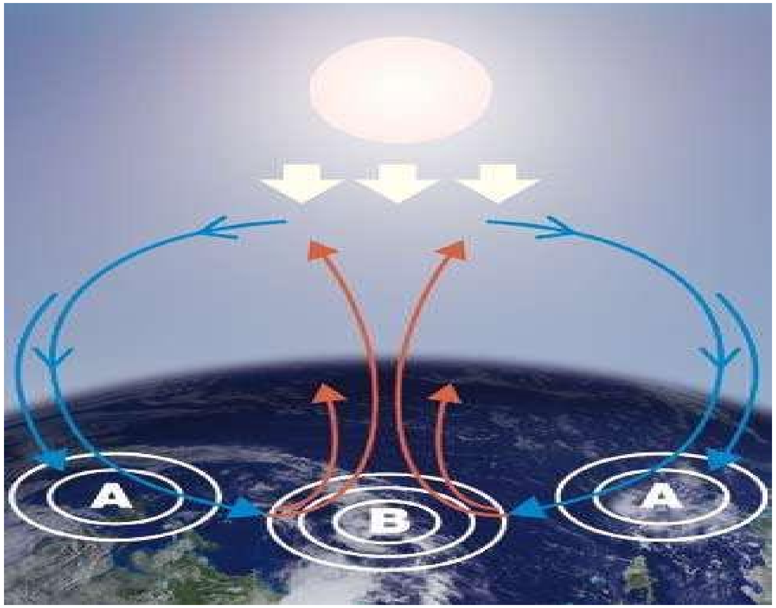
Wind is simply defined as moving air. When the earth heats up from sunrays it releases wind, this is a balanced reaction meant to cool the earth. The sun heat is felt more on dry land than on the sea. The air expands and easily reaches maximum high altitudes, then cool air drops down and moves as wind.



Generalities on wind power plants
Physics and nature of wind

- The Earth continuously releases into the atmosphere the heat received by the sun, but unevenly.
- In the areas where less heat is released(cool air zones) the pressure of atmospheric gases increases, whereas where more heat is released, air warms up and gas pressure decreases.





- Since the atmosphere tends to constantly re-establish the pressure balance, the air moves from the areas where the pressure is higher towards those where it is lower; therefore, wind is the movement of an air mass, more or less quick, between zones at different pressure.
- The profile and unevenness of the surface of the dry land or of the sea deeply affect the wind and its local characteristics; in fact the wind blows with higher intensity on large and flat surfaces, such as the sea: this represents the main element of interest for wind plants on- and off shore.
- Moreover, the wind gets stronger on the top of the rises or in the valleys oriented parallel to the direction of the dominant wind, whereas it slows down on uneven surfaces, such as towns or forests, and its speed with respect to the height above ground is influenced by the conditions of atmospheric stability.

ADVANTAGES AND DISADVANTAGES OF WIND POWER PLANT

ADANTAGES:

- Energy For Free Of Cost
- Produces Electricity Throughout The Day.
- Pollution Free And Clean.
- Vast Wind Energy Is Available. (10 Million Mw) Can Supply The Power To Remote areas.
- Economically Competitive.
- Mechanical Power For Grading, Pumping Etc. ; Using Wind Energy.
- Wind Energy → Domestic, Renewable Source Of Energy .
- Up To 95 % Land Of Wind Farms Can Be Used For Ranching, Farming And Forestry.

Site selection

1. ***High annual average wind speed***
2. ***Availability of anemometry data***
3. ***Availability of wind V(t) Curve at the proposed site***
4. ***Wind structure at the proposed site***
5. ***Altitude of the proposed site***
6. ***Terrain and its aerodynamic***
7. ***Local Ecology***
8. ***Distance to road or railways***
9. ***Nearness of site to local centre/users***
10. ***Nature of ground***
11. ***Favourable land cost***

SITE SELECTION OF WIND POWER PLANT

- Most important decision throughout your installation.
- Vital part in the performance and efficiency of a wind turbine.
- High, exposed sites.
- Not suitable sites in highly populated residential areas.
- Avoid roof mounted turbines.
- Power transmission loss
- Distance between the turbine and the nearest obstacle
- Connection with national power grid

Working Principle of Wind turbine :

- Wind turbines operate on a simple principle. Wind is merely air in motion. Wind turbines convert kinetic energy from the wind that passes over the rotors into electricity.
- The kinetic 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 for more widespread electricity distribution.
- wind turbines harness the power of the wind and use it to generate electricity.
- Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity.

Aero-generators/Small Wind Energy Hybrid Systems (SWES) programme

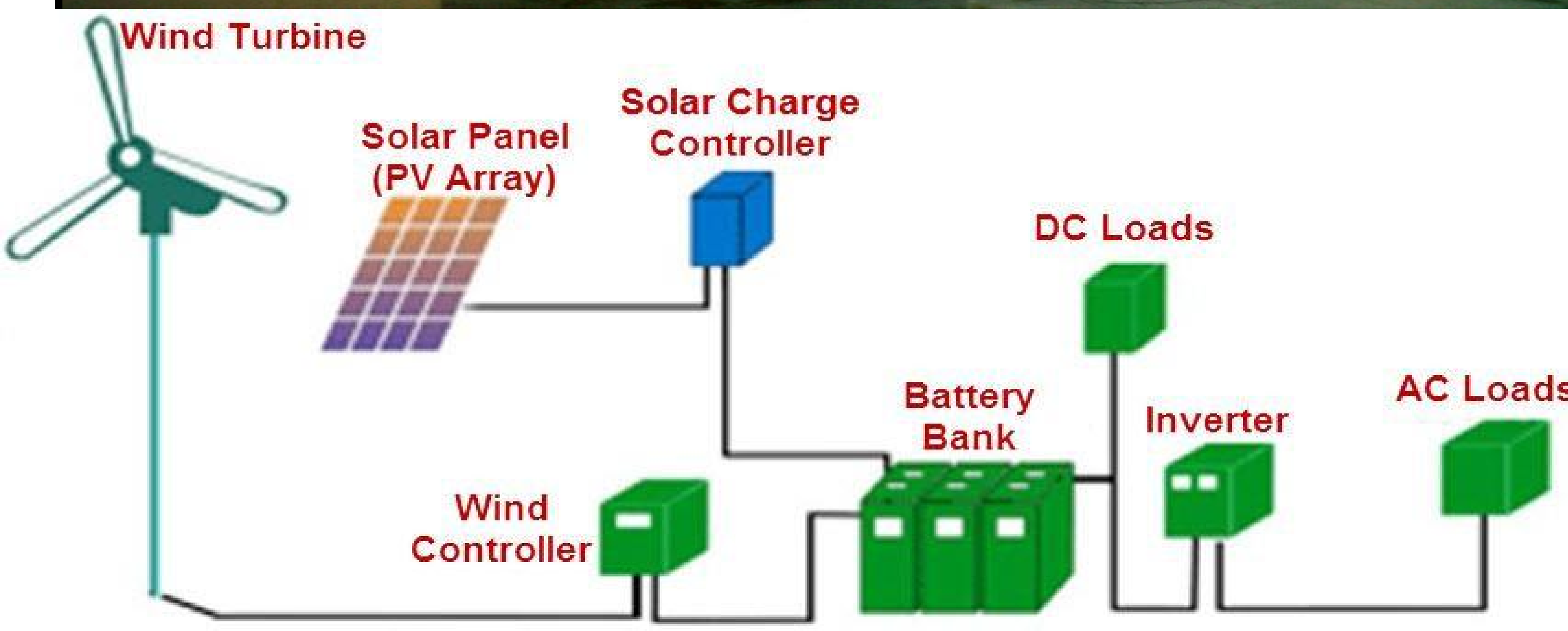
Providing Electricity Access through

- Water pumping windmills
- Aero-generators
- Wind-solar hybrid systems

Target category

- Government buildings,
- Schools, colleges, Goshala's, community halls/ centres,
- Gram panchayats etc along coastal/ hilly and remote regions
- Telecom towers etc.

ROOF-TOP WIND-SOLAR HYBRID SYSTEM



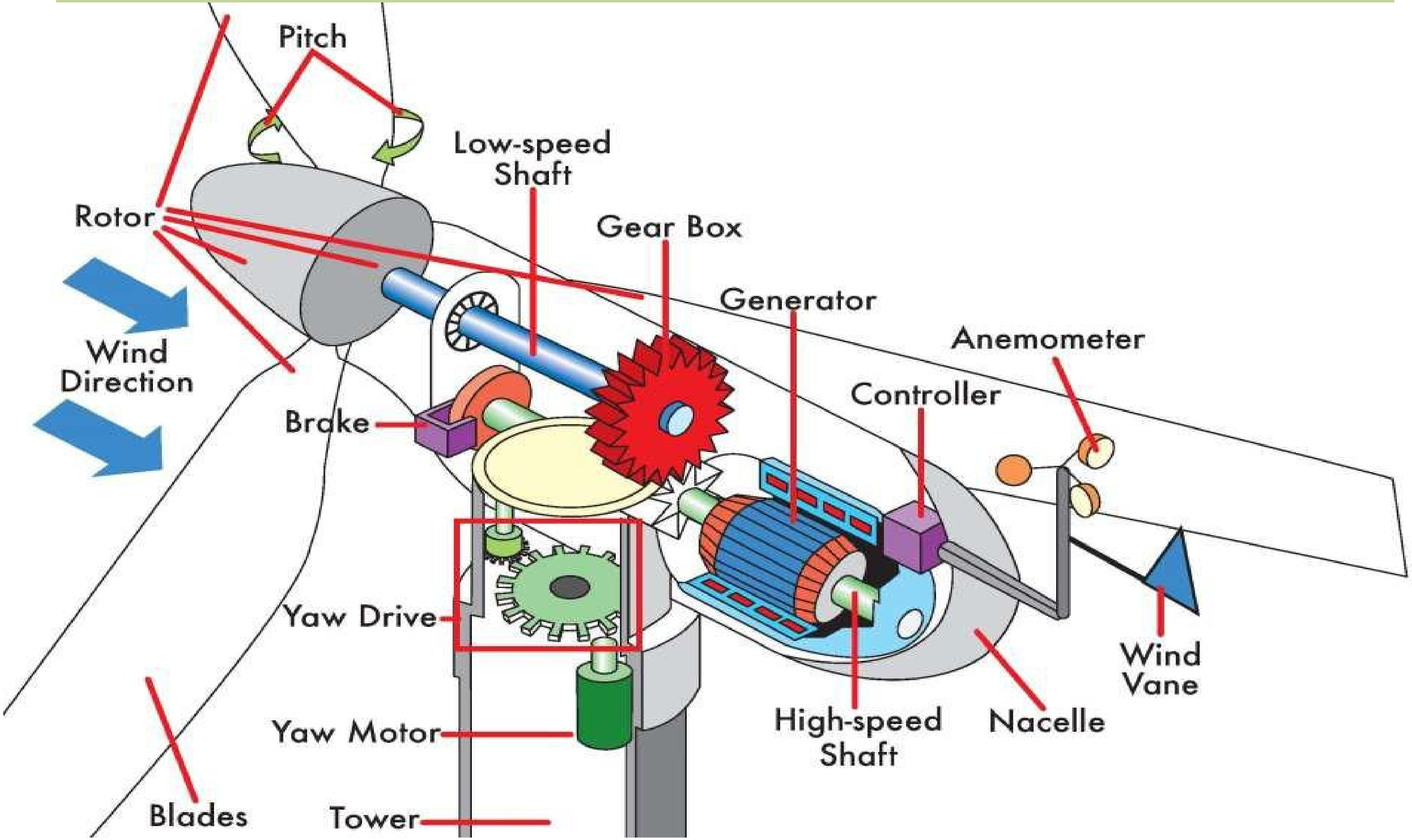
WORKING PRINCIPLE

- The wind power can be gained by making it blow past the blades that will cause the rotor to twist.

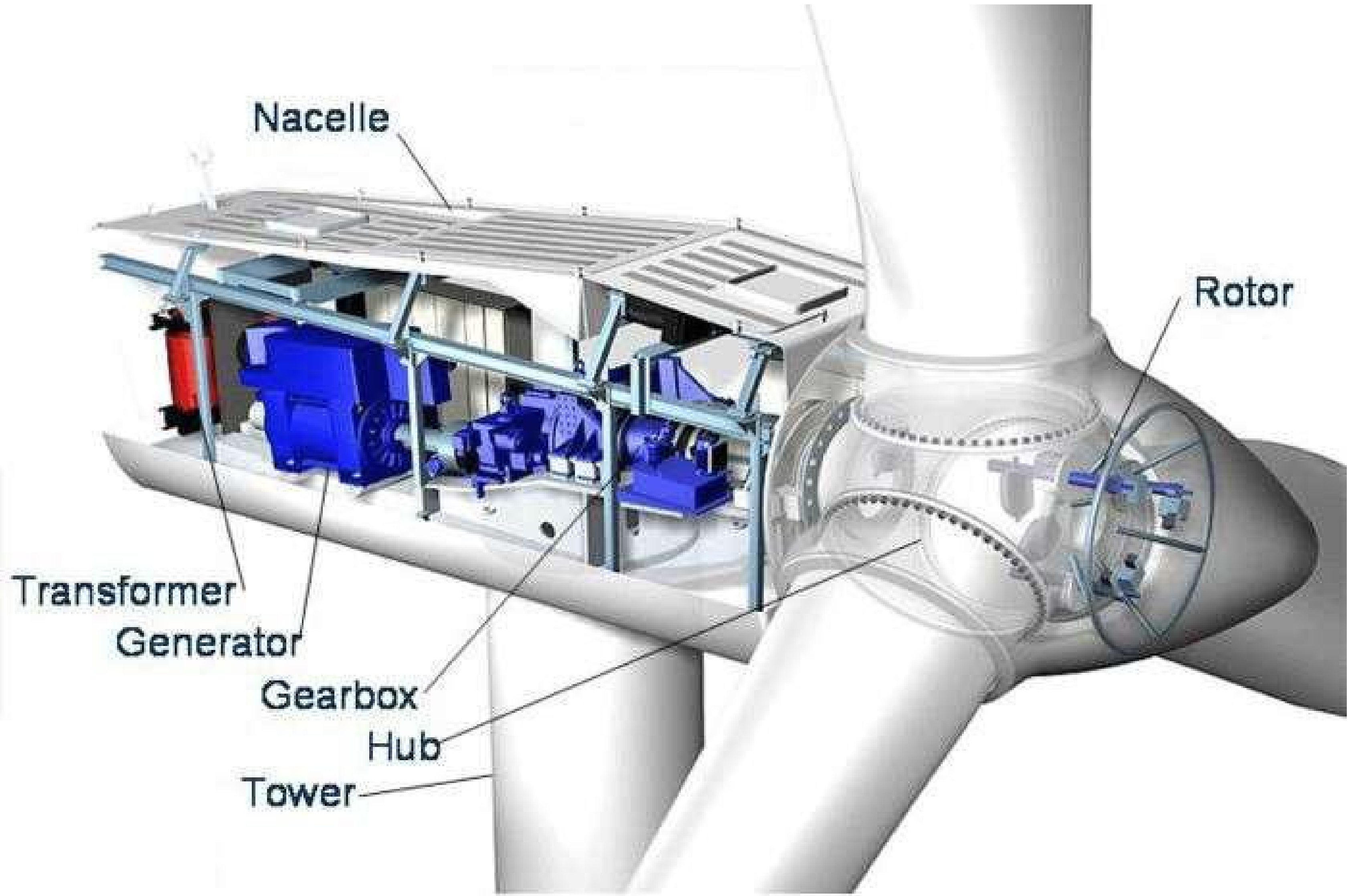
- The amount of power transferred is directly proportional to the density of the air, the area swept out by the rotor, and the cube of the wind speed. It can be found out by the following equation:

$$P = \frac{1}{2}\rho\pi R^2 v^3$$

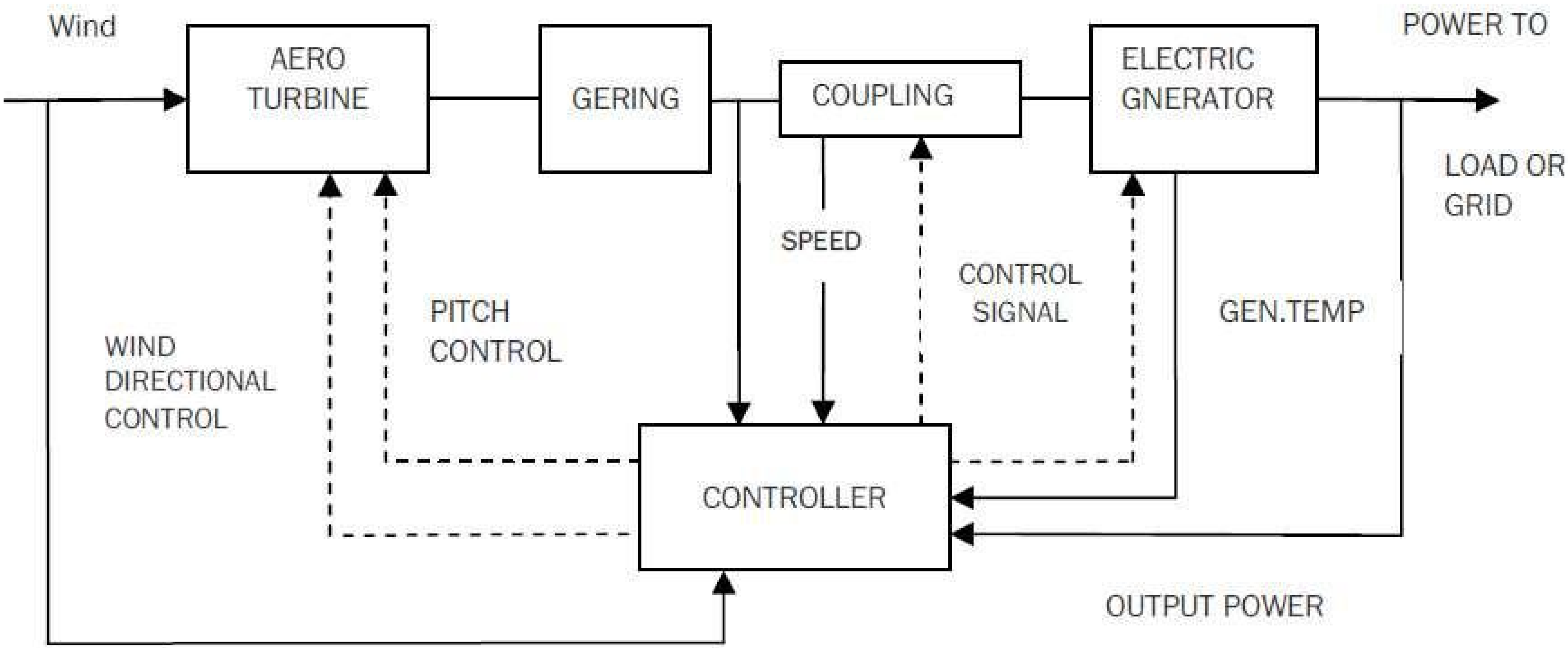
Main components

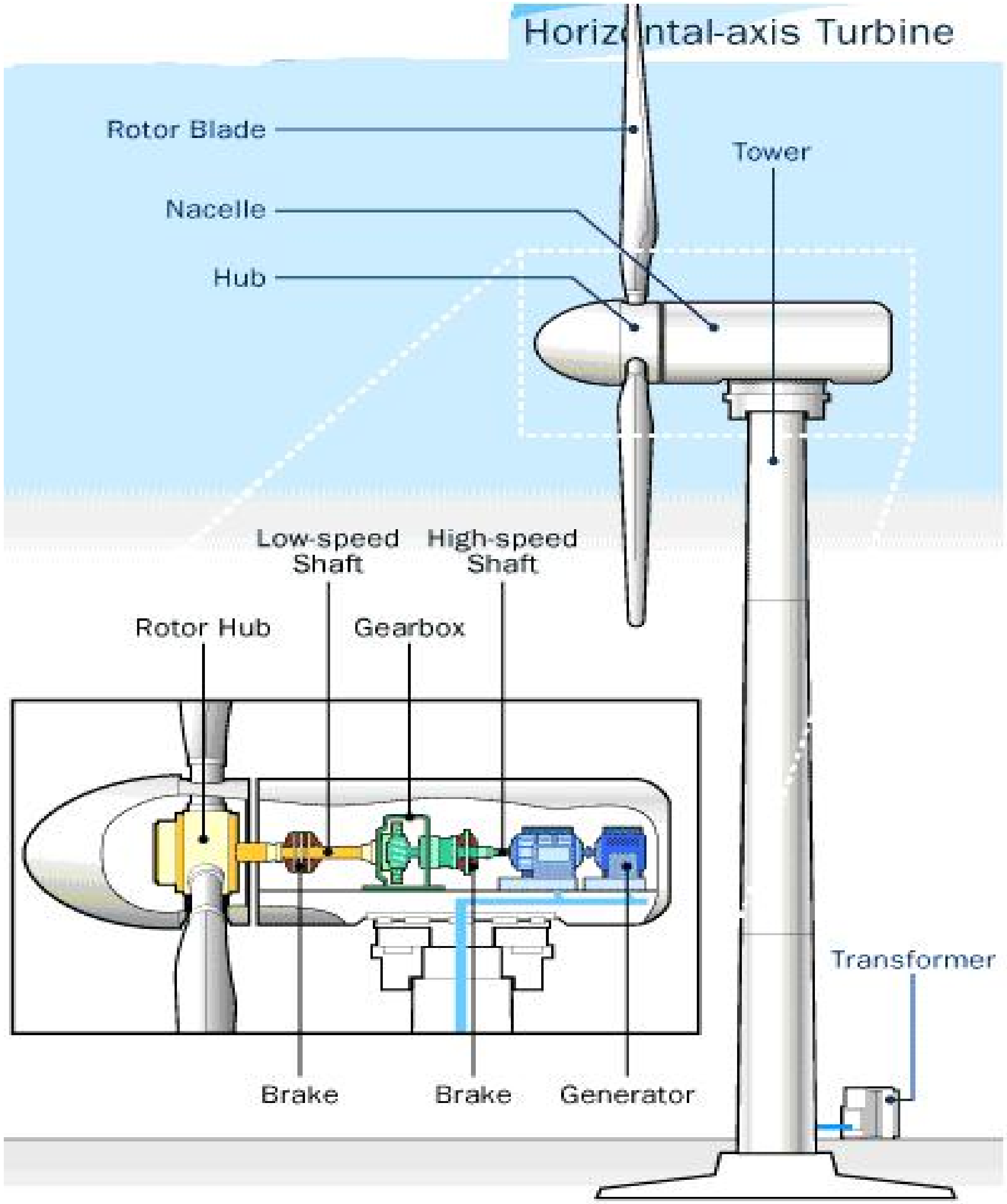


Working of Wind Mill:
https://www.youtube.com/watch?v=qSWm_nprfqE

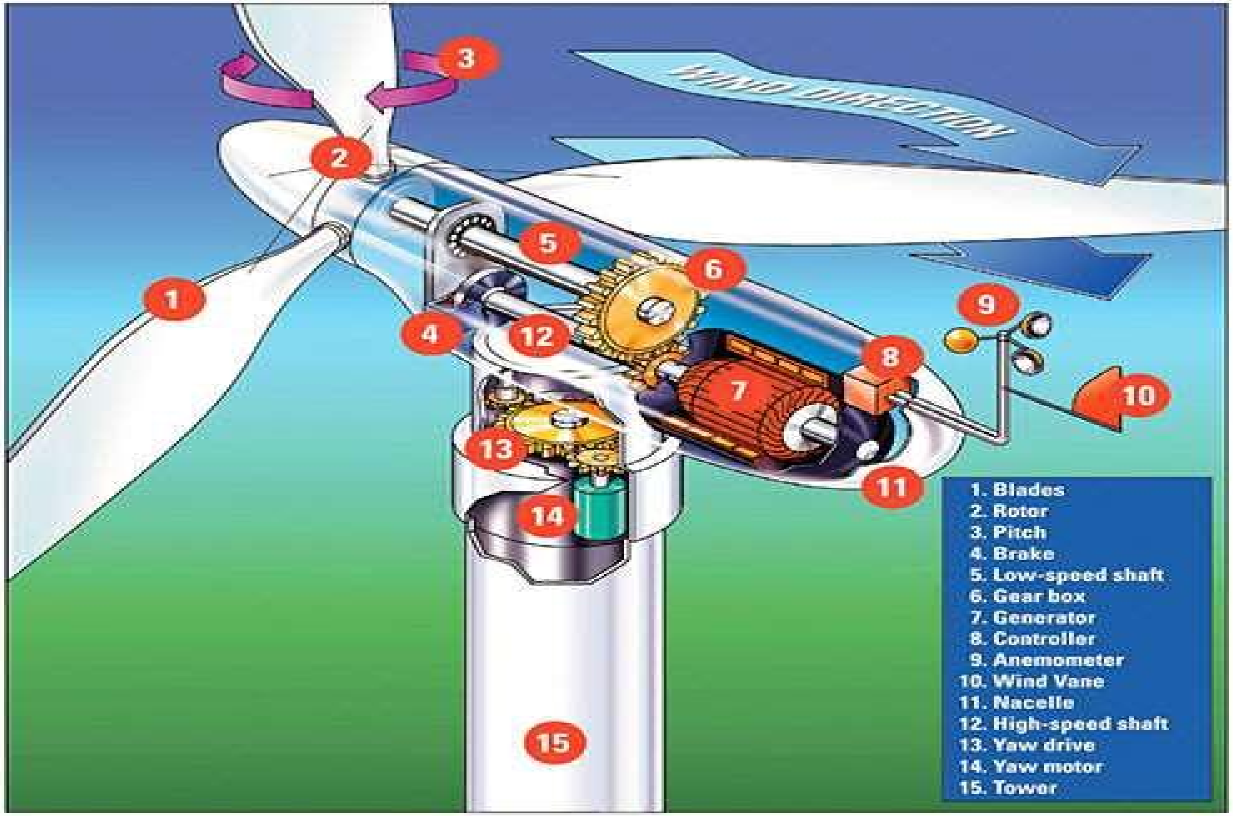

Nacelle
Rotor
Transformer
Generator
Gearbox
Hub
Tower

BLOCK DIAGRAM




Horizontal-axis Turbine
Rotor Blade
Tower
Nacelle
Hub
Low-speed Shaft
High-speed Shaft
Rotor Hub
Gearbox
Transformer
Brake
Brake
Generator

PARTS OF WIND TURBINE :



Horizontal Axis Wing mill videos
(1) https://www.youtube.com/watch?v=IG9Jon5nLVc
(2) https://www.youtube.com/watch?v=LNXTm7aHvWc
(3) offshore wind turbine:
https://www.youtube.com/watch?v=hQwgXrb3XPs
https://www.youtube.com/watch?v=aS4iY-cFmlU

PARTS OF WIND TURBINE :

1. Hub controller
2. Pitch cylinder
3. Main shaft
4. Oil cooler
5. Gear Box
6. VMP top-controller
7. Parking break
8. Service crane
9. Transformer
10. Blade Hub
11. Blade Bearing
12. Blade
13. Rotor lock system
14. Hydraulic Unit
15. Hydraulic shrink disk
16. Yaw ring
17. Machine foundation
18. Yaw gear
19. Generator
20. Generator Cooler

Wind turbines consist of four main components—the rotor, transmission system, generator, and yaw and control systems

Rotor:

The rotor consists of the hub, three blades and a pitch regulation system, all of which are located upwind of the tower. The blades are airfoils, which depend on aerodynamic lift to move the blades and cause rotation. (Air moving over the blades creates a negative pressure on the upper side of the airfoil and a positive pressure on the lower side; this causes the rotor to rotate.) The design speed of the rotor is 16 rpm.

Transmission system:

The mechanical power generated by the rotor blades is transmitted to the generator by the transmission system. This consists of a gearbox and a braking system plus the auxiliary lubricating and cooling systems. The gearbox is needed to increase the rotor's speed (16 rpm) to the 1800-rpm speed of the generator. The braking system is designed to lock the rotor when shut down.

Generator:

The generator converts the mechanical energy to electrical energy in an asynchronous (induction) generator.

Yaw and control systems:

The yaw system turns the nacelle into the actual wind direction using a rotary actuator and a gear mechanism at the top of the tower. A fully automatic microprocessor-based control and monitoring system is a part of the wind turbine. The control system is designed for remote operation from the shore-based operations center via a fiber optic communications system.

Explain various components of wind energy conversion system with diagram.

Rotor blades - capture wind's energy and convert it to rotational energy of shaft

Shaft - transfers rotational energy into generator

Nacelle - casing that holds:

Gearbox - increases speed of shaft between rotor hub and generator

Generator - uses rotational energy of shaft to generate electricity using electromagnetism

Electronic control unit (not shown) - monitors system, shuts down turbine in case of malfunction and controls yaw mechanism

Yaw controller (not shown) - moves rotor to align with direction of wind

Brakes - stop rotation of shaft in case of power overload or system failure

Tower - supports rotor and nacelle and lifts entire setup to higher elevation where blades can safely clear the ground

Electrical equipment - carries electricity from generator down through tower and controls many safety elements of turbine

WORKING OF WIND POWER PLANT:

Wind turbines harness the wind's energy to generate electricity. Here, in short, is how they do it:

Wind makes BLADES turn.

Blades turn a shaft .

Gearbox connected to shaft increases ROTATIONAL speed.

Direct drive, Gearless technology

CONVERSION : Mechanical energy → Electrical energy.

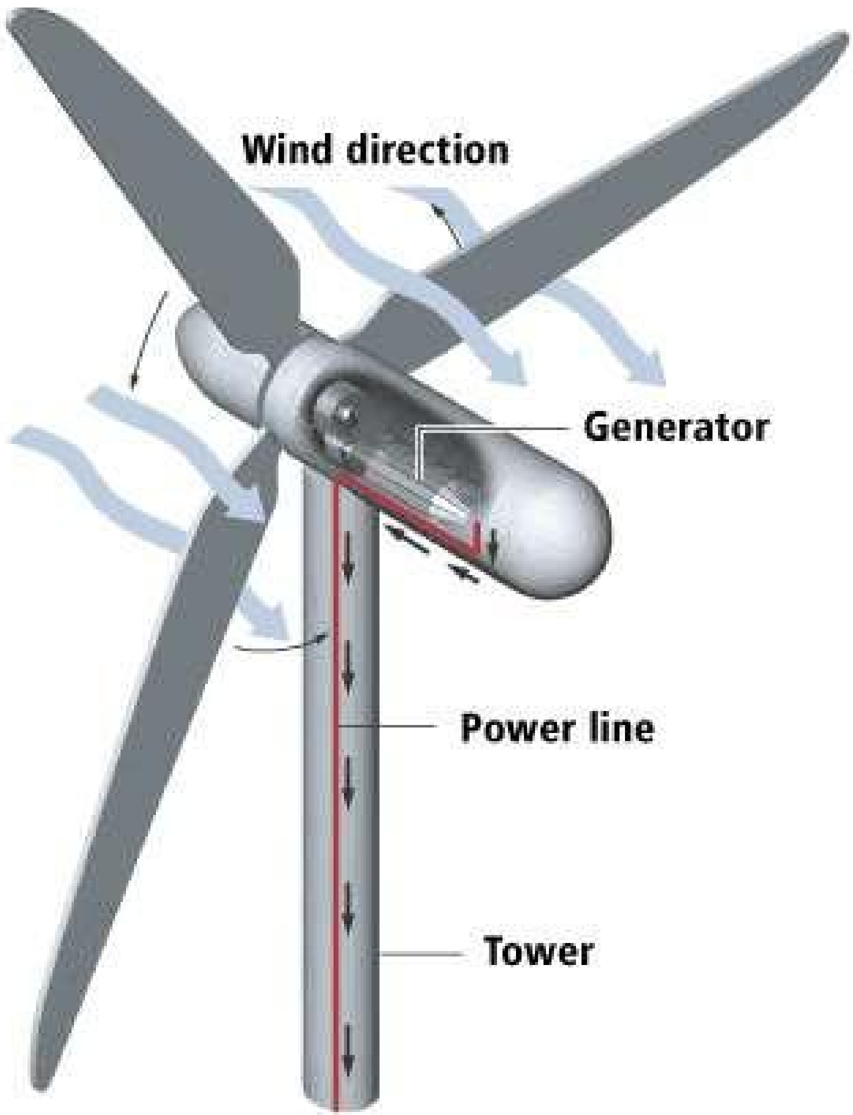
Power inverter

Transformer : output voltage of inverter / 11 KV – 33KV.

Local distribution / national greed.

TURNING WIND INTO ELECTRICITY

Wind power is the fastest-growing energy source in the world. Turbines powered by wind are mounted on towers 100 or more feet above the ground, where the wind is faster and less turbulent.

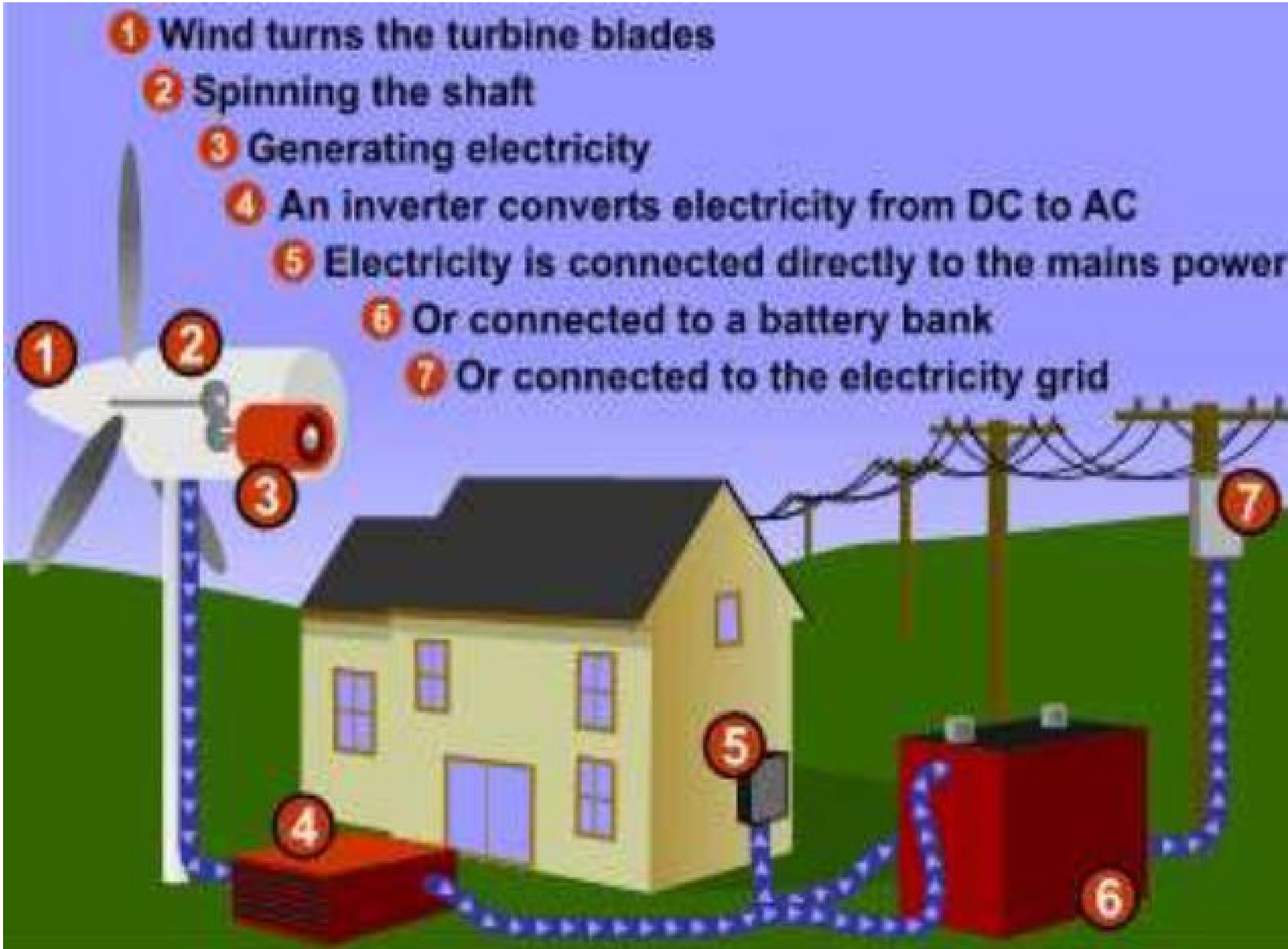


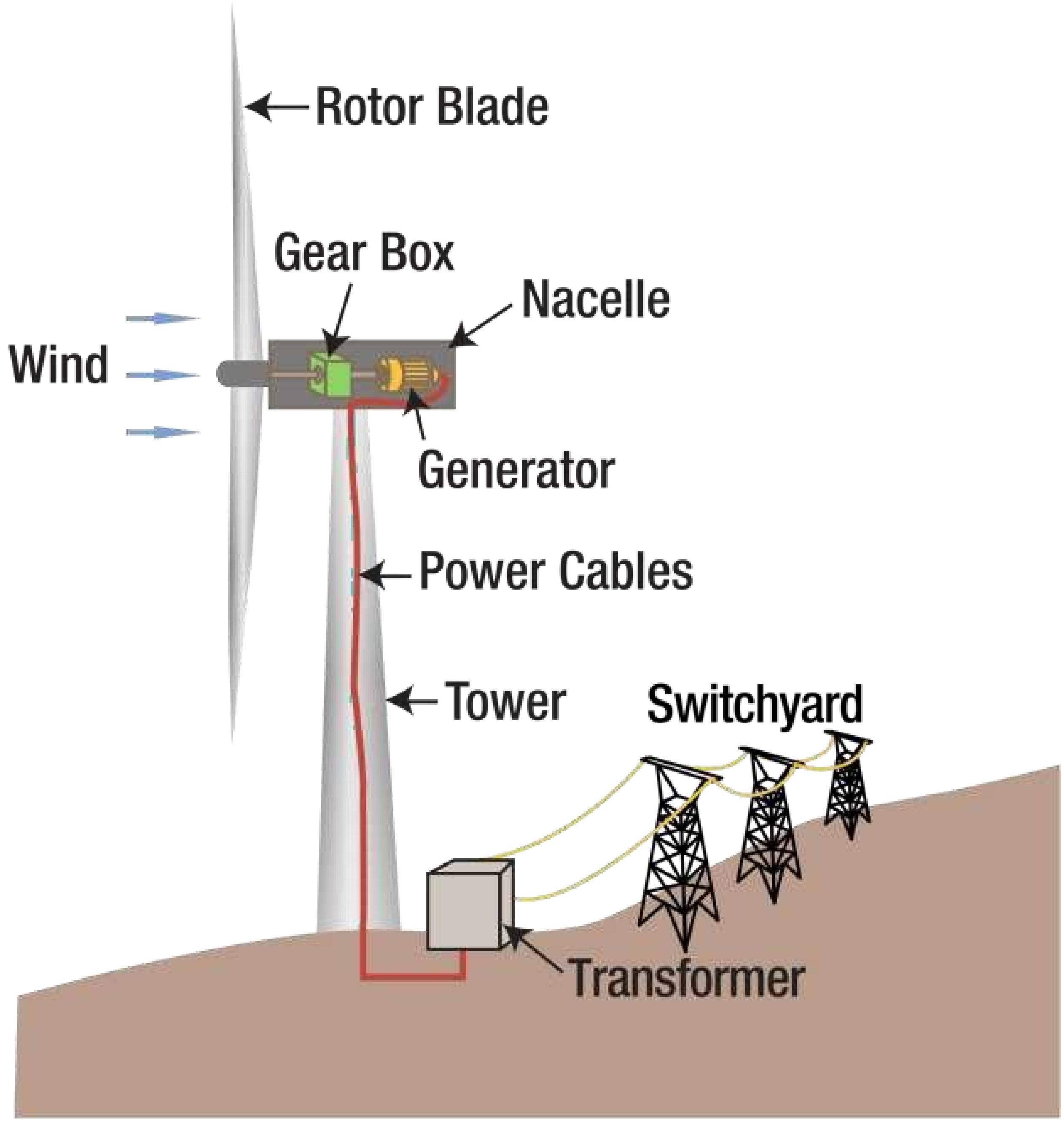
HOW IT WORKS

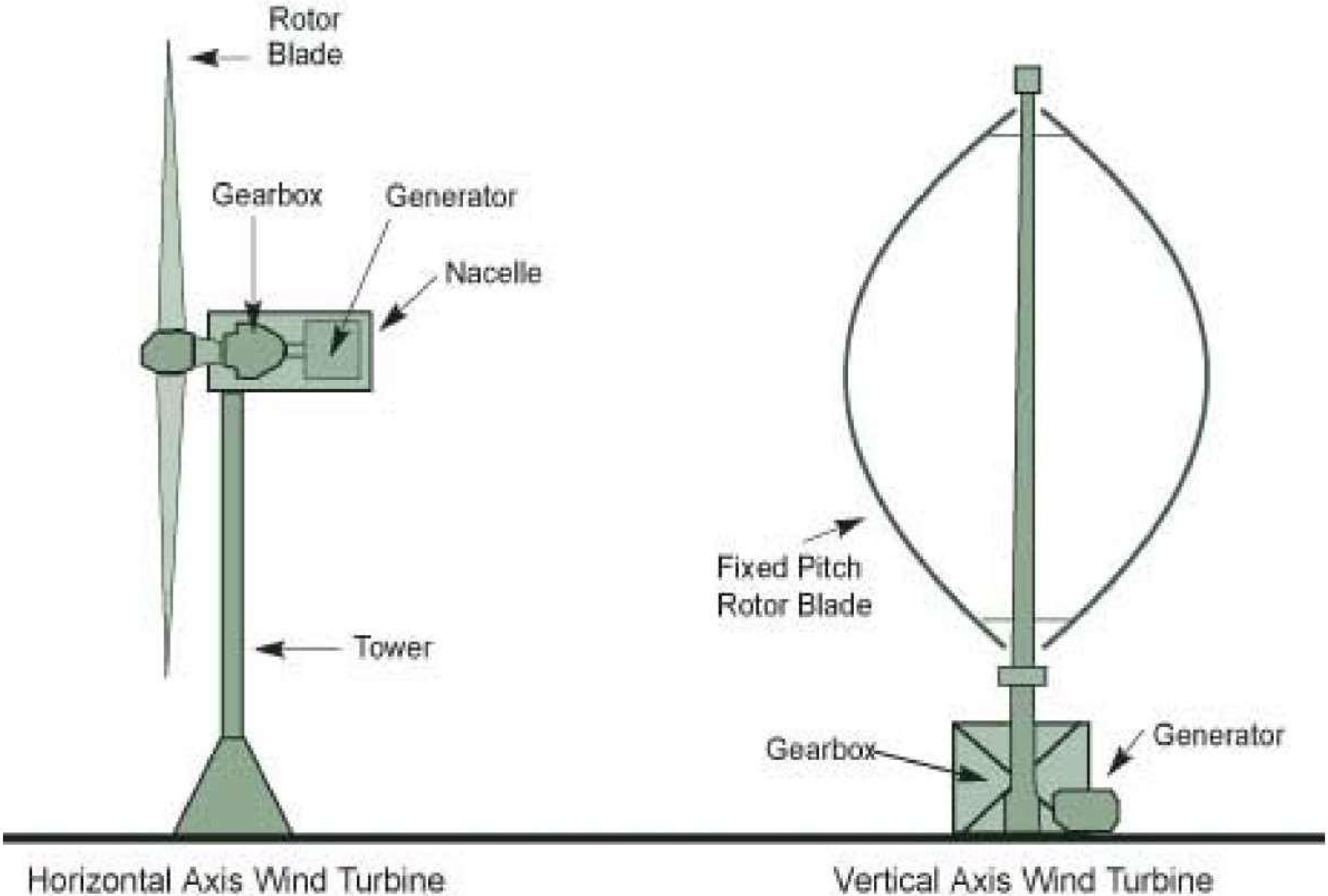
1. When the blades start moving, they spin a shaft that leads to a generator.
2. The generator consists of a conductor, such as a coiled wire, that is surrounded by magnets.
3. The rotating shaft turns the magnets around the conductor and generates an electrical current.
4. Sensors cause the top of the turbine to rotate to face into the wind and the blades change their angle to best catch the wind. The blades are flexible and stop spinning if wind is too strong.

Source: U.S. Department of Energy

SEATTLE P-I


1 Wind turns the turbine blades
2 Spinning the shaft
3 Generating electricity
4 An inverter converts electricity from DC to AC
5 Electricity is connected directly to the mains power
6 Or connected to a battery bank
7 Or connected to the electricity grid
1
2
3
4
5
6
7


Rotor Blade
Gear Box
Nacelle
Wind
Generator
Power Cables
Tower
Switchyard
Transformer


Rotor
Blade
Gearbox
Generator
Nacelle
Tower
Fixed Pitch
Rotor Blade
Gearbox
Generator
Horizontal Axis Wind Turbine
Vertical Axis Wind Turbine

Number of Blades – One

- 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 assembled on ground
- Captures 10% less energy than two blade design
- Ultimately provide no cost savings

Number of Blades - Two

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

Number of Blades - Three

Balance of gyroscopic forces
Slower rotation

- increases gearbox & transmission costs
- More aesthetic, less noise, fewer bird strikes

DISADVANTAGES:

- Low energy density.
- Irregular , unsteady wind energy
- Variable speed.
- Variable wind direction.
- Higher capital cost.
- Can be located only in vast open areas .
- Far location from load centers.
- Complex designs.

Drawbacks of Horizontal Axis Wind Turbine

- Massive tower construction is required to support the heavy blades,
- gearbox, and generator.
- Components of a horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being lifted into position.
- Their height makes them obtrusively visible across large areas,
- disrupting the appearance of the landscape and sometimes creating local opposition.
- Down wind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).

- HAWTs require an additional yaw control mechanism to turn the blades toward the wind.
- HAWTs generally require a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.
- Cyclic Stresses & Vibration – When the turbine turns to face the wind, the rotating blades act like a gyroscope. As it pivots, gyroscopic precession tries to twist the turbine into a forward or backward somersault. For each blade on a wind generator's turbine, force is at a minimum when the blade is horizontal and at a maximum when the blade is vertical. This cyclic twisting can quickly fatigue and crack the blade roots, hub and axle of the turbines.
- Noise occurs when blades are rotating.

Vertical Axis Wind Turbine (VAWT):

VAWTs are a type of wind turbine where the main rotor shaft is set transverse to the wind (but not necessarily vertically) while the main components are located at the base of the turbine

Vertical axis turbines are powered by wind coming from all 360 degrees, and even some turbines are powered when the wind blows from top to bottom.

Types of VAWT:

The Savonius wind turbine

The Darrieus wind turbine

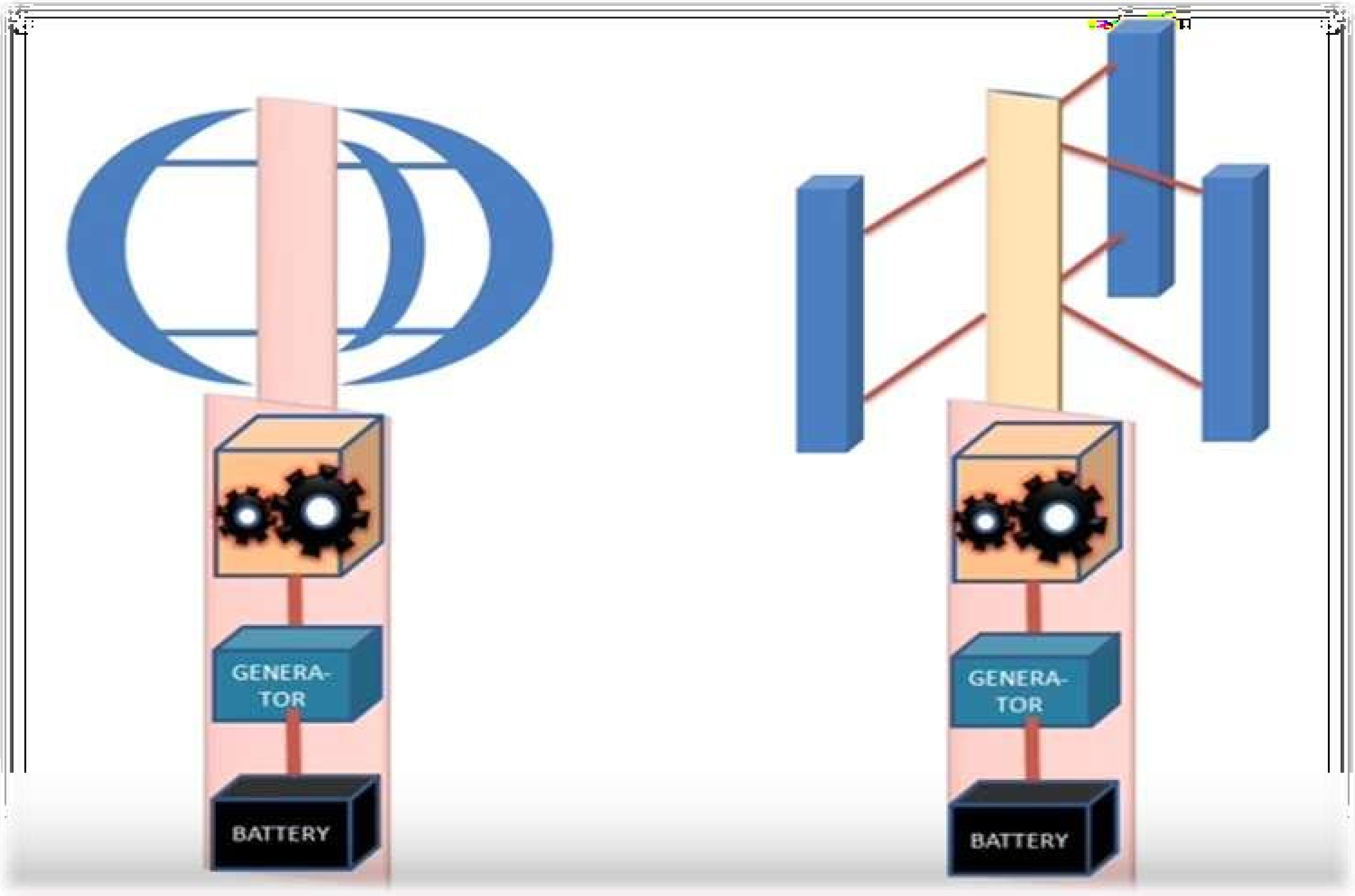
Vertical Axis wind turbine videos:

(1) https://www.youtube.com/watch?v=h5ZyYphMUUg

(2) https://www.youtube.com/watch?v=RPcQLZ0xBAI

(3) https://www.youtube.com/watch?v=cYh7jR4vLQg&t=10s

CONSTRUCTION UNDER ROTOR AXIS



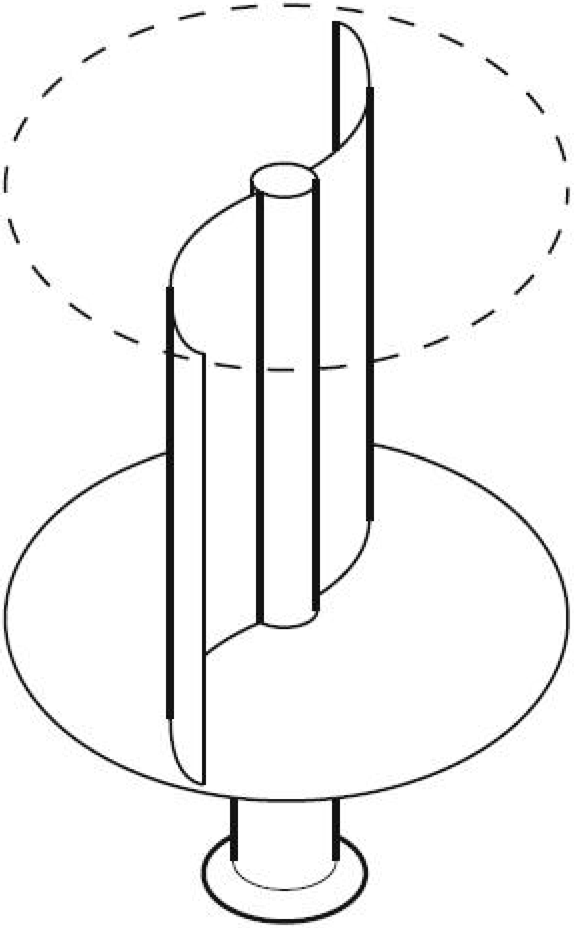
Savonius wind turbine

The Savonius rotor is an extremely simple vertical-axis device that works entirely because of the thrust force of wind.

The basic equipment is a drum cut into two halves vertically.

The two parts are attached to the two opposite sides of a vertical shaft.

As the wind blowing into the structure meets with two dissimilar surfaces-one convex and the other concave–the forces exerted on the two surfaces are different, which gives the rotor a torque.



- By providing a certain amount of overlap between the two drums, the torque can be increased.
- This is because the wind blowing into the concave surface turns around and gives a push to the inner surface of the other drum, partly cancelling the wind thrust on the convex side.
- It has been found that an overlap of about one–third the drum diameter gives the optimum result.
- The Savonius rotor is inexpensive and simple, and the material required for it is generally available in any rural area, enabling onsite construction of such windmills.
- However, its utility is limited to pumping water because of its relatively low efficiency.

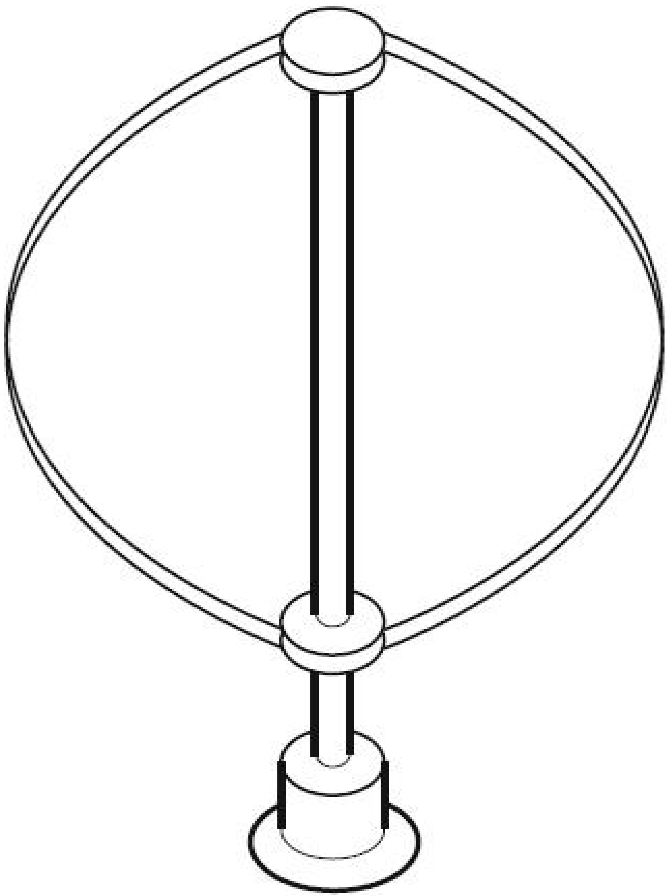
Darrieus wind turbine

In 1931, a vertical-axis device for wind energy conversion was invented by G.' Darrieus of the United States, but wa forgotten for a long time.

The energy crisis renewed interest in windmill development in the 1970s, which reinvented th use of the Darrieus rotor for wind energy conversion.

The peculiarity of the Darrieus rotor is that its working is not at all evident from its appearanc

Two or more flexible blades are attached to a vertical shaft as shown in Figure.



The blades bow outward, taking approximately the shape of a parabola, and are of symmetrical aerofoil section.

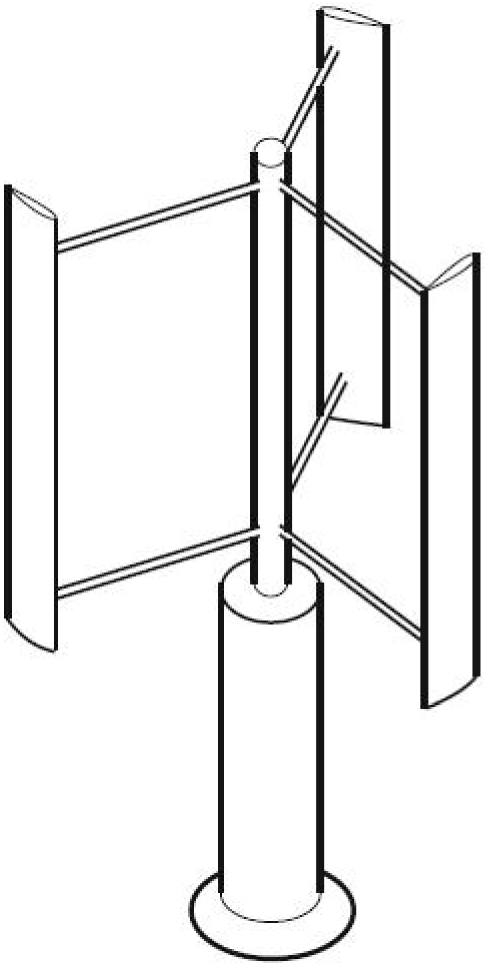
At first sight it appears that the forces on the blades at the two sides of the shaft should be the same, producing no torque.

In fact, the torque is zero when the rotor is stationary.

It develops a positive torque only when it is already rotating.

This means that such a rotor has no starting torque and has to be started using some external means.

H-Darrieus-Rotor



Helical type Darrius Vertical axis windmill

- Helical twist to the vertical blades to optimize wind capture, create axis-within-axis to segregate weight bearing and turning structures, and integrate composites in blades, the core and support arms to minimize weight.
- Three helical blades curve around the shell axis, and each blade is attached to the shell axis by two arms that are bonded to the back of the blade.
- The wind pulls each blade around on both the windward and leeward sides of the turbine, this feature spreads the torque evenly over the entire revolution, thus preventing destructive pulsations.

(a) (b) (c)

The principle of operation is shown in Figure.

One blade of the rotor is shown in three successive positions along the path of rotation.

At each position the blade velocity vector u, the wind velocity vector υ, the relative wind w , the lift force F_L, and the drag force F_D are shown.

It can be seen that at each position the lift force has a positive component in the direction of rotation, giving rise to a net positive torque.

This torque is not the same in all the positions.

It varies from zero when the blade is moving directly upwind or downwind to a maximum about a quarter of a revolution later.

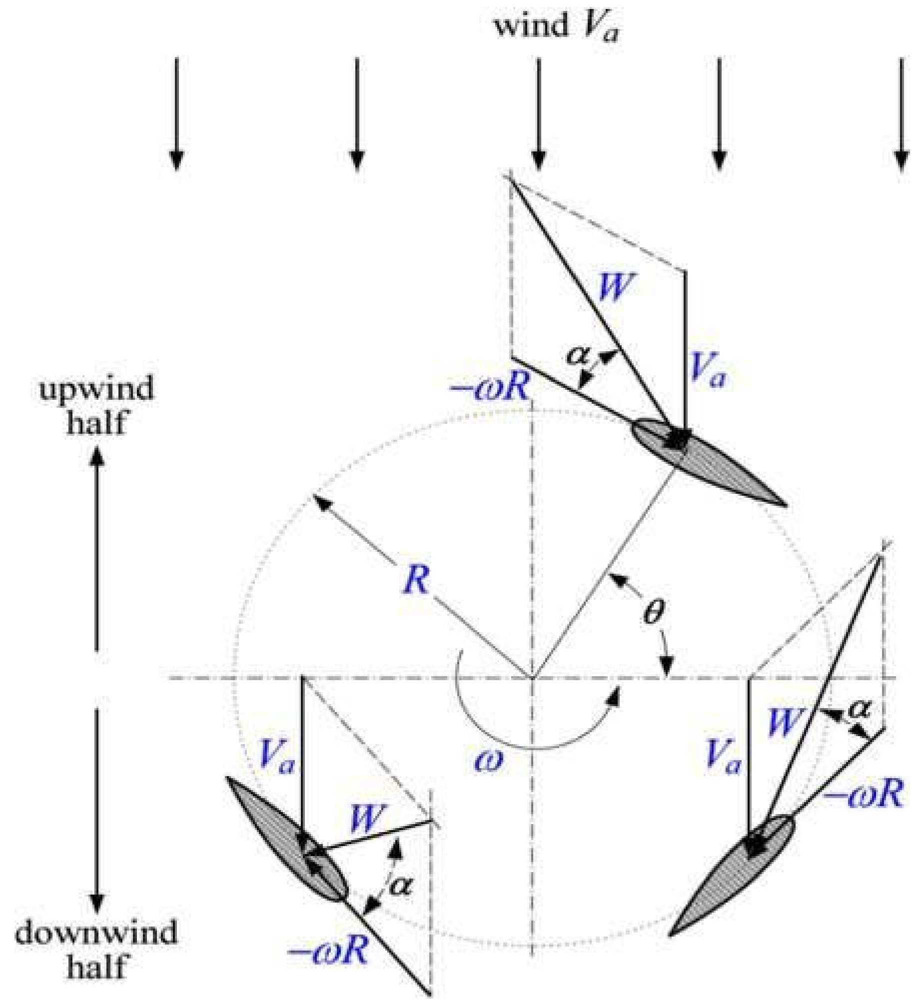
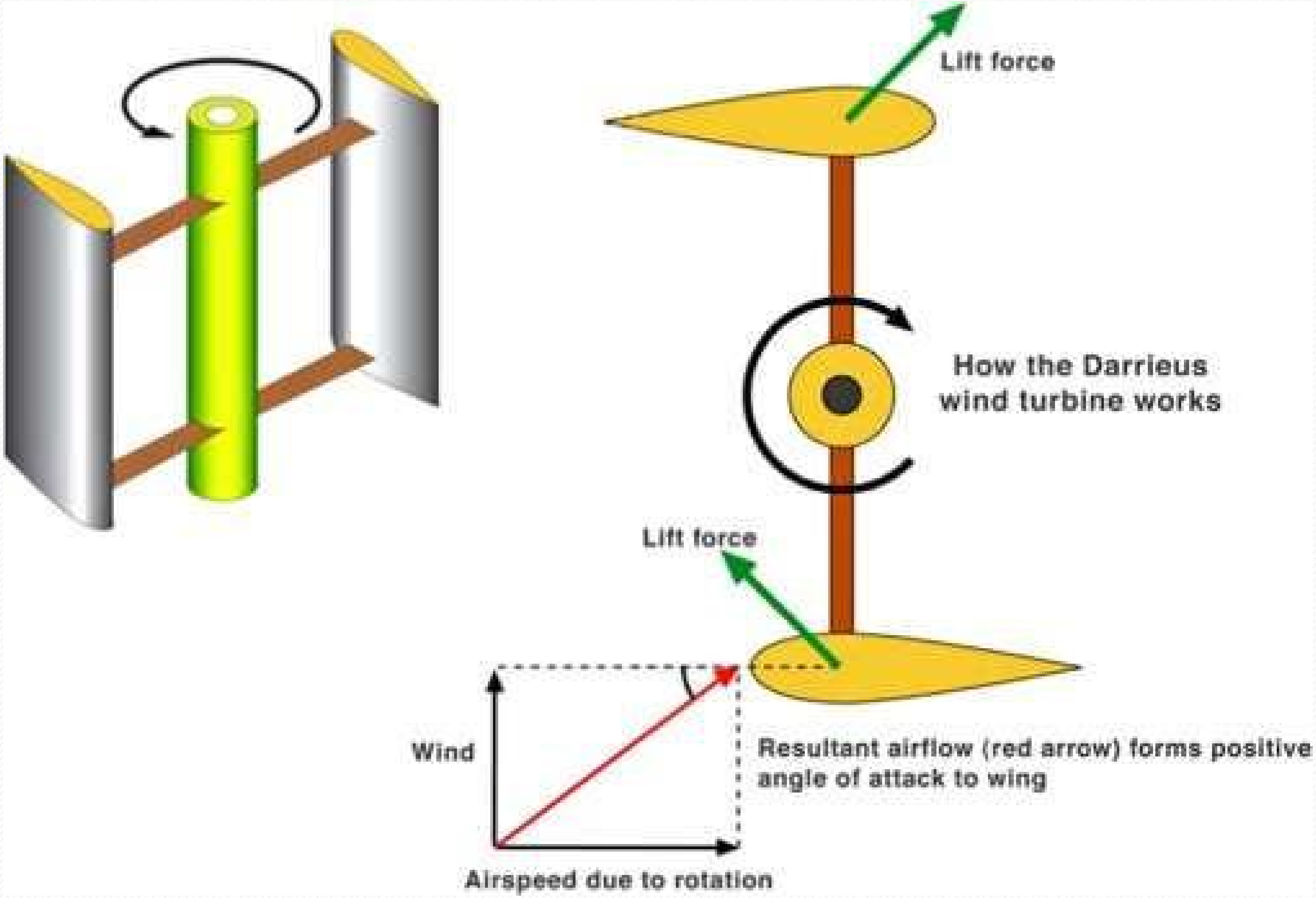


Fig: Top view of a three-blade VAWT showing the velocity components relative to the blade. The linear velocity of the blade b W can be obtained by deriving its position with respect to time.


Lift force
How the Darrieus
wind turbine works
Lift force
Wind
Resultant airflow (red arrow) forms positive
angle of attack to wing
Airspeed due to rotation

Advantages of VAWTs

They can produce electricity in any wind direction.

Strong supporting tower in not needed because generator, gearbox and other components are placed on the ground.

Low production cost as compared to horizontal axis wind turbines.

As there is no need of pointing turbine in wind direction to be efficient so yaw drive and pitch mechanism is not needed.

Easy installation as compared to other wind turbine.

Easy to transport from one place to other.

Low maintenance costs.

They can be installed in urban areas.

Low risk for human and birds because blades moves at relatively low speeds.

They are particularly suitable for areas with extreme weather conditions, like in the mountains where they can supply electricity to mountain huts.

Disadvantages of VAWTs

As only one blade of the wind turbine works at a time, efficiency is very low compared to HAWTS.

They need an initial push to start; this initial push that to make the blades start spinning on their own must be started by a small motor.

When compared to horizontal axis wind turbines they are very less efficient because of the additional drag created when their blades rotate.

They have relative high vibration because the air flow near the ground creates turbulent flow.

Because of vibration, bearing wear increases which results in the increase of maintenance costs.

Differentiate between Horizontal and Vertical Axis Wind Turbine

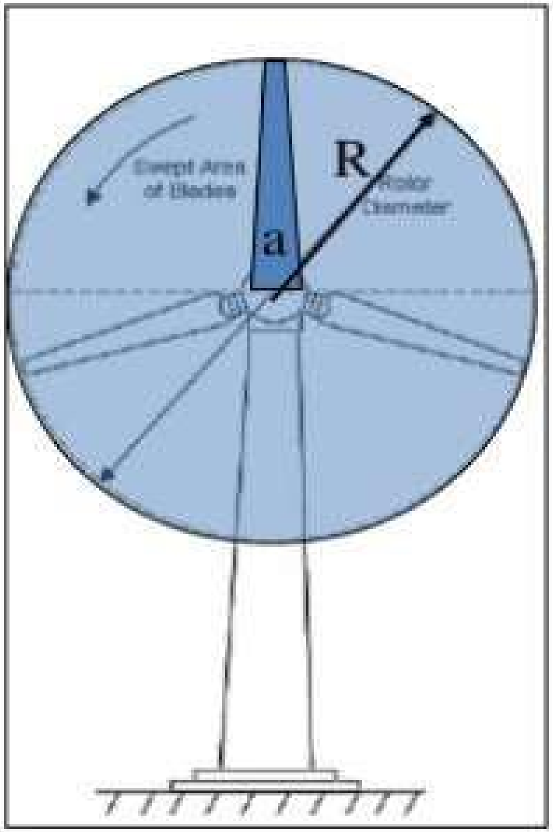
Horizontal Axis	Vertical Axis
1. Major components at height	1. Major components at ground level
2. Rotating Speed –High	2. Rotating Speed –Low
3. Maintenance– High	3. Maintenance– Low
4. Cable standing Problem	4. No Cable standing Problem
5. Less life span	5. Long Life Span
6. Installation cost is High	6. Installation cost is Low
7. It run on high wind speed	7. It can run on lower wind speed
8. High tip to wind speed ration so high power output	8. Low tip to wind speed ration so low power output
9. Starting torque is less	9. Starting torque is high
10.Rotation is parallel to the wind direction.	10. Rotation is perpendicular to the wind direction

Rotor

Solidity is the ratio of total rotor plan form area to total swept area

Low solidity (0.10) = high speed, low torque

High solidity (>0.80) = low speed, high torque



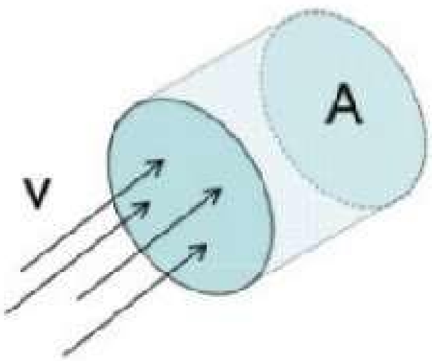
- Ratio of the blade area to the swept frontal area of wind turbine.

$$Solidity(\Upsilon) = \frac{Blade\ area}{Swept\ area} = \frac{nC}{R}$$

Derive equation for maximum power of wind turbine

- Wind Power depends on:
  - amount of air (volume)
  - speed of air (velocity)
  - mass of air (density)

  flowing through the area of interest (flux)



- **Kinetic Energy** definition:
  - $KE = \frac{1}{2} * m * v^2$
- Power is KE per unit time:

  $$\dot{m} = \frac{dm}{dt}$$ mass flux

  - $P = \frac{1}{2} * \dot{m} * v^2$
- Fluid mechanics gives **mass flow rate** (density * volume flux):
  - $dm/dt = \rho * A * v$
- Thus:
  - $P = \frac{1}{2} * \rho * A * v^3$

- Power ~ cube of velocity
- Power ~ air density
- Power ~ rotor swept area $A = \pi r^2$

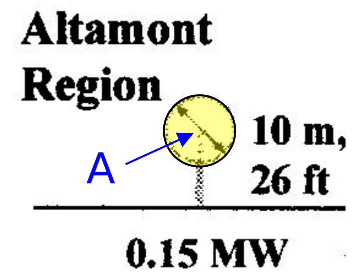
Power Generated by Wind Turbine

$$\text{Power} = \tfrac{1}{2}(\rho)(A)(V)^3$$

ρ = Density of air = 1.2 kg/m^3 (.0745 lb/ft^3), at sea level, 20 ^{o}C and dry air

A = swept area = ≺(radius)^2, m^2

V = Wind Velocity, m/sec.



ρ = 1.16 kg/m3, at 1000 feet elevation

ρ = 1.00 kg/m3, at 5000 feet elevation

ρ = 1.203 kg/m3 at San Jose, at 85 feet elevation. The average wind velocity is 5 mph at 50m tower height

ρ = 1.16 kg/m3 at Altamont pass, at 1010 feet elevation and average wind velocity of 7m/s at 50m tower height (turbines need a minimum of 14mph, 6.25 m/s, wind velocity to generate power).

Define power coefficient, tip speed ratio and solidity. Discuss their effect on performance of wind turbine.

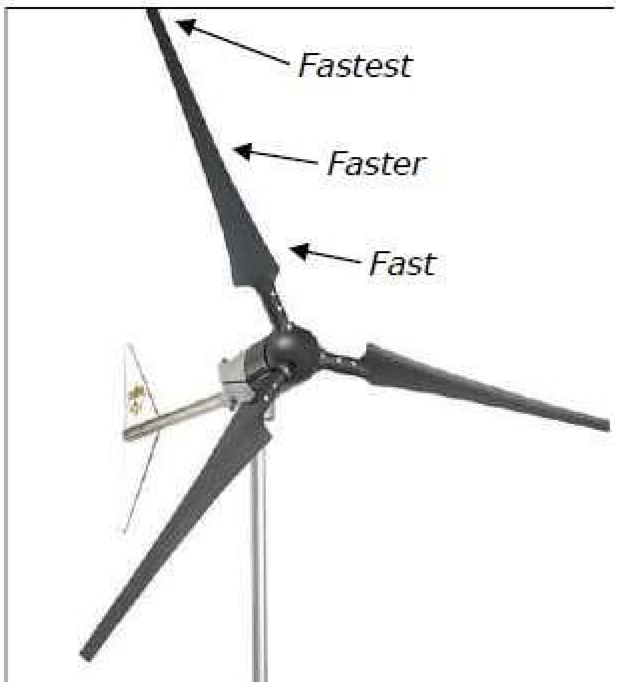
Power Coefficient (Cp) is a measure of wind turbine efficiency often used by the wind power industry. Cp is the ratio of actual electric power produced by a wind turbine divided by the total wind power flowing into the turbine blades at specific wind speed.

$$Cp = \frac{\text{Actual Electrical Power Produced}}{\text{Wind Power into Turbine}} = \frac{P_{out}}{P_{in}}$$

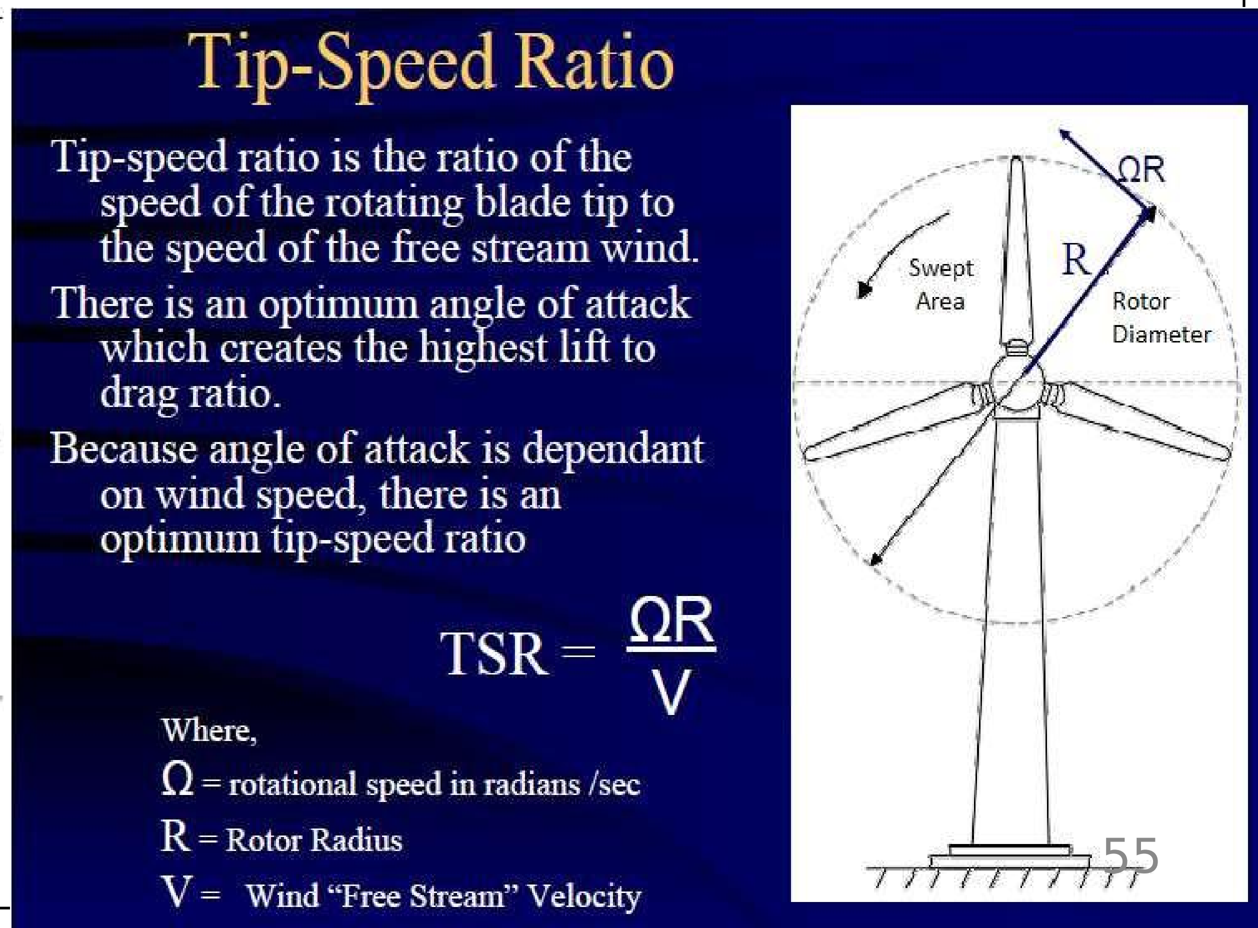
Beltz Limit:
https://www.youtube.com/watch?v=9NwnvA0KS1k

The *Tip Speed Ratio (TSR) is an extremely* important factor in wind turbine design.

TSR refers to the ratio between the wind speed and the speed of the tips of the wind turbine blades



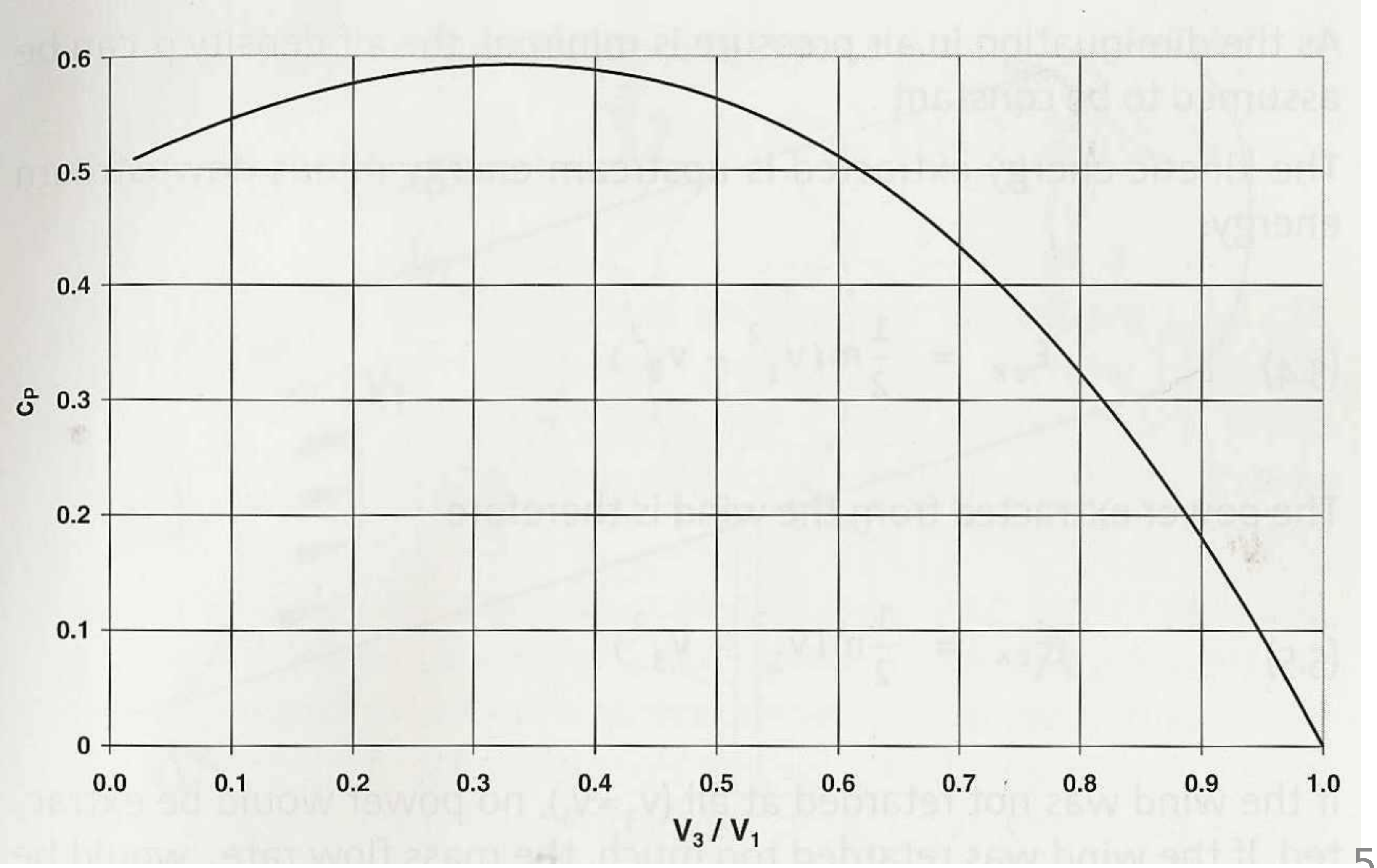
The further away from the center, the faster the blades spin.



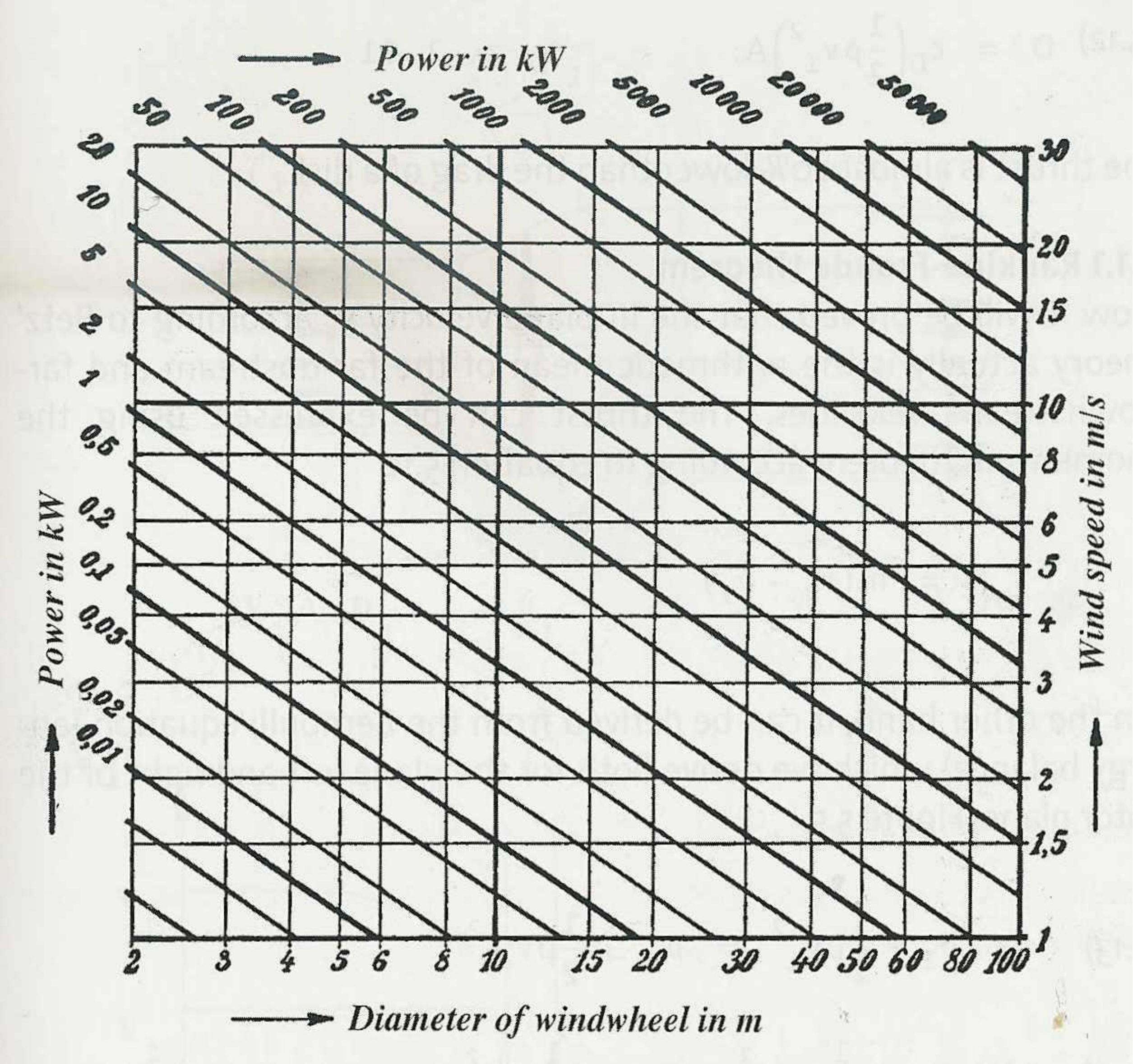
Beltz limit

Video:
(1) https://www.youtube.com/watch?v=MJr4dHPWu8w
(2) https://www.youtube.com/watch?v=kuuo8bntCMg

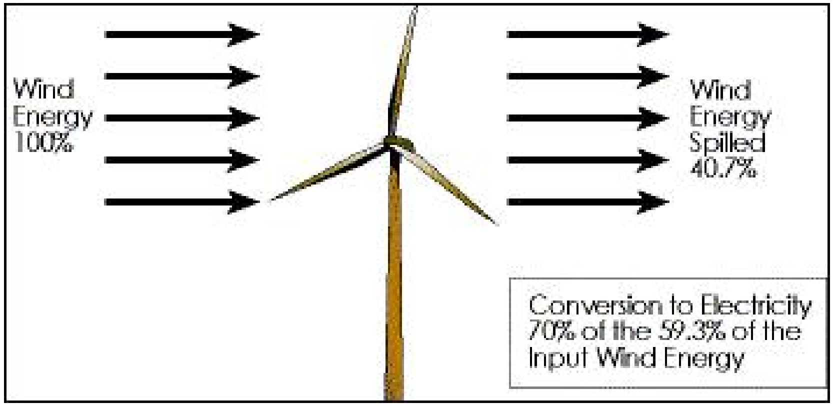
Power Coefficient

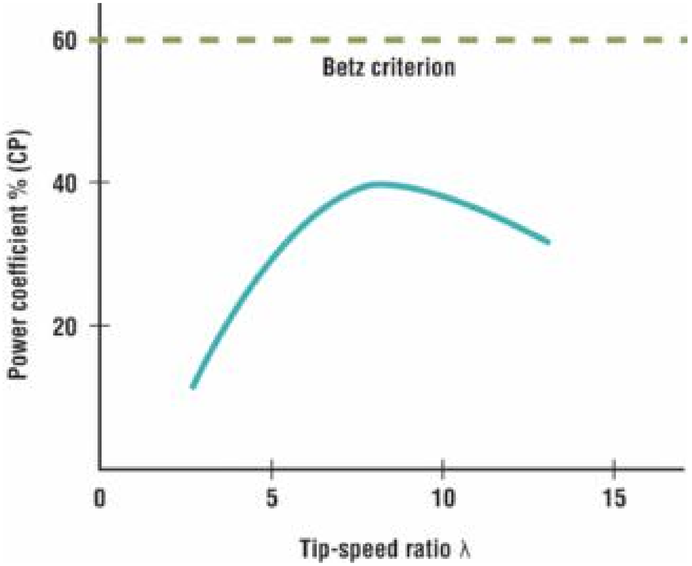


The Betz Power



Betz Limit





All wind power cannot be captured by rotor or air would be completely still behind rotor and not allow more wind to pass through.

Theoretical limit of rotor efficiency is 59%

Most modern wind turbines are in the 35 – 45% range

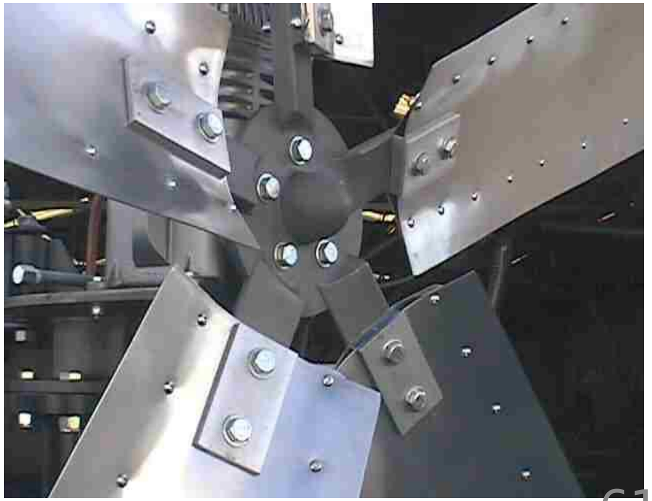
Blade Composition Wood

- Wood
  - Strong, light weight, cheap, abundant, flexible
  - Popular on do-it yourself turbines
- Solid plank
- Laminates
- Veneers
- Composites

Blade Composition
Metal

Steel
- Heavy & expensive

Aluminum
- Lighter-weight and easy to work with
- Expensive
- Subject to metal fatigue



Blade Construction Fiberglass

Lightweight, strong, inexpensive, good fatigue characteristics

Variety of manufacturing processes

- Cloth over frame
- Pultrusion
- Filament winding to produce spars

Most modern large turbines use fiberglass

Large Wind Turbines

450’ base to blade
Each blade 112’
Span greater than 747
163+ tons total
Foundation 20+ feet deep
Rated at 1.5 – 5 megawatt
Supply at least 350 homes


393 ft. full height
to tip of rotor
262 ft. from ground to hub
The blades on the wind turbines at the FPL Energy Gray County Wind Farm are the length of a wing on a commercial jetliner.
Blade 131 ft.
Hub 10 ft.

Lift & Drag Forces

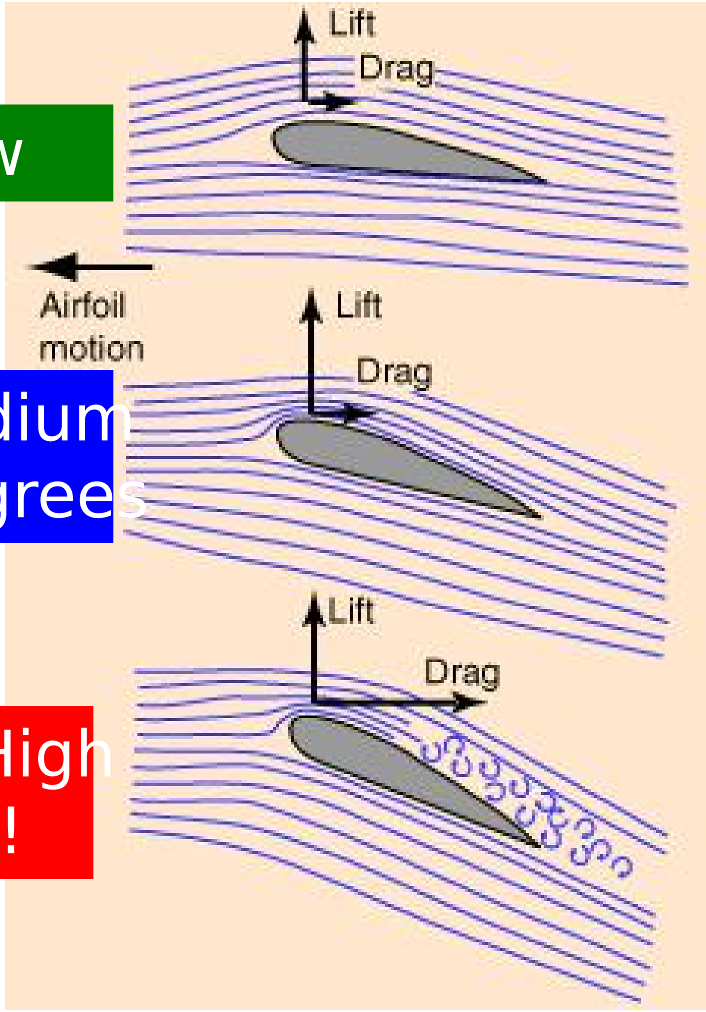
The *Lift Force* is perpendicular to the direction of motion. We want to make this force BIG.

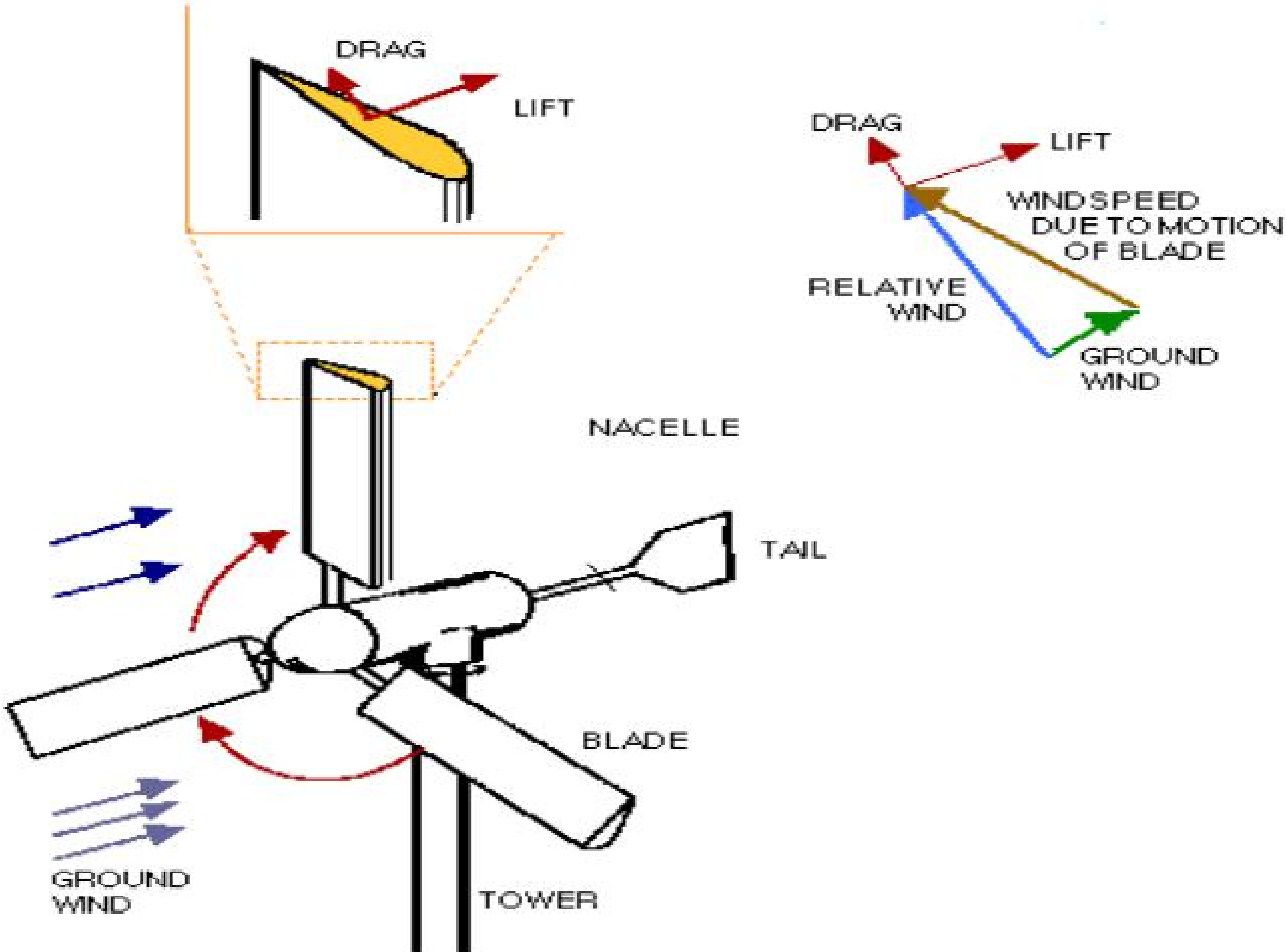
The *Drag Force* is parallel to the direction of motion. We want to make this force small.

α = low

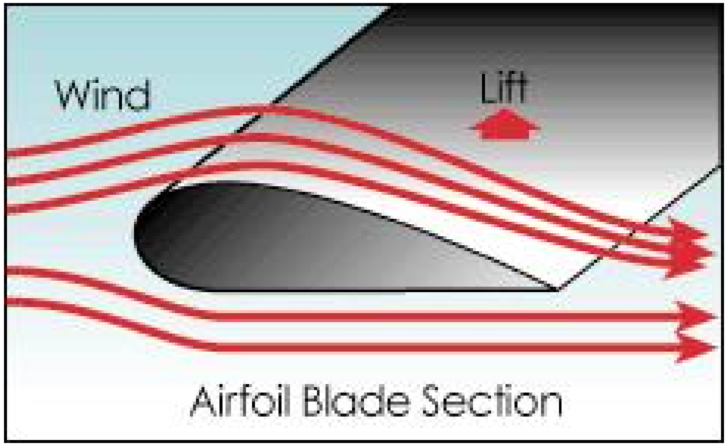
α = medium
<10 degrees

α = High
Stall!!

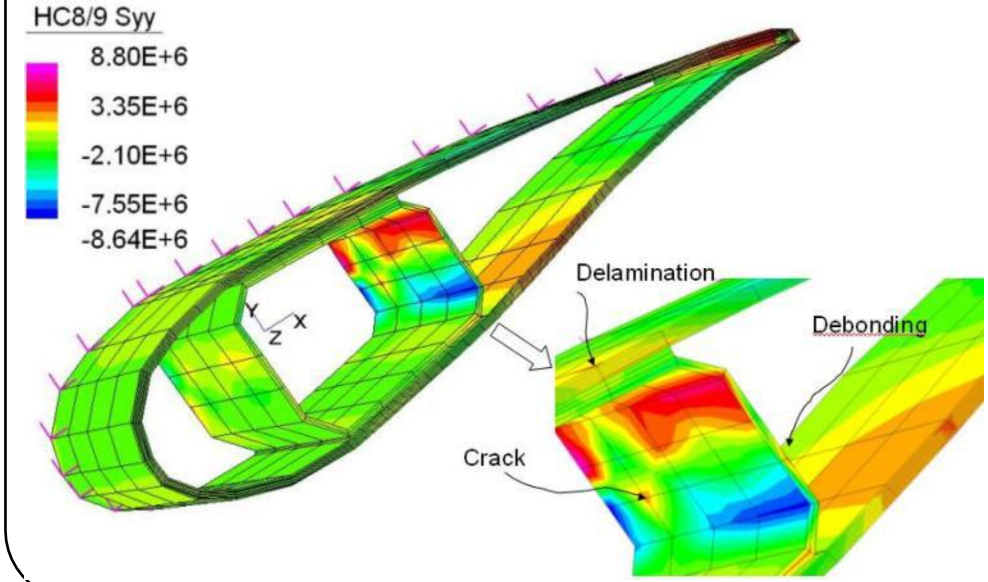



DRAG
LIFT
DRAG
LIFT
WINDSPEED
DUE TO MOTION
OF BLADE
RELATIVE
WIND
GROUND
WIND
NACELLE
TAIL
BLADE
GROUND
WIND
TOWER

Airfoil Shape

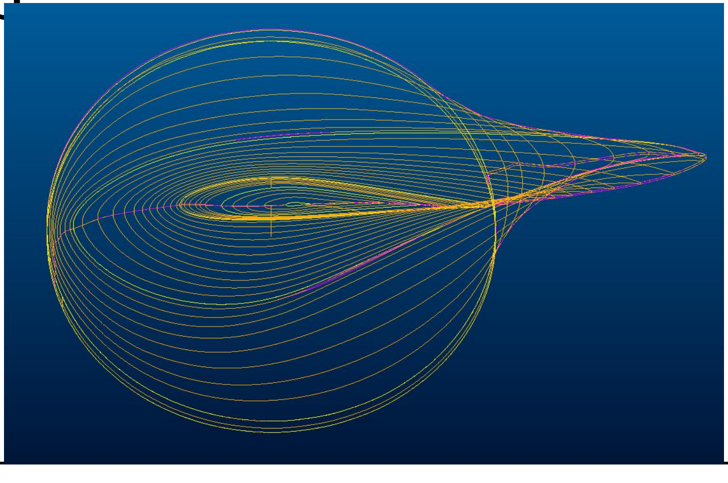


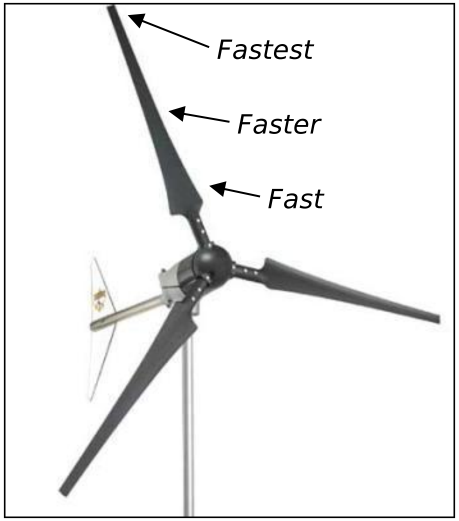
Just like the wings of an airplane, wind turbine blades use the airfoil shape to create lift and maximize efficiency.

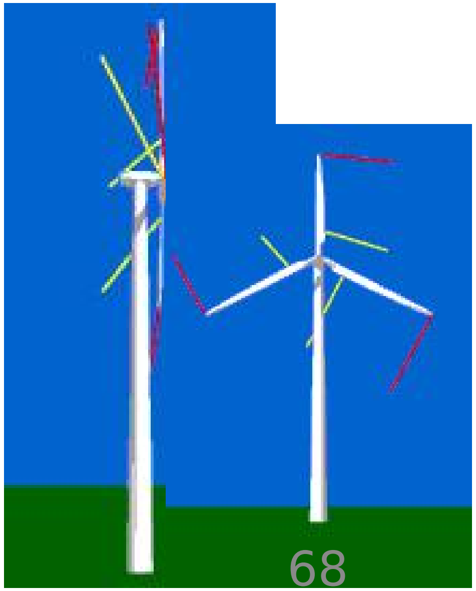


Twist & Taper

- Speed through the air of a point on the blade changes with distance from hub
- Therefore, tip speed ratio varies as well
- To optimize angle of attack all along blade, it must twist from root to tip



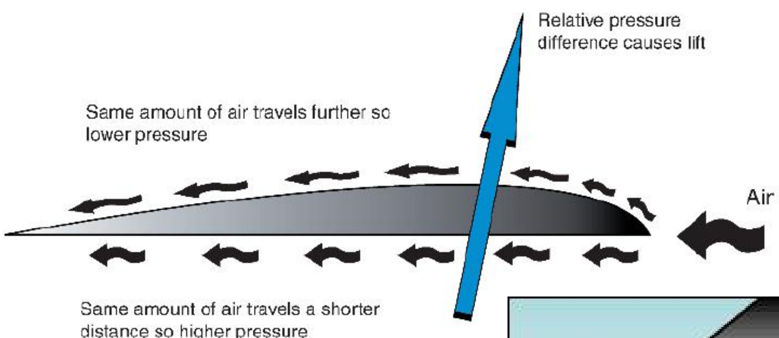


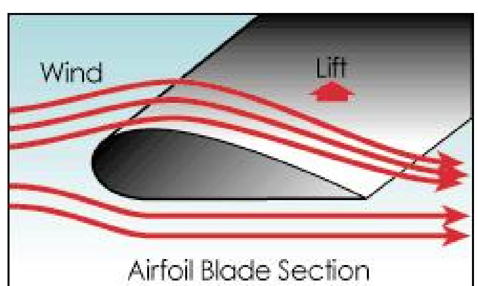


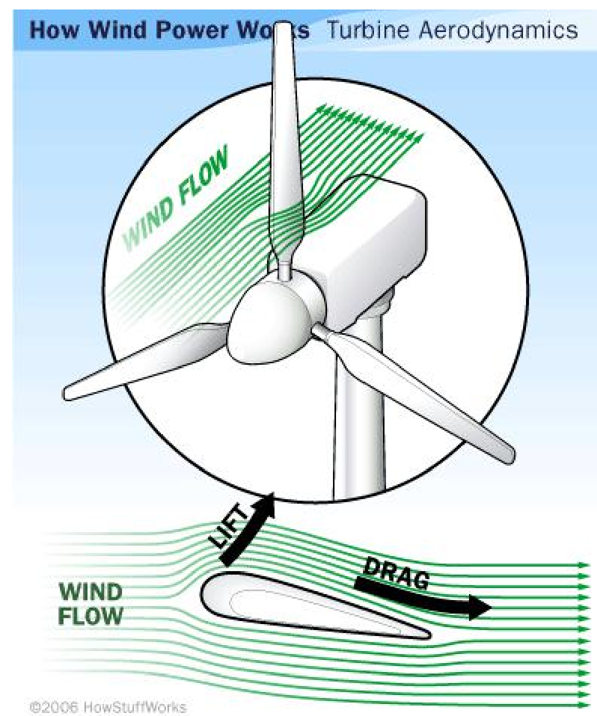
Wind Turbine

Lift Design

The lift blade design employs the same principle that enables airplanes, kites and birds to fly. The blade is essentially an airfoil, or wing. When air flows past the blade, a wind speed and pressure differential is created between the upper and lower blade surfaces. The pressure at the lower surface is greater and thus acts to "lift" the blade. When blades are attached to a central axis, like a wind turbine rotor, the lift is translated into rotational motion. Lift-powered wind turbines have much higher rotational speeds than drag types and therefore are well suited for electricity generation.



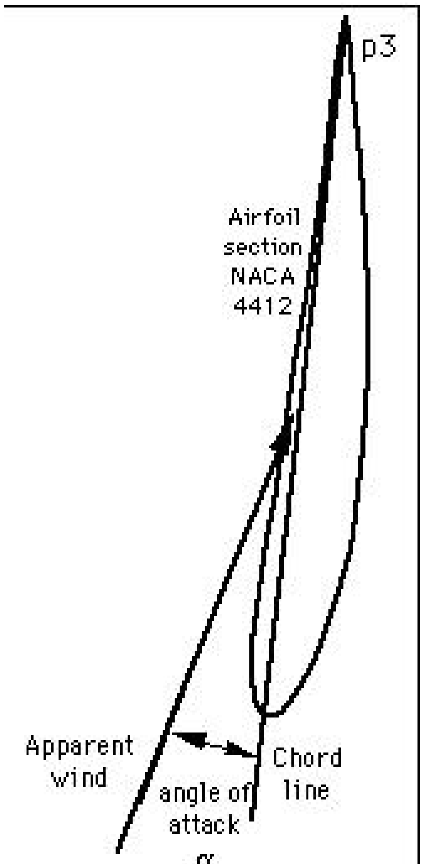


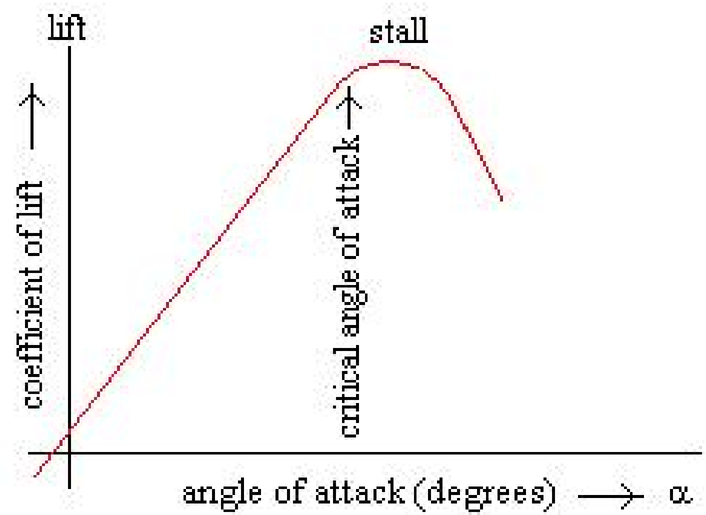


Wind Turbine – Blade Design

Angle of attack (blade angle)

The angle between the chord line of the airfoil and the flight direction is called the angle of attack. Angle of attack has a large effect on the lift generated by an airfoil. This is the propeller efficiency. Typically, numbers here can range from 1.0 to 15.0 degrees.





Wind Turbine – Blade Design

Blade Number

The determination of the number of blades involves design considerations of aerodynamic efficiency, component costs, system reliability, and aesthetics. Noise level is not affected significantly by the blade count. Aerodynamic efficiency increases with the number of blades but with diminishing return. Increasing the number of blades from one to two yields a six percent increase in aerodynamic efficiency, whereas increasing the blade count from two to three yields only an additional three percent in efficiency. Further increasing the blade count yields minimal improvements in aerodynamic efficiency and sacrifices too much in blade stiffness as the blades become thinner. Generally, the fewer the number of blades, the lower the material and manufacturing costs will be. Higher rotational speed reduces the torques in the drive train, resulting in lower gearbox and generator costs.

One blade rotor

Wind Turbine – Blade Design

The ideal wind turbine design is not dictated by technology alone, but by a combination of technology and economics: Wind turbine manufacturers wish to optimize their machines, so that they deliver electricity at the lowest possible cost per kilowatt hour (kWh) of energy.

Wind turbines are built to catch the wind's kinetic (motion) energy. You may therefore wonder why modern wind turbines are not built with a lot of rotor blades, like the old "American" windmills you have seen in the Western movies and still being used in many farms.

The ideal wind turbine rotor has an infinite number of infinitely thin blades. In the real world, more blades give more torque, but slower speed, and most alternators need fairly good speed to cut in.

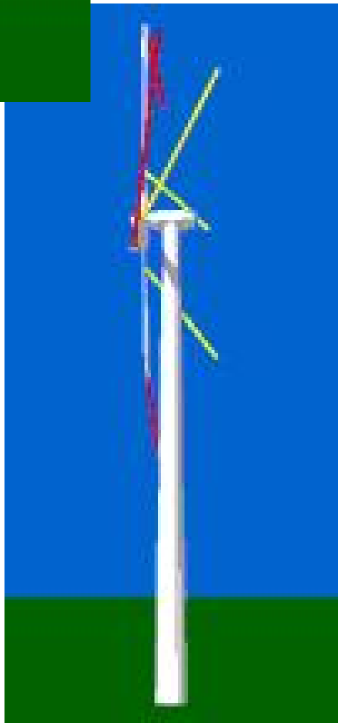
Turbines with many blades or very wide blades will be subject to very large forces, when the wind blows at a hurricane speed.

Wind Turbine – Blade Design

Even or Odd Number of Blades

A rotor with an even number of blades will cause stability problems for a wind turbine. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower. This produces uneven forces on the rotor shaft and rotor blade.

Wind Turbine – Blade Design (Shape)



To study how the wind moves relative to the rotor blades of a wind turbine, attach red ribbons to the tip of the rotor blades and yellow ribbons about 1/4 of the way out from the hub.

Since most wind turbines have constant rotational speed, the speed with which the tip of the rotor blade moves through the air (the tip speed) is typically some 64 m/s, while at the centre of the hub it is zero. 1/4 out from the hub, the speed will then be some 16 m/s.

The yellow ribbons close to the hub of the rotor will be blown more towards the back of the turbine than the red ribbons at the tips of the blades. This is because, at the tip of the blades, the speed is some 8 times higher than the speed of the wind hitting the front of the turbine.

Wind Turbine – Blade Design (Shape)

Rotor blades for wind turbines are always twisted. Seen from the rotor blade, the wind will be coming from a much steeper angle (more from the general wind direction in the landscape), as you move towards the root of the blade, and the centre of the rotor. A rotor blade will stop giving lift (stall), if the blade is hit at an angle of attack which is too steep.
Therefore, the rotor blade has to be twisted, so as to achieve an optimal angle of attack throughout the length of the blade.

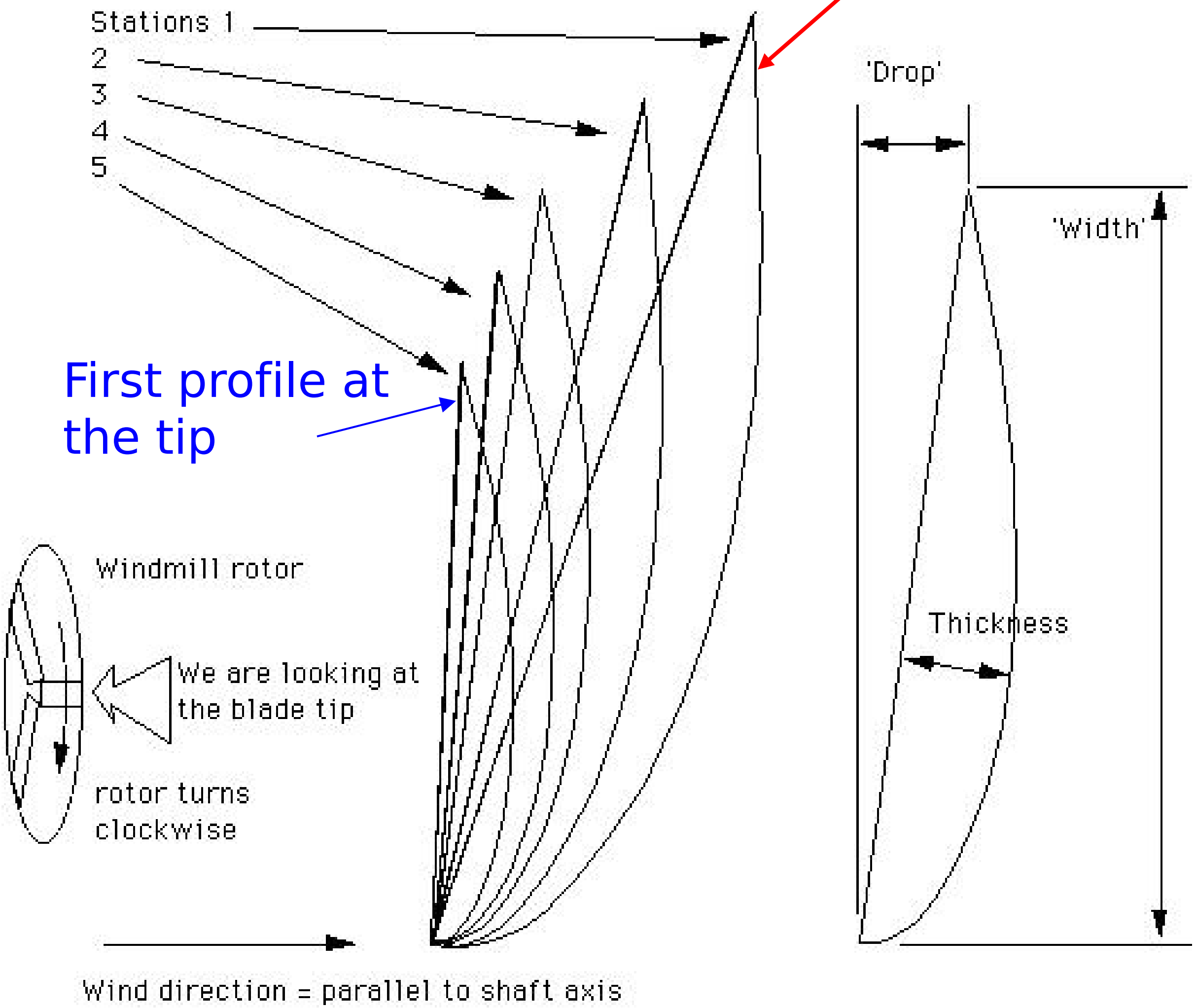
Wind Turbine – Blade Design

Blade size and shape

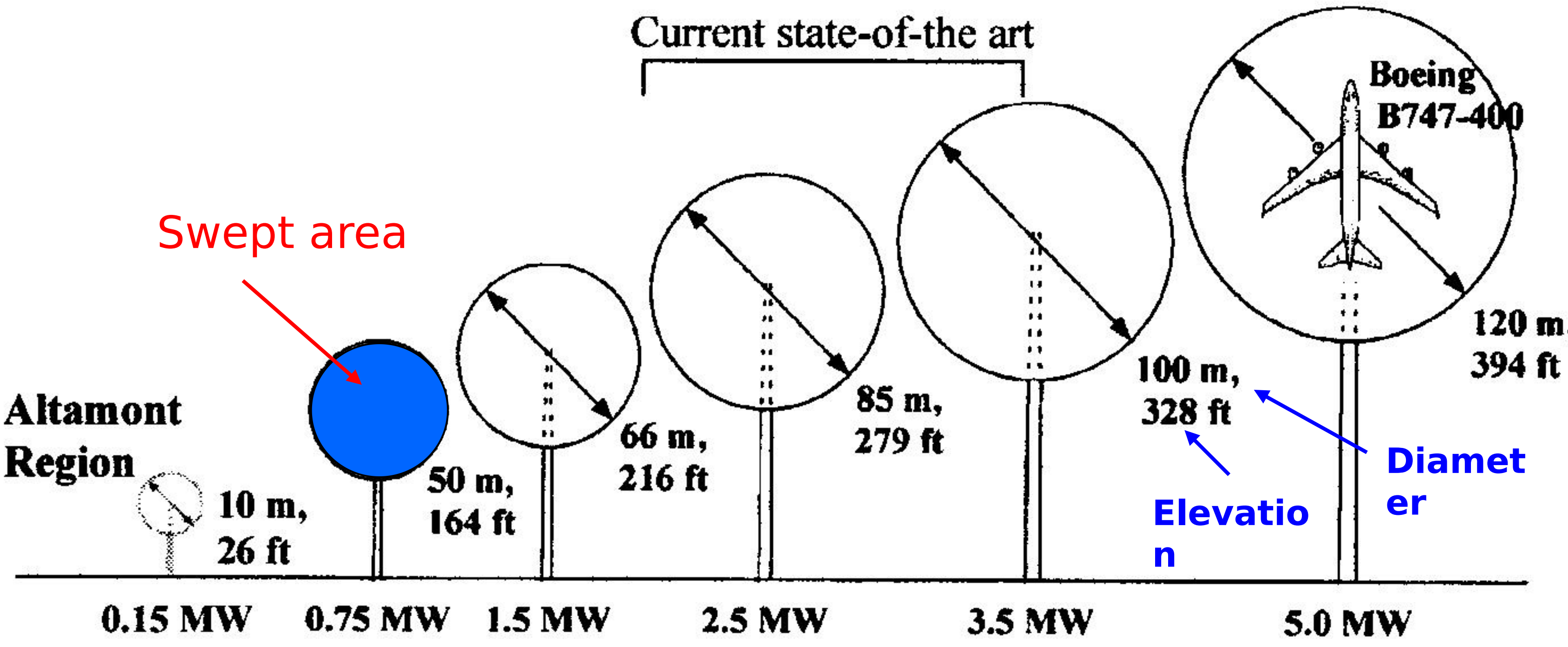
5-station design as seen from the tip

Last profile next to the hub

First profile at the tip

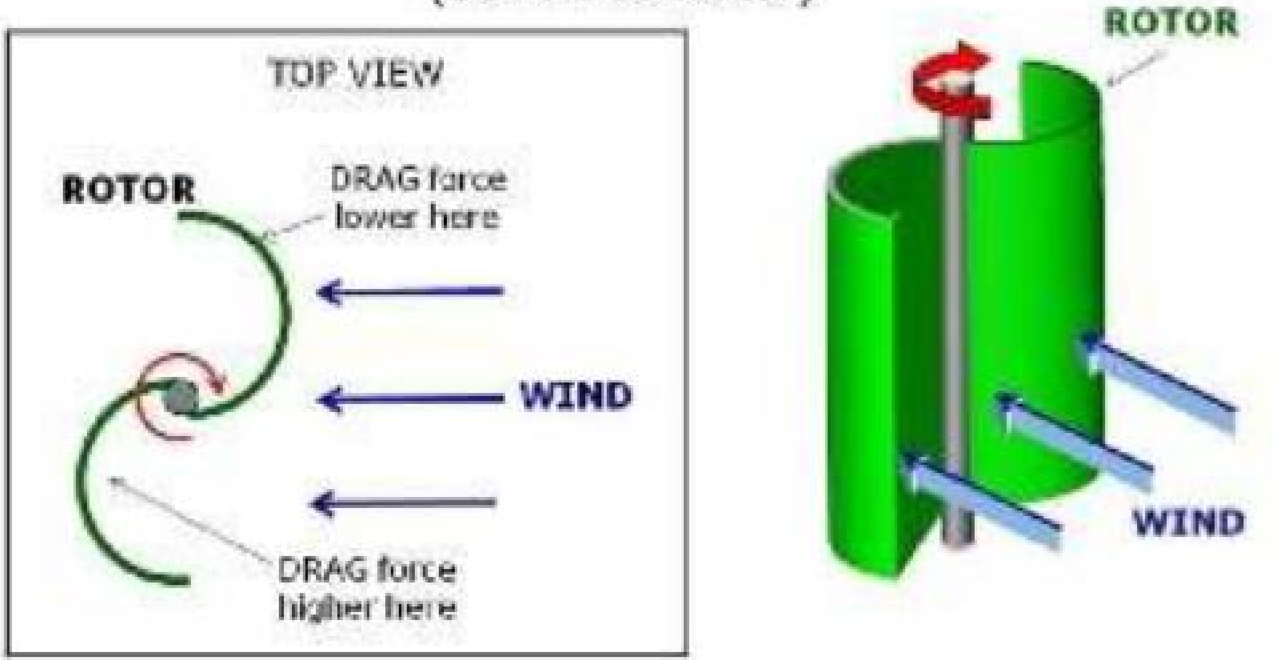


Power Generated by Wind Turbine

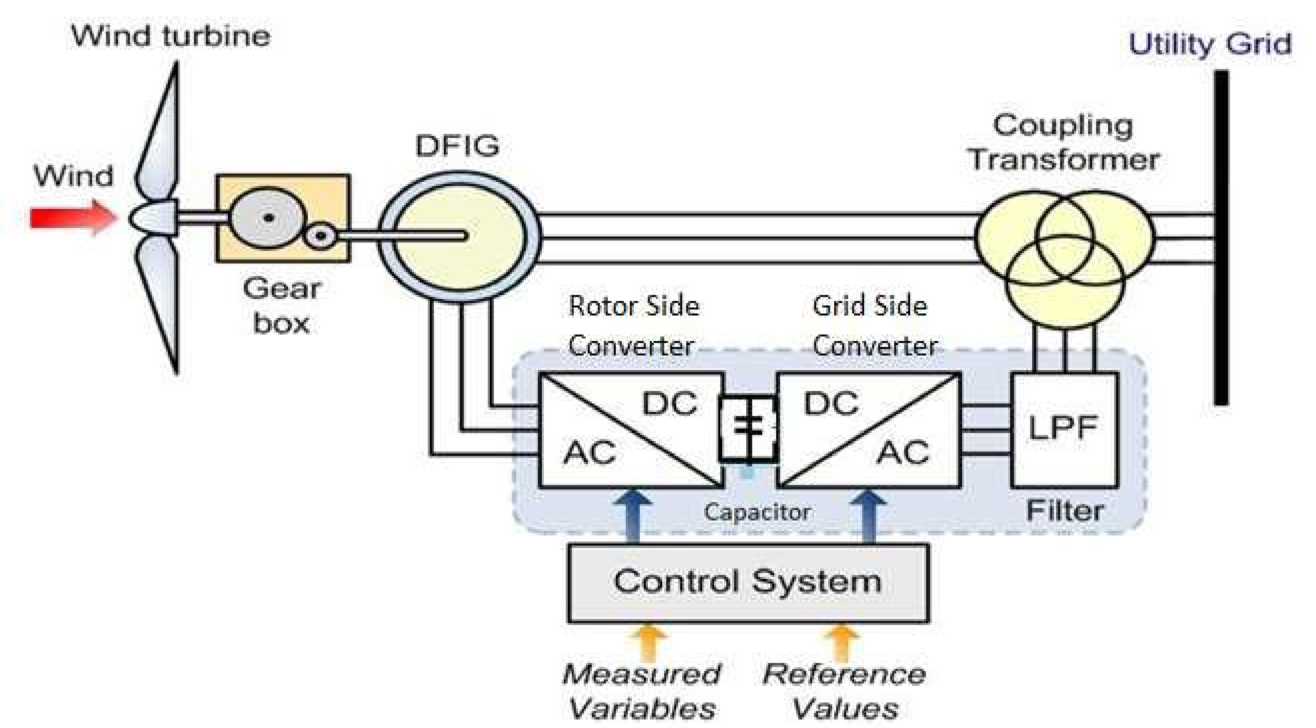


There are about 4,800 wind turbines in California at Altamont Pass (between Tracy and Livermore). The capacity is 580 MW, enough to serve 180,000 homes. In 2003, Altamont generated 822x106 kW hours, enough to provide power for 126,000 homes (6500 Kw-hr per house)

Figure 1: Drag-based Wind Turbine Concept
(Savonius Rotor)

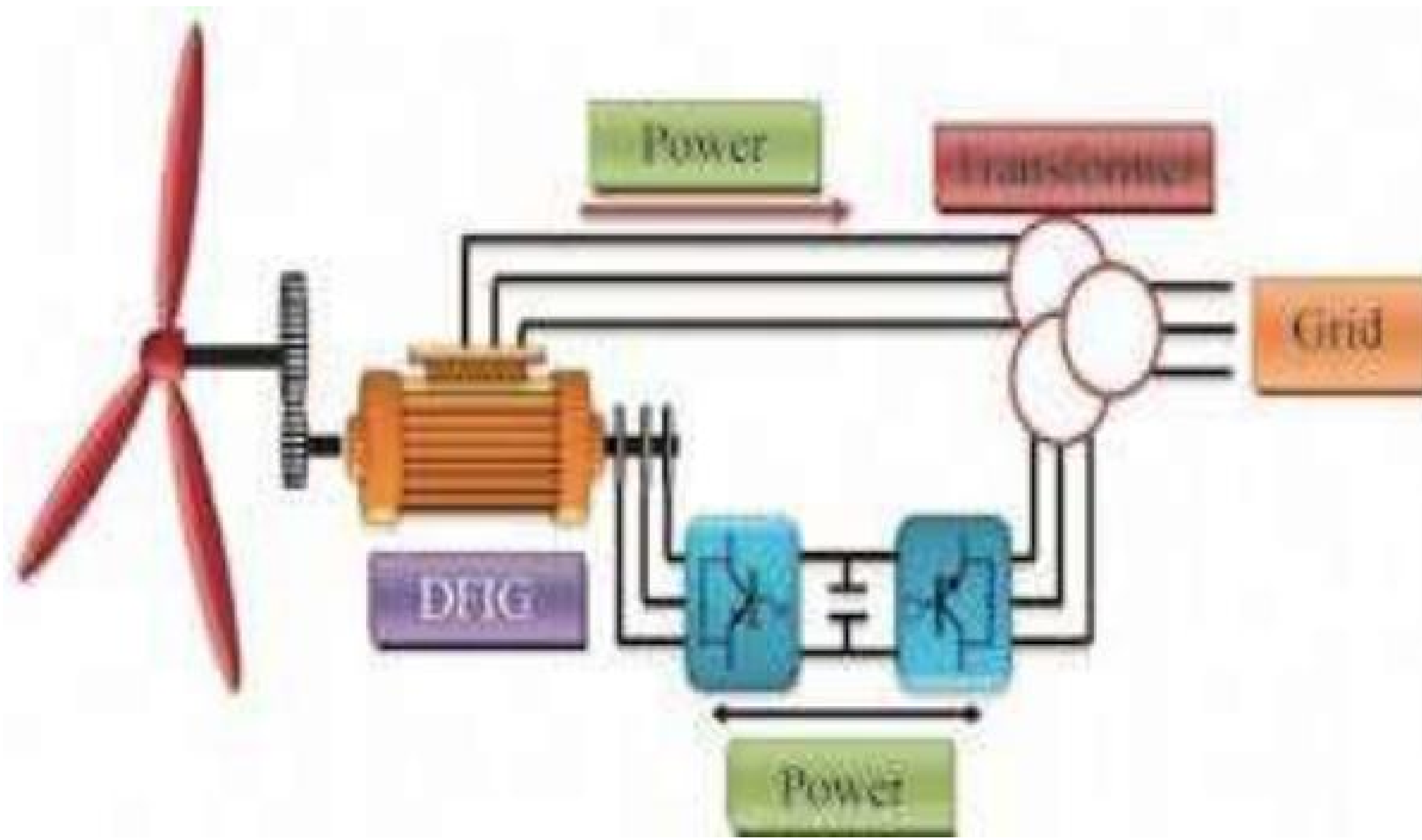


Rotation created by difference in DRAG forces on the convex and concave surfaces of the rotor



Explain construction and working of DFIG

A Wind Turbine: use to convert wind energy to mechanical energy.
Gear Box: uses to convert energy from one device to another.
Double Fed Induction Generator: used to convert mechanical energy to electrical energy which is in form of variable frequency.
Grid Side Converter: It is an AC–DC converter circuit which is used to provide a regulated DC voltage to the inverter. It is used maintain a constant DC link voltage.
Rotor Side Converter: It is a DC–AC inverter which is used to provide controlled AC voltage to the rotor.


Power
Grid
DFIG
Power

working of DFIG

It connected directly to the grid, where the rotor speed is adjusted using back to back converters.

The DFIG consists of a 3 phase wound rotor and a 3 phase wound stator. The rotor is fed with a 3 phase AC signal by slip rings, which induces an ac current in the rotor windings. As the wind turbines rotate, they exert mechanical force on the rotor, causing it to rotate.

As the rotor rotates the magnetic field produced due to the ac current also rotates at a speed proportional to the frequency of the ac signal applied to the rotor windings.

As a result a constantly rotating magnetic flux passes through the stator windings which cause induction of ac current in the stator winding. Thus the speed of rotation of the stator magnetic field depends on the rotor speed as well as the frequency of the ac current fed to the rotor windings.

The whole system consists of two back to back converters – a generator side converter and a grid side converter, connected in the feedback loop of the system.

The generator side converter is used to control the active and reactive powers by controlling the d–q components of the rotor and also torque and speed of the machine.

The grid side converter is used to maintain a constant dc link voltage and ensures the unity power factor operation by making the reactive power drawn from the utility grid to zero.

A capacitor is connected between the two converters such that it acts as an energy storage unit.

This back to back arrangement provides a fixed voltage fixed frequency output
irrespective of the variable frequency, variable voltage output of the generator.

Advantages:

Output voltages to be maintained at a constant value, no matter the speed of the wind blowing on the wind turbine rotor.

Ability to control the power factor.

Constant frequency output signal to the grid irrespective of the variable rotor speed.

Low power rating required for the power electronic devices and hence low cost of control system.

Power factor is controlled, i.e. maintained at unity.

Electric power generation at low wind speed.

Power electronic converter has to handle the fraction of the total load i.e., $20–30\%$ and also cost of this converter is low than in case of the other types of generators.

Wind energy companies

ENERCON
ENERGY FOR THE WORLD

NATIONAL RENEWABLE ENERGY LABORATORY

Wind

RESEARCH | STAFF | IMPACTS | PUBLICATIONS | DATA & TOOLS

» Wind » Land-Based Wind Research

Researchers at the National Wind Technology Center design, research, and validate advanced wind power plant control systems to maximize energy production and reduce structural loads for land-based wind power plants.

Reliability

Through the use of its on-site facilities, NREL simulates wind turbine drivetrains, collects and analyzes data, and evaluates a variety of technologies and systems to improve land-based wind power plant reliability.

Design Methods, Tools, and Standards

NREL has developed and maintains robust open-source modeling tools capable of simulating a wide range of land-based wind systems. The two primary modeling efforts include computer-aided engineering tools and systems engineering tools. NREL researchers work with industry partners to conduct technical assistance, validate and verify models, and engage in collaborative research. Learn more about NREL's wind modeling software suites: FAST v8 and WISDEM.

Research and Development centre- Suzlon

Country	Unit	Focus Area
Germany	Hamburg	Development & Integration Certification
	Rostock	Development & Integration Design & Product Engineering Innovation & Strategic Research
Netherlands	Hengelo	Blade Design and Integration
India	Pune	Design & Product Engineering Turbine Testing & Measurement Technical Field Support Blade Engineering
	Vadodara	Blade Testing Center
	Hyderabad	Design & Product Engineering (BOP team)
	Chennai	Design & Product Engineering (Gear Box Team)
Denmark	Aarhus	SCADA
	Vejle	Blade Science Center

Technical Data

PARTICULARS	93 MTR RD + 80 MTR HH
OPERATING DATA	
Rated power	2000 kW
Cut-in-wind speed	3.0 m/s
Rated wind speed	11.5 m/s
Cut-out wind speed	20.0 m/s
Survival wind speed	52.5 m/s
Hub height	80 meters
Type class	TC IIIB
Rated speed	15.9 rpm
Operational mode	Variable speed

ROTOR	
Pitch system	Pitch control – electrical, variable speed inverters, power backup with ultra capacitors
Diameter	93 meters
Swept area	6795 sq meters
Blade material type	Epoxy glass fibre

GENERATOR	
Type	Double fed induction generator
Rated power	2000kW
Rated voltage	690 V AC, 3 Phase
Frequency	50 Hz
Cooling system	Water cooled
Insulation	Class H

TOWER	
Type	Conical tubular steel tower
Tower height	78 meters
Corrosion protection	Protective paint

The Siemens MADE 75-meter-long (246-ft) blades consist of a single component made from epoxy resin and balsa reinforced with glass fiber, cast in a gigantic mold using a process Siemens has cunningly named Integral Blade.

QUESTIONS / QUERIES / DOUBTS ?