Wind Power – Features, Technicalities and status

Wind Energy

- It is indirect form of solar energy (???)
- It is K.E. associated with movement of large masses of air
- These motion results from uneven heating of the atmosphere by the sun, creating temp., density and pressure difference
- Unlike solar radiation, can be available throughout the day
- It is clean, cheap and eco-friendly renewable energy source
- But it is dispersed, erratic and location specific
- It is harnessed as mechanical energy with the help of wind turbine
- It can be used as such to operate farm appliance and water pumping
- Very slow wind is useless. On the other hand, very strong stormy winds cannot be utilized due to safety of turbine
- Moderate to high speeds (5-20 m/sec) are considerably favorable
- It is fastest growing energy source among all renewables

Factors leading to Accelerated Development

- Availability of high strength fibre composites for constructing large low cost rotor blades
- Falling prices of power electronics
- Variable speed operation of electrical generators to capture maximum energy
- Improved plant operation, pushing availability up to 90%
- Economy of scale
- Accumulated field experience
- Short energy pay back period

Cumulative RE installed capacity (till 31 March 2018)

Resource	Installed Capacity (MW)
Wind Power	34046
Small Hydro	4486
Bio Power	8700
Solar Power	21651

Wind Power across the Globe

Country	Installed Capacity (GW)
China	145
USA	75
Germany	44
India	34
Spain	23
United Kingdom	13
Canada	11
France	10

Year-wise cumulative wind power installed capacity in India (MW)

Up to 2002	1666
2002-03	1908
2003-04	2523
2004-05	3635
2005-06	5351
2006-07	7093
2007-08	8756
2008-09	10241
2009-10	11806
2010-11	14155
2011-12	17352
2012-13	19052
2013-14	21132
2014-15	23444
2015-16	26777
2016-17	32280

State-wise Wind Power Capacity (till 31 March 2017)

State	Installed Capacity (MW)
Andhra Pradesh	3618
Gujarat	5340
Karnataka	3751
Kerala	51
Madhya Pradesh	2498
Maharashtra	4771
Rajasthan	4281
Tamilnadu	7861
Telangana	101
Others	4

Features of Wind Energy

- Renewable and free
- Enormous potential (10^{12} MW for entire planet)
- Present installed capacity more than 500 GW
- Non-polluting
- Highly variable
- Small footprints
- Less capacity credit (20-30%) as compared to conventional power plants
- Shorter (1 year) energy pay back period

Applications of of Wind Energy

A. Applications requiring mechanical power

- wind pumps
- space heating
- sea transport

B. As Off-grid electric power

- Low power (up to 1kW) for battery charging, running home appliances, water heating
- Medium power (50 kW) for navigation signals and remote communication
- Intermediate power (100-250 kW) to supply power to isolated population, commercial refrigeration and other small industries

C. As Grid connected electric power source

Wind Turbine Siting

- No tall obstruction in the direction of incoming wind
- A wide and open view
- Top of smooth well rounded hill with gentle slope
- An island in a lake or sea
- A narrow mountain gap through which wind is channeled
- Site reasonably close to power grid
- Soil conditions such that heavy construction and roads are possible
- Experience of existing wind turbines to assess local wind conditions

Optimum Tip Speed Ratio

If the tip speed ratio is too low (rotor tip is moving relatively slow as compared to wind) some of the wind travels through the rotor swept area without interacting with the blades

whereas

If the tip speed ratio is too high, the turbine offers too much resistance to the wind so that some of the wind goes around it. In other words, rotor tip is moving rather fast and before the wind passes by, the tip again falls in an area from where the energy has already been extracted

Hence an optimal value of TSR

Optimum Tip Speed Ratio

No. of blades	Optimum TSR	Rotor Radius (m)	Wind speed (m/sec)	Revolution (rpm)
2	6.28	40	15	22.5
3	4.18	40	15	15.0
4	3.14	40	15	11.3

Solidity

- The term 'solidity' of a wind turbine/rotor describes the fraction of the swept area of the rotor that is solid

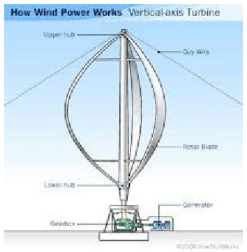
$$\text{Solidity} = \frac{\text{Total Blade Area}}{\text{Total Swept Area}}$$

- Wind turbines with larger number of blades have highly solid swept areas and are referred to as 'High Solidity' wind turbines
- Wind turbines with smaller number of narrow blades are referred to as 'Low-Solidity' wind turbines

Classification of Wind Turbines

- On the basis of Axis of Rotation
  - Horizontal axis – axial flow type
  - Vertical Axis – cross flow type
- On the basis of Predominant Type of Force
  - Lift type
  - Drag type

Classification of Wind Turbines



Components of Horizontal Axis Wind Turbine

- The Rotor: consisting of the blades and the supporting hub
- The Transmission System and Generator (or drive train) which includes the rotating parts of the wind turbine (excluding the rotor)

⇩

It usually consists of the shafts, gearbox, coupling, a mechanical brake, and the generator

- The Nacelle and mainframe, including wind turbine housing, bedplate and the yaw system

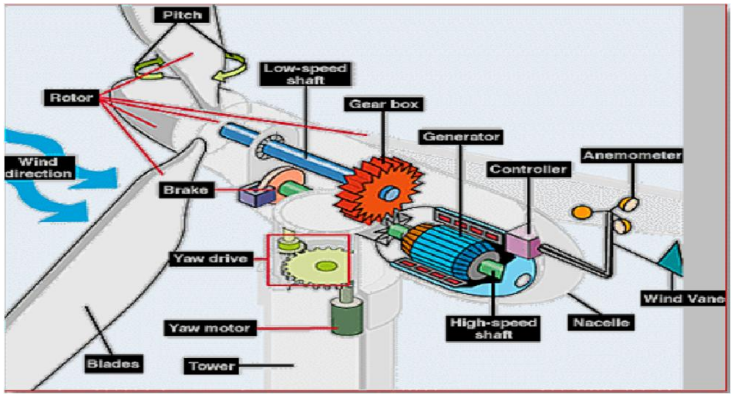
⇩

The Nacelle can rotate yaw according to the wind direction which is mounted on the tower

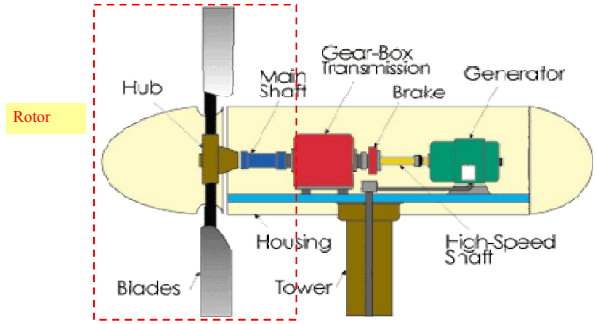
Components of Horizontal Axis Wind Turbine (continued..)

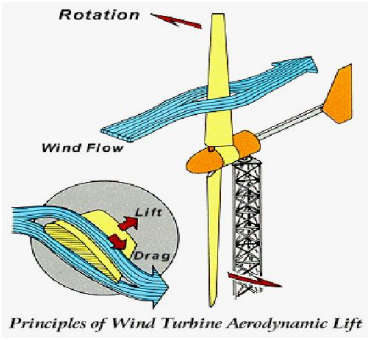
- The tower and the foundation
- The machine controls
- The balance of the electrical system, including cables, switchgear, transformers, and electronic power converters

A Typical Horizontal Axis Wind Turbine



Common HAWT Construction





Rotors

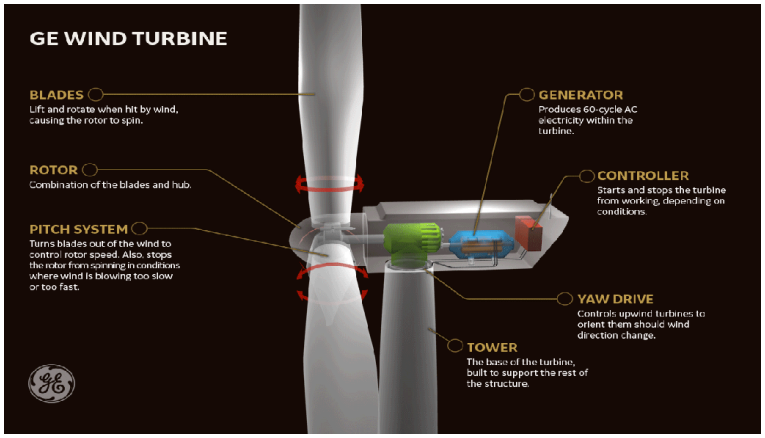
- Rotor consists of the hub and blades of the wind turbine
- It is considered to be the most important component of the wind turbine form both a performance and overall cost standpoint
- Turbines for wind farm applications typically have two or three blades and a tip speed of 50 to 70 m/s
- With tip speeds in the range of 50 to 70 m/s, a three blade rotor usually gives the best efficiency, though 2-blade rotors are only 2-3% less efficient

Generator

- All grid connected wind turbines drive three phase alternating current (AC) generators to convert mechanical to electrical power
- Two main types of generators used are
  - a)Synchronous generators or Alternators
    - These operate at the same frequency as that of the network
  - b)Asynchronous generators or Induction Generators
    - These operate at slightly higher frequency than the network

Yaw System

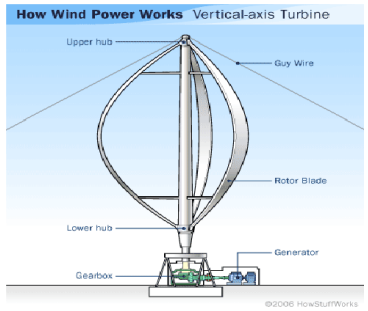
- A Horizontal Axis Wind Turbine has a yaw system that turns the nacelle according to the actual wind direction
- It uses a rotary actuator engaging on a gear ring at the top of the tower
- A slow closed loop control system is used to control the yaw drives
- A wind vane, usually mounted on the top of the nacelle, senses the relative wind direction and the wind turbine controller then operate the yaw drives



Tower

- The most common type of tower are the lattice or tubular types constructed from steel or concrete
- Smaller, cheaper towers may be supported by guy wires
- Most of the modern medium-sized and large wind turbines have tubular towers, which allow access from inside the tower to the nacelle during bad weather conditions
- The nacelle is placed on top of the tower and the yaw system allows the nacelle to turn into the wind direction
- The tower has to be mounted to a strong foundation in the ground

Vertical Axis Wind Turbine



Vertical Axis Wind Turbine

- Can accept wind from any direction, eliminating the need of yaw control
- Gearbox, generator etc. are located at the ground thus eliminating heavy nacelle at the top of the tower
- Inspection and maintenance is easier
- Overall cost is less

Vertical Axis Wind Turbine – Main Components

Tower

- Hollow vertical rotor shaft that rotates freely between top and bottom bearings
- Upper part of tower is supported by guy ropes

Blades

- It has 2 -3 curved blades shaped like an eggbeater
- As the rotor blades of a VAWT turn, they sweep a three dimensional surface as distinct from the single circular plane swept by the blades of a horizontal axis wind turbine

Different designs of Vertical Axis Wind Turbine



Speed Control Strategies for Wind Turbine

- No speed control at all. i.e. various components are designed to withstand extreme speed under gusty conditions
- Yaw and tilt control, in which rotor axis is shifted out of wind direction
- Pitch control, in which pitch of the rotor blades is controlled to regulate the speed
- Stall control, in which blades are shifted to a position such that they stall when wind speed exceeds the safe limit

Wind Turbine operation

- A wind turbine is often characterized in terms of three values of wind speeds:

a)Cut-in Wind Speed : The minimum value of wind speed at which the wind turbine start producing electricity

b)Rated Wind Speed : The wind speed at which the wind turbine produces its rated output

Even with wind speeds higher than the rated speed the output remains at rated output

c)Cut-out Wind Speed : the wind speed at which the rotor furls down and stops functioning (to safeguard the wind turbine from potential damage)

Wind Turbine operation

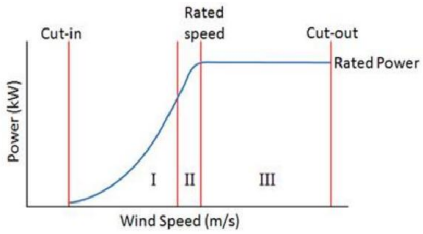
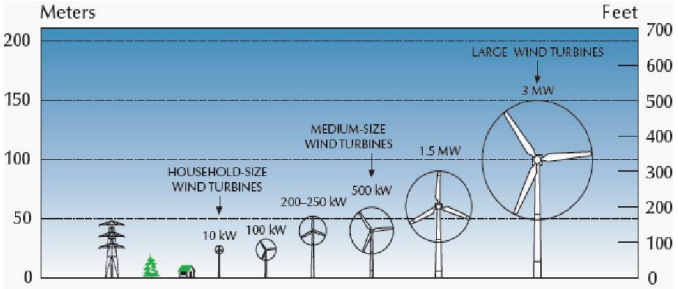


Figure 4. Ideal Wind Turbine Power Curve

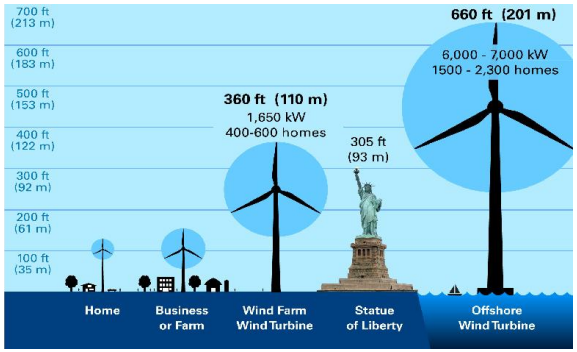
Specifications of a Wind Turbine in UK

- Rated Capacity : 1.5 MW
- Make: Enercon 66
- Rotor Diameter : 66 m
- Hub Height : 65 m
- Cut in speed : 2.5 m/s
- Rated wind speed : 13 m/s
- Annual electricity output = 3000 MWh per year

Wind Turbine Sizing



Wind Turbine Sizing



Environmental Aspects of Wind Turbines

- Indirect energy use and emissions
- Impact on birds
- Noise
  a) mechanical noise and b) aerodynamic noise
- Visual impact
- Telecommunication interference (badly affect quality of radio and TV signals)
- Evapo-transpiration (affects crop yield)
- Effect on Eco-systems
- Safety

Environmental Aspects of Wind Turbines