Unit 4:- Wind Energy

Syllabus…Unit 4

- **Wind Energy:** Wind characteristics, resource assessment, horizontal and vertical axis wind turbines, electricity generation and water pumping, Micro/Mini hydro power system, water pumping and conversion to electricity, hydraulic pump.

Books …

- Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley - IEEE

Press, August 2004.

- Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
- Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

Supplementary Reading:

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

Lecture 4

- Wind Characteristics:
- Wind Speed
- Weibull distribution & Turbulence
- Wind Gust, Wind Shear & Wind Direction
- Wind Power Curve
- Wind Power Technology
- Wind Turbine Classification:
- Horizontal Axis Wind Turbine
- Vertical Axis Wind Turbine
- Upwind Wind and Down Wind Turbines
- As per Wind Turbine Capacity
- Direct Drive and Geared Drive
- On-Grid and Off-Grid Wind Turbines
- On-Shore and Off- Shore Wind Turbines

Wind Characteristics

Wind varies with the geographical locations, time of day, season, and height above the earth's surface, weather, and local landforms. The understanding of the wind characteristics will help optimize wind turbine design, develop wind measuring techniques, and select wind farm sites

- **Wind speed**

Wind speed is a random parameter, measured wind speed data are usually dealt with using statistical methods.
The diurnal variations of average wind speeds are often described by sine waves. As an example, the diurnal variations of hourly wind speed values, which are the average values calculated based on the data between 1970 and 1984, at Dhahran.
Saudi Arabia have shown the wavy pattern

Wind Characteristics

- **Weibull distribution:**

The variation in wind speed at a particular site can be best described using the Weibull distribution function, which illustrates the probability of different mean wind speeds occurring at the site during a period of time.

- **Wind turbulence**

Wind turbulence is the fluctuation in wind speed in short time scales, especially for the horizontal velocity component. The wind speed $u (t)$ at any instant time t can be considered as having two components:

mean wind speed u– and the instantaneous speed fluctuation $u'(t)$, i.e.: $u(t)= u + u' (t)$

Wind Characteristics

- **Wind gust**

Wind gust refers to a phenomenon that a wind blasts with a sudden increase in wind speed in a relatively small interval of time. In case of sudden turbulent gusts, wind speed, turbulence, and wind shear may change drastically. Reducing rotor imbalance while maintaining the power output of wind turbine generator constant. During such sudden turbulent gusts calls for relatively rapid changes of the pitch angle of the blades.

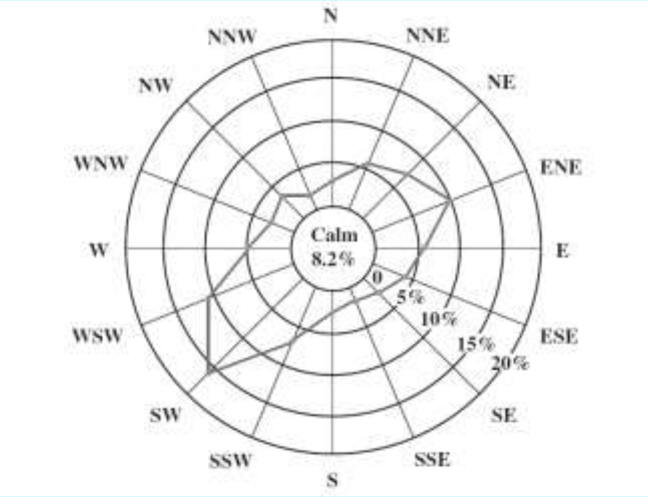
- **Wind shear**

Wind shear is a meteorological phenomenon in which wind increases with the height above the ground. The effect of height on the wind speed is mainly due to roughness on the earth's surface and can be estimated using the Hellmann power equation that relates wind speeds at two different heights

Wind Characteristics

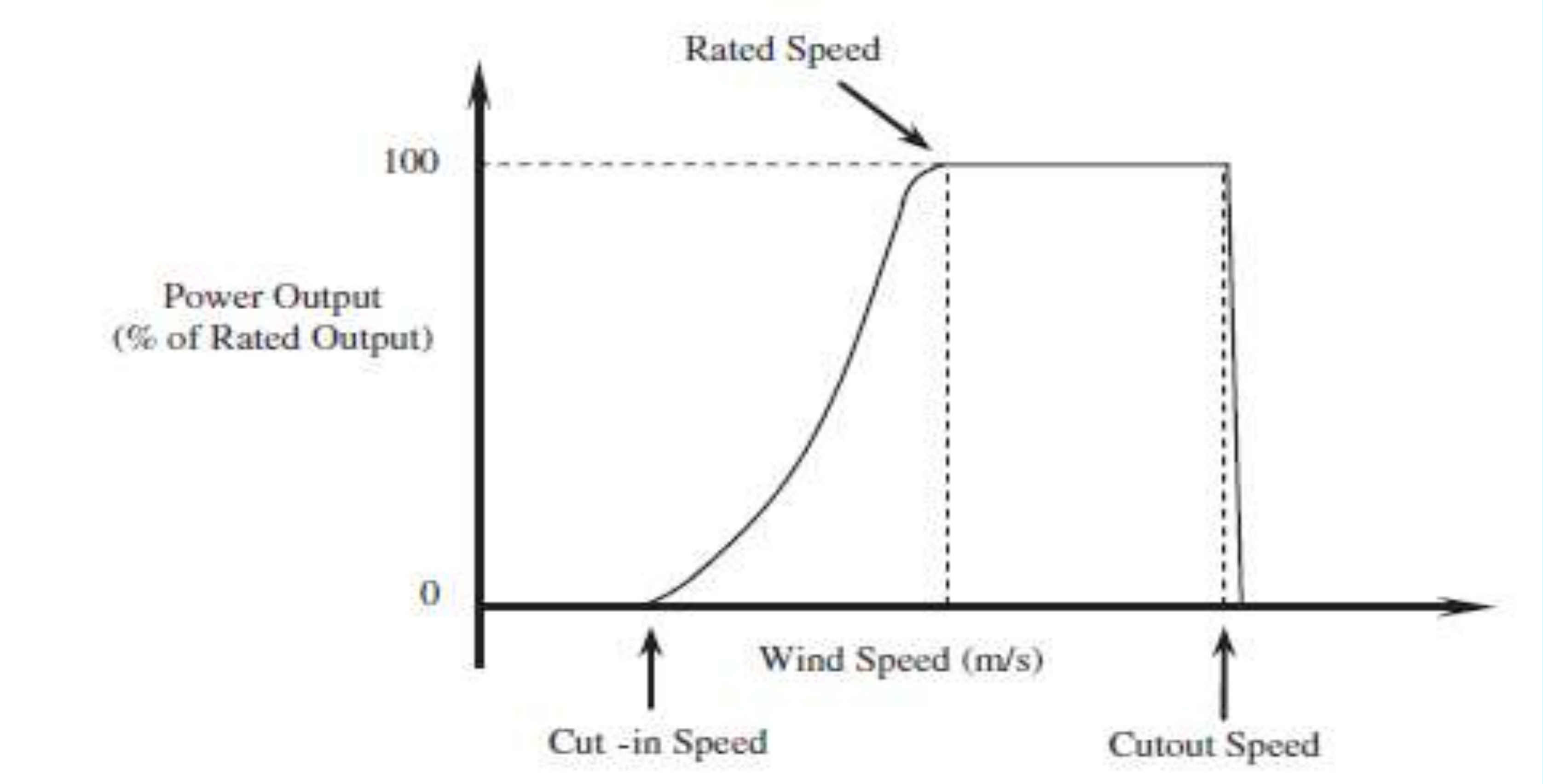
- **Wind direction**

Wind direction is one of the wind characteristics. Statistical data of wind directions over a long period of time is very important in the site selection of wind farm and the layout of wind turbines in the wind farm. The wind rose diagram is a useful tool of analyzing wind data that are related to wind directions at a particular location over a specific time period (year, season, month, week, etc.)



Wind Power Curve

The power curve of a wind turbine displays the power output (either the real electrical power output or the percentage of the rated power) of the turbine as a function of the mean wind speed.



Wind Power Curve

- The wind turbine starts to produce power at a low wind speed, called *cut-in speed*.
- The power output increases continuously with the increase of the wind speed until reaching a saturated point and reaches its maximum value called as *Rated Power Output.*
- The speed at this point is Called *Rated Speed*.
- Above this speed will not increase the power output due to the activation of the power control.
- When the wind speed becomes too large to potentially damage the wind turbine, This wind speed is defined as the cut-out speed

Wind Power Technology

Turbines

• Almost all electrical power on Earth is produced with a turbine of some type. It is converting rectilinear flow motion to shaft rotation through rotating airfoils

	Type of Generation	Combustion Type	Turbine Type Gas	Steam	Water	Aero	Primay Power	Electrical Conversion
3	Traditional Boiler	External		•			Shaft	Generator
3	Fluidized Bed	External		•			Shaft	Generator
	Combustion						–	–
	Integrated Gasification	Both	•	•			Shaft	Generator
	Combined-Cycle						–	–
	Combustion Turbine	Internal	•				Shaft	Generator
	Combined Cycle	Both	•	•			Shaft	Generator
3	Nuclear			•			Shaft	Generator
	Diesel Genset	Internal					Shaft	Generator
	Micro-Turbines	Internal	•				Shaft	Generator
	Fuel Cells						Direct	Inverter
	Hydropower				•		Shaft	Generator
3	Biomass & WTE	External		•			Shaft	Generator
	Windpower					•	Shaft	Generator
	Photovoltaics						Direct	Inverter
3	Solar Thermal			•			Shaft	Generator
3	Geothermal			•			Shaft	Generator
	Wave Power		•				Shaft	Generator
	Tidal Power				•		Shaft	Generator
3	Ocean Thermal			•			Shaft	Generator

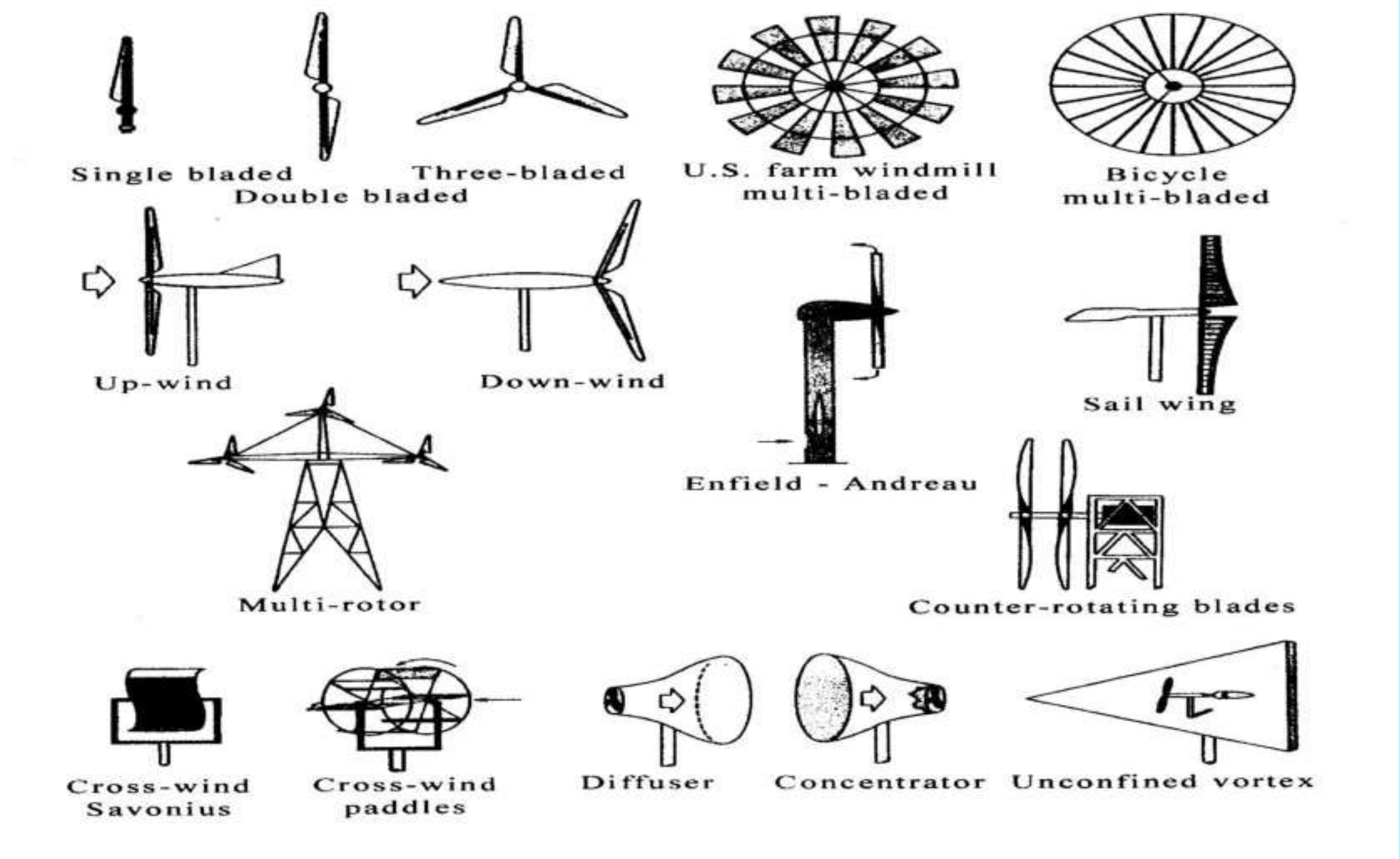
Wind Turbine Classification :Horizontal-axis

Wind turbines can be classified according to the turbine generator configuration, airflow path relatively to the turbine rotor, turbine capacity, the generator-driving pattern, the power supply mode, and the location of turbine installation.

- **Horizontal-axis Wind Turbines**

- Most commercial wind turbines today belong to the *Horizontal-axis type*, in which the rotating axis of blades is parallel to the wind stream.
- The advantages of this type of wind turbines include the high turbine efficiency, high power density, low cut-in wind speeds, and low cost per unit power output.

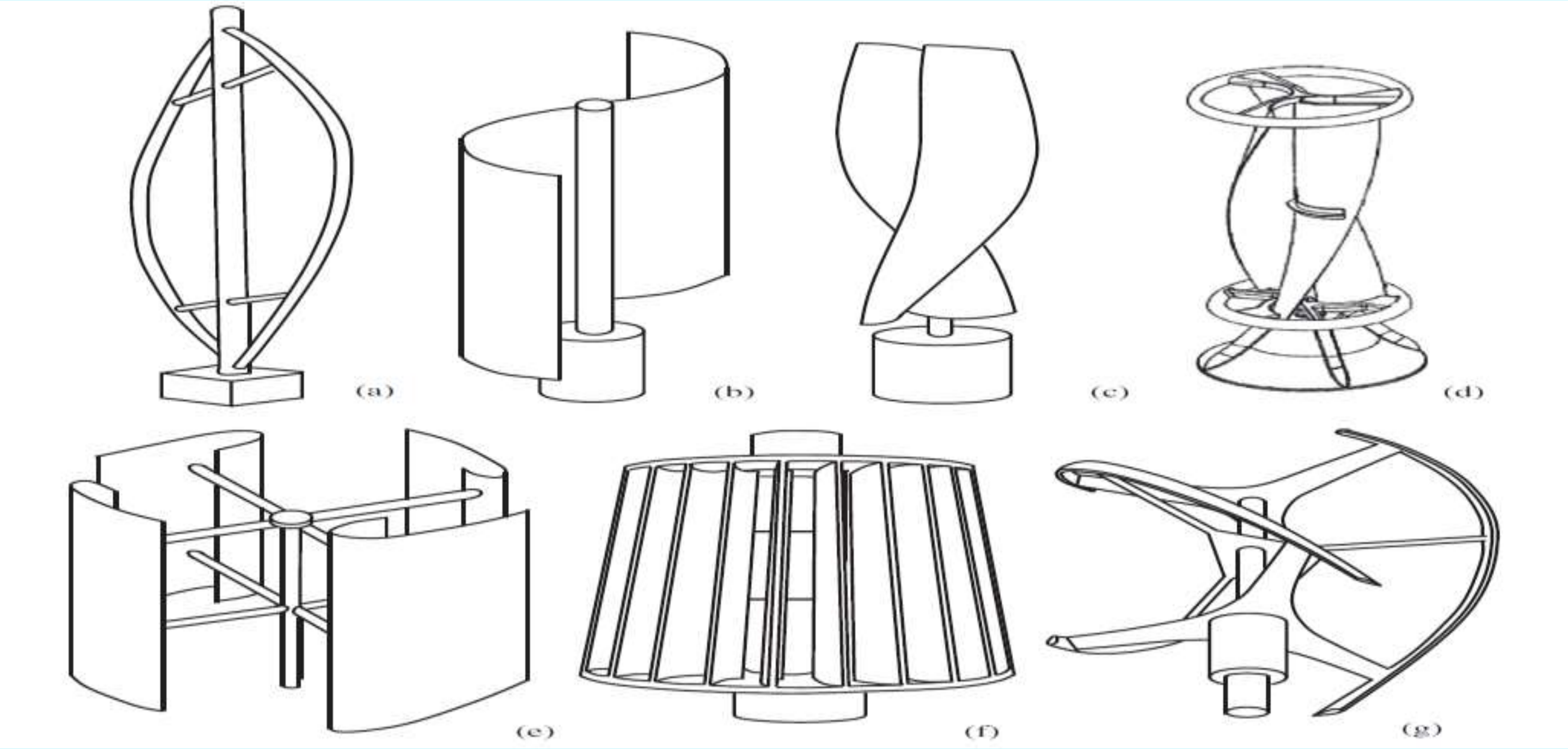
Horizontal-axis Wind Turbines



Vertical-axis Wind Turbine

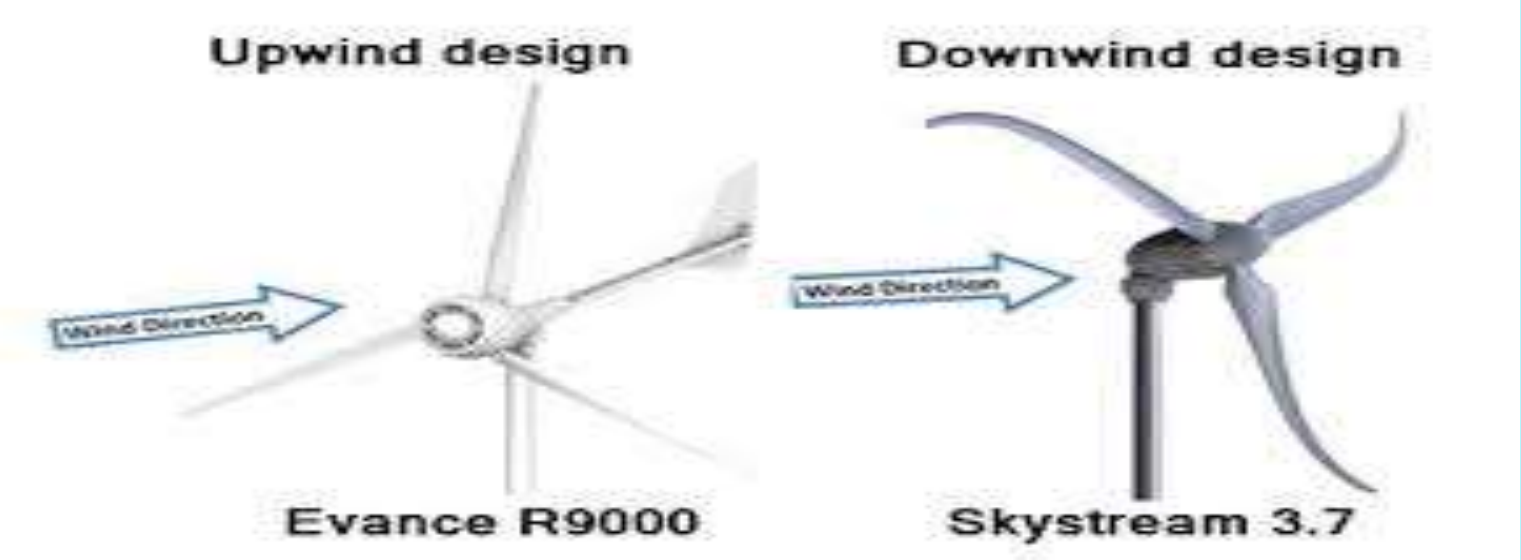
- The blades of the vertical-axis wind turbines are perpendicular to the ground.
- A significant advantage of vertical-axis wind turbine is that the turbine can accept wind from any direction and thus no yaw control is needed.
- The wind generator, gearbox, and other main turbine components can be set up on the ground, hence simplifies the tower design. And hence reduces the turbine cost.
- However, these turbines uses an external energy source to rotate the blades during initialization. Because the axis of the wind turbine is supported only on one end at the ground.
- Its also reduces maximum practical height of turbine.
- Due to the lower wind power efficiency, vertical-axis wind turbines today make up only a small percentage of usage.

Vertical-axis wind turbines



Several typical types of vertical-axis wind turbines:
(a) Darrius (b) Savonius (c) Solarwind (d) Helical (e) Noguchi (f) Maglev (g) Cochrane

Upwind and Downwind Wind Turbines



Upwind and Downwind Wind Turbines

- Based on the configuration of the wind rotor with respect to the wind flowing direction, the horizontal-axis wind turbines can be further classified as upwind and downwind wind turbines
- The majority of horizontal-axis wind turbines being used today are ***Upwind Turbines***, in which the wind rotors face the wind.
- The main advantage of upwind designs is to avoid the distortion of the flow field as the wind passes though the wind tower and nacelle.
- For a ***Downwind Turbine***, wind blows first through the nacelle and tower and then the rotor blades. In this type the rotor blades are made more flexible without considering tower strike.
- However, due to distorted unstable wakes behind the tower and nacelle, the power output fluctuates and greatly unstable, have more aerodynamic losses and more fatigue loads on the turbine. The blades may produce higher impulsive or thumping noise .

Wind Turbines Capacity

Wind turbines can be divided as per their rated capacities:
Micro, Small, Medium, Large, And Ultra-large Wind Turbines

Turbine Type	Output Power Capacity	Remarks
Micro Turbines	Less than several KWs	For Non grid Application Can be used on a per-structure basis, such as street lighting
Small Turbines	Less than 100 kW	extensively used at residential houses, farms, and other individual remote applications
Medium Turbines	100KW to 1MW	Either on-grid or off-grid systems, for villages, hybrid systems and distributed power etc.
Large wind turbines	Up to 10 MW	Most wind farms, especially in offshore wind farms
Ultra-large wind turbines	More than 10 MW	Still in the earlier stages of research and development

Direct Drive And Geared Drive Wind Turbines

Direct Drive Wind Turbines

- The generator shaft is directly connected to the blade rotor
- The direct-drive concept is more superior in terms of energy efficiency, reliability, and design simplicity.

Geared Drive Wind Turbines

- To increase the generator speed to gain a higher power output, a regular geared drive wind turbine typically uses a multi-stage gearbox. It changes speed from the low-speed shaft of the blade rotor into the high-speed shaft of the generator rotor.
- The **advantages** of geared generator systems include lower cost and smaller size and weight.
- The **disadvantage** of a gearbox is significantly lower wind turbine reliability and increase turbine noise and mechanical losses.

On-Grid and Off-Grid Wind Turbines

- Wind turbines can be used for either on-grid or off-grid applications
- Most medium-size and almost all large-size wind turbines are used in grid tied applications.
- The main advantages for on-grid wind turbine systems is that there is no energy storage problem
- Most of small wind turbines are off-grid for residential homes, farms, telecommunications, and other applications
- off-grid wind turbines are usually used in connection with batteries, diesel generators, and photovoltaic systems for improving the stability of wind power supply

Onshore and Offshore Wind Turbines

Onshore and Offshore Wind Turbines

- ***Onshore Turbines*** have a number of advantages including lower cost of foundations, easier integration with the electrical-grid network, lower cost in tower building and turbine installation, and more convenient access for operation and maintenance

- ***Offshore Turbines*** have developed faster than onshore since the 1990s due to the excellent offshore wind resource, in terms of wind power intensity and continuity.
- A wind turbine installed offshore can make higher power output and operate more hours each year compared with the same turbine installed onshore
- Environmental restrictions are more lax at offshore sites than at onshore sites. Turbine noise is never an issue for offshore wind turbines

Thank You