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:

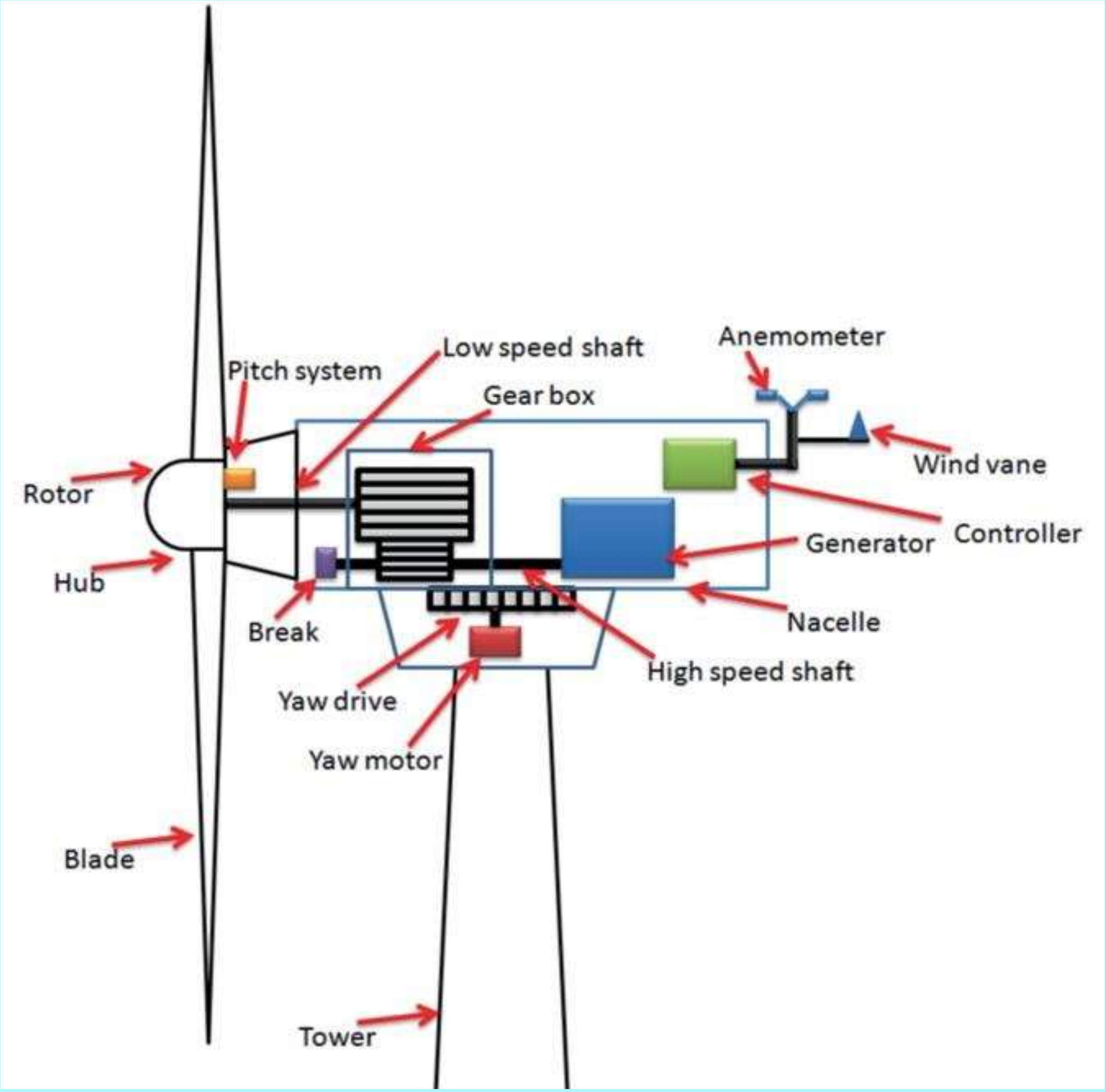
- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

Lecture 5

- Components of Wind turbine
- Wind Turbine Subsystems
- Functions Of Subsystems
- Turbines Parts
- Rotor Design Methodology
- Blade Type and Wind Turbines Efficiency
- Pitch Control Wind Turbine
- Stall & Yaw Control
- Wind Energy Storage
- Wind Turbine Generation System
- Electrical Generators
- Squirrel Cage Asynchronous Induction Generator
- Wound Type Asynchronous Induction Generator
- Doubly Fed Induction Generator
- HTS Wind Generator

Components of Wind Turbine

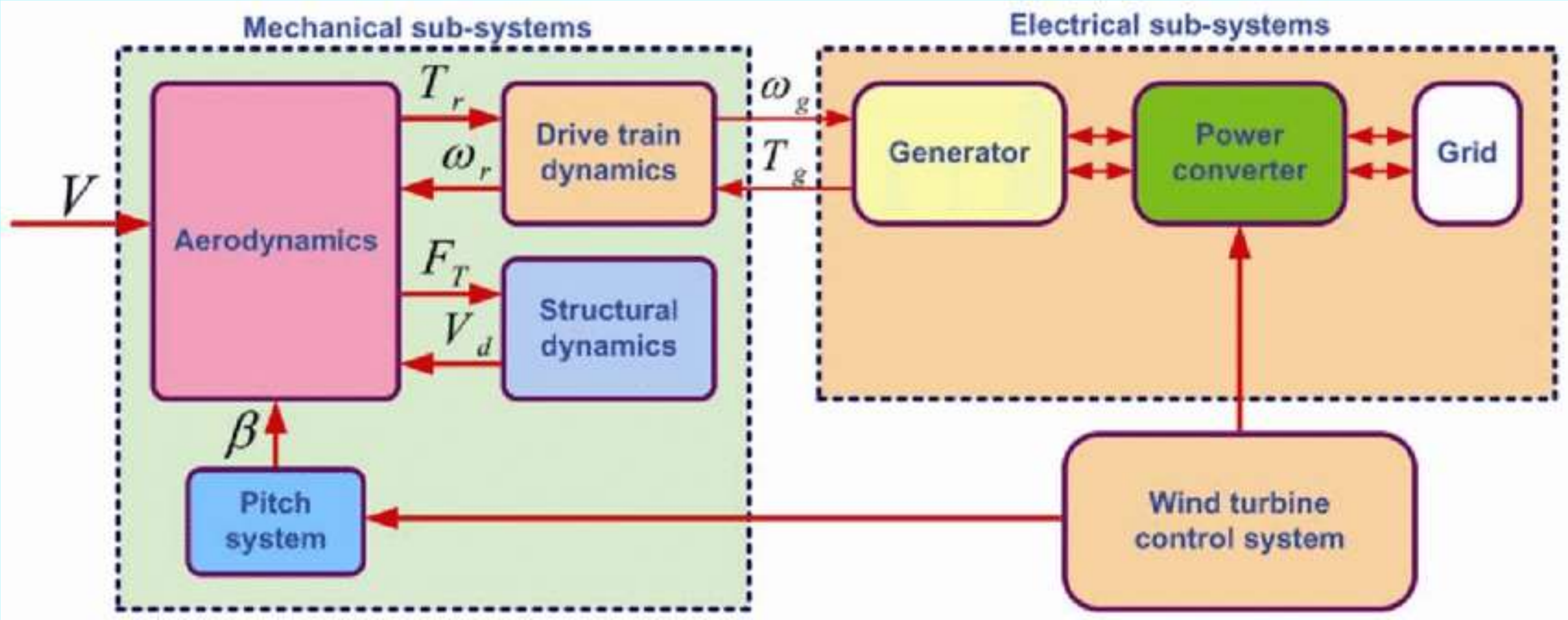
- Foundation, Tower
- Nacelle,
- Hub & Rotor
- Drivetrain
- Gearbox
- Generator
- Electronics & Controls
- Yaw
- Pitch
- Braking
- Power Electronics
- Cooling
- Diagnostics



Wind Turbine Subsystems

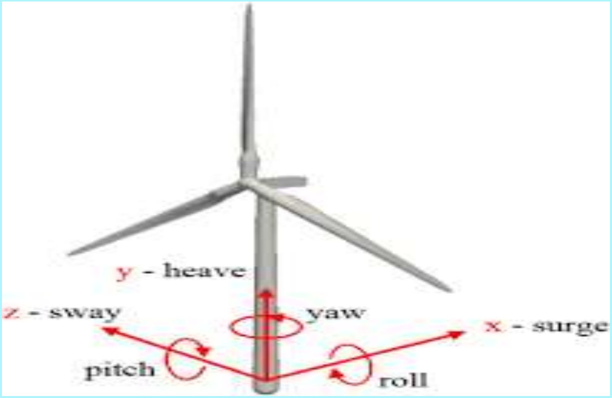
Mechanical Sub-systems: The mechanical sub-systems contain 1) the wind turbine rotor, 2) the drive train, 3) the nacelle structure, and 4) the tower.

Electrical Sub-Systems: The electrical sub-systems contain 1) the generator and 2) power electronic converter.

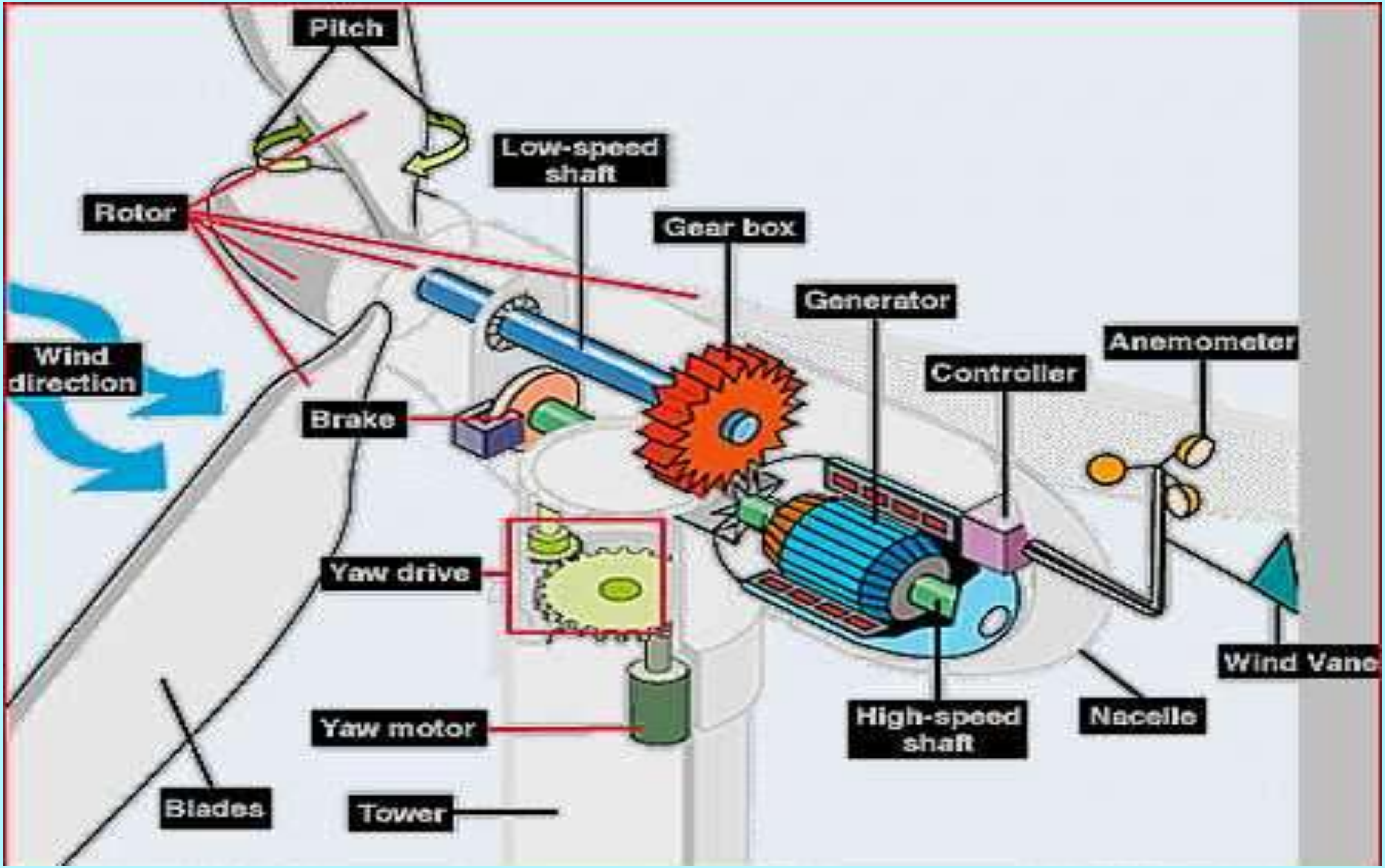


Functions of Subsystems

System	Function
Yaw	Track incoming wind direction
Pitch	Control blade position
Drivetrain	Shift torque and speed characteristic
Generator	Convert from mechanical to electrical energy
Power system interconnection	Interface generator with load or power grid
SCADA	Monitor performance, control set-points, human interface

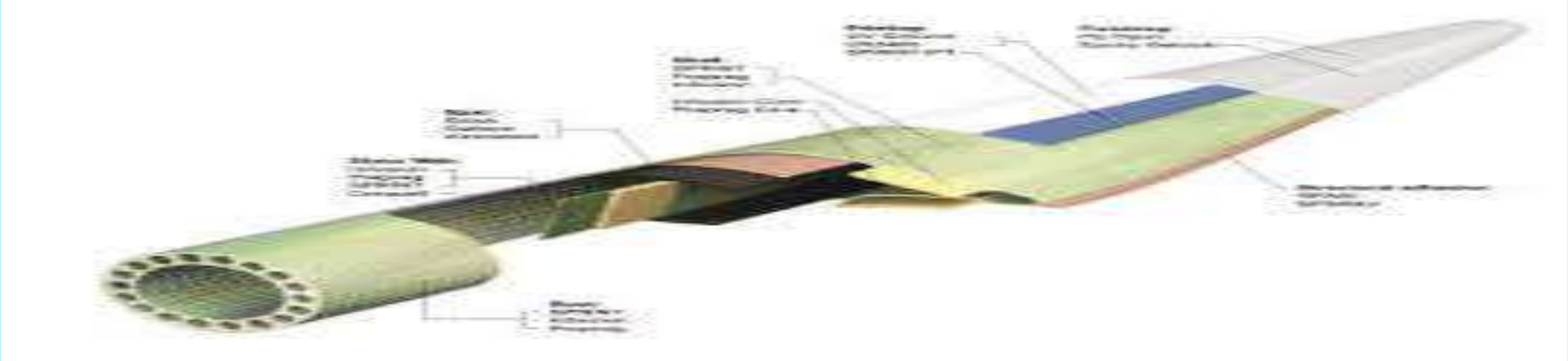


Turbine Parts

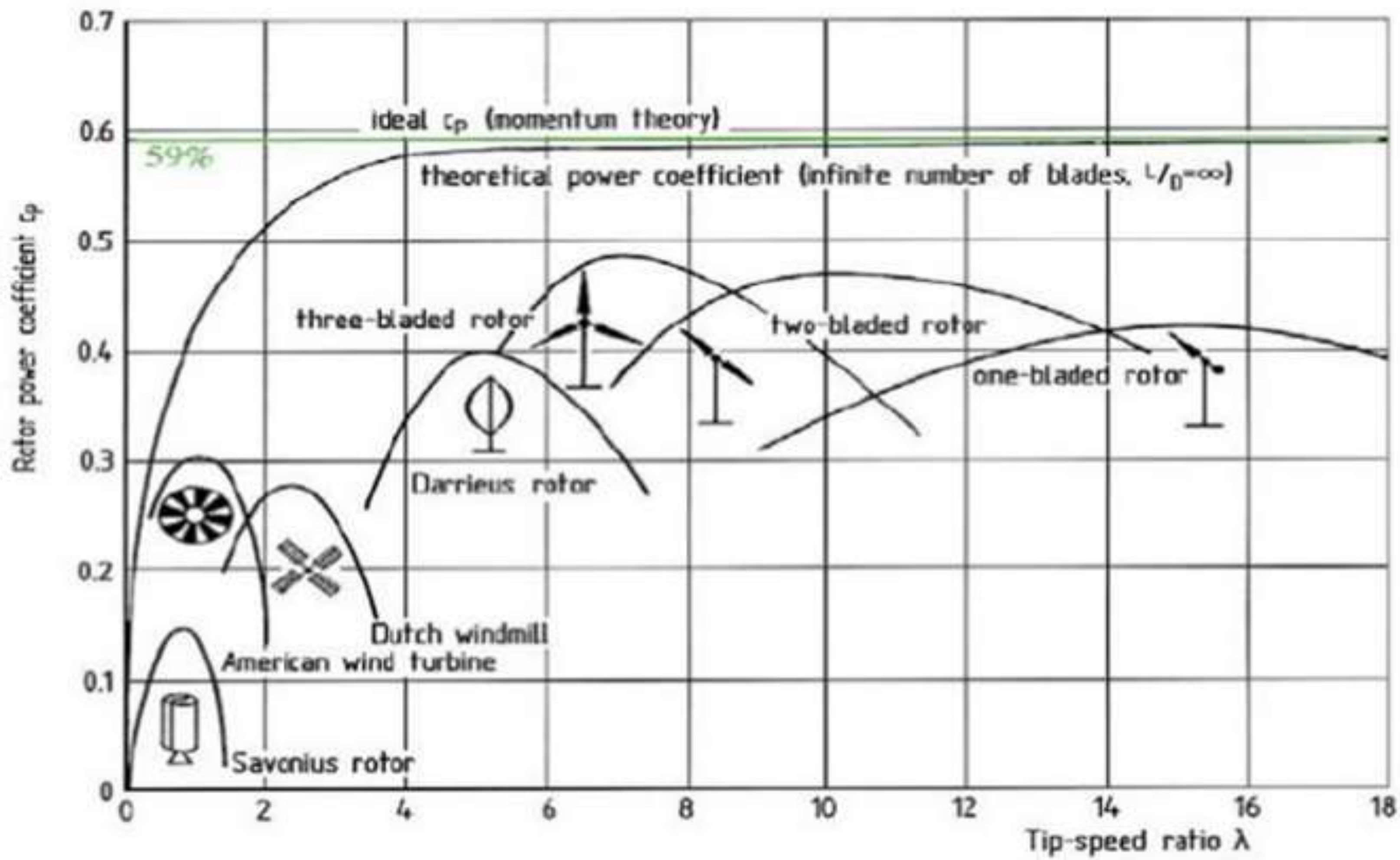


Rotor Design Methodology

1. Determine basic configuration: orientation and blade number
2. Take site wind speed and desired power output
3. Calculate rotor diameter (accounting for efficiency losses)
4. Select tip-speed ratio (if higher more complex airfoils, noise) and blade number (higher efficiency with more blades)
5. Design blade including angle of attack, lift and drag characteristics
6. Combine with theory or empirical methods to determine optimum blade shape



Blade Type and Wind Turbines Efficiency



Coefficient of Performance (efficiency) of wind rotors of various designs

Pitch Control Wind Turbines

- The pitch control system is important because it not only continually regulates the wind turbine's blade but also controls pitch angle to enhance the efficiency of wind energy conversion and power generation stability. It also serves as the security system in case of high wind speeds or emergency situations.
- It requires that even in the event of grid power failure, the rotor blades can be still driven into their feathered positions by using either the power of backup batteries or capacitors.

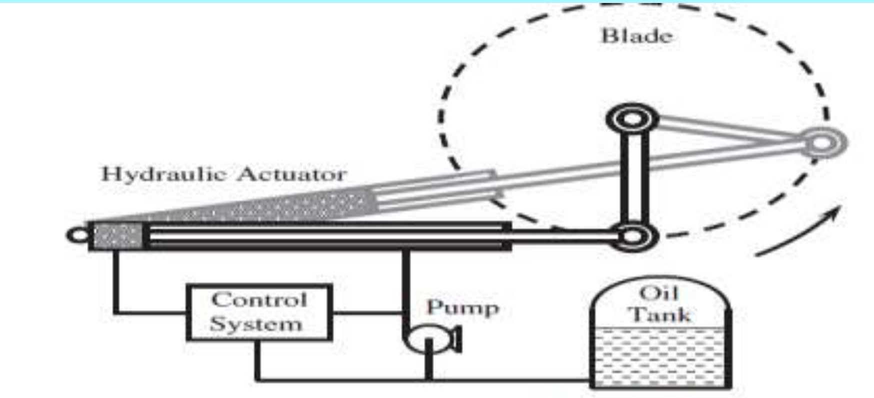


Figure 11: Hydraulic pitch control system.

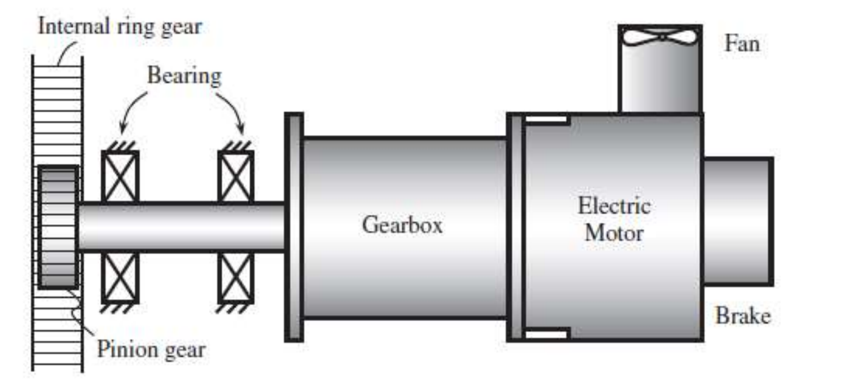


Figure 12: Electric pitch control system.

Pitch Control Wind Turbines

- Early techniques of active blade pitch control applied hydraulic actuators to control all blades together.
- However, these collective pitch control techniques could not completely satisfy all requirements of blade pitch angle regulation, especially for MW wind turbines with the increase in blade length and hub height.
- More superior individual blade pitch control techniques have been developed and implemented, allowing control of asymmetric aerodynamic loads on the blades, as well as structural loads in the non-rotating frame such as tower side-side bending. In such a control system, each blade is equipped with its own pitch actuator, sensors and controller.

Stall Control & Yaw control

Stall control

Besides pitch control, stall control is another approach for controlling and protecting wind turbines. The concept of stall control is that the power is regulated through stalling the blades after rated speed is achieved.

Yaw control

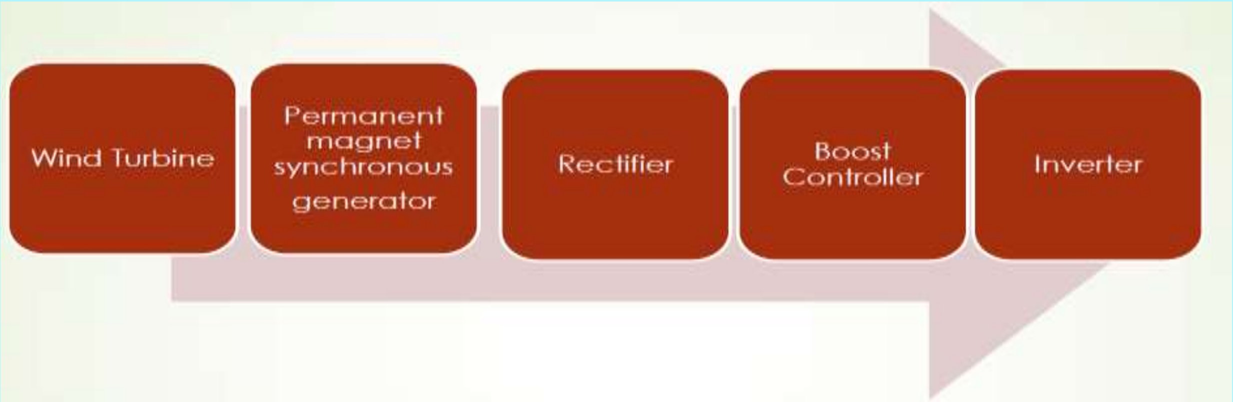
In order to maximize the wind power output and minimize the asymmetric loads acting on the rotor blades and the tower, a horizontal-axis wind turbine must be oriented with rotor against the wind by using an active yaw control system

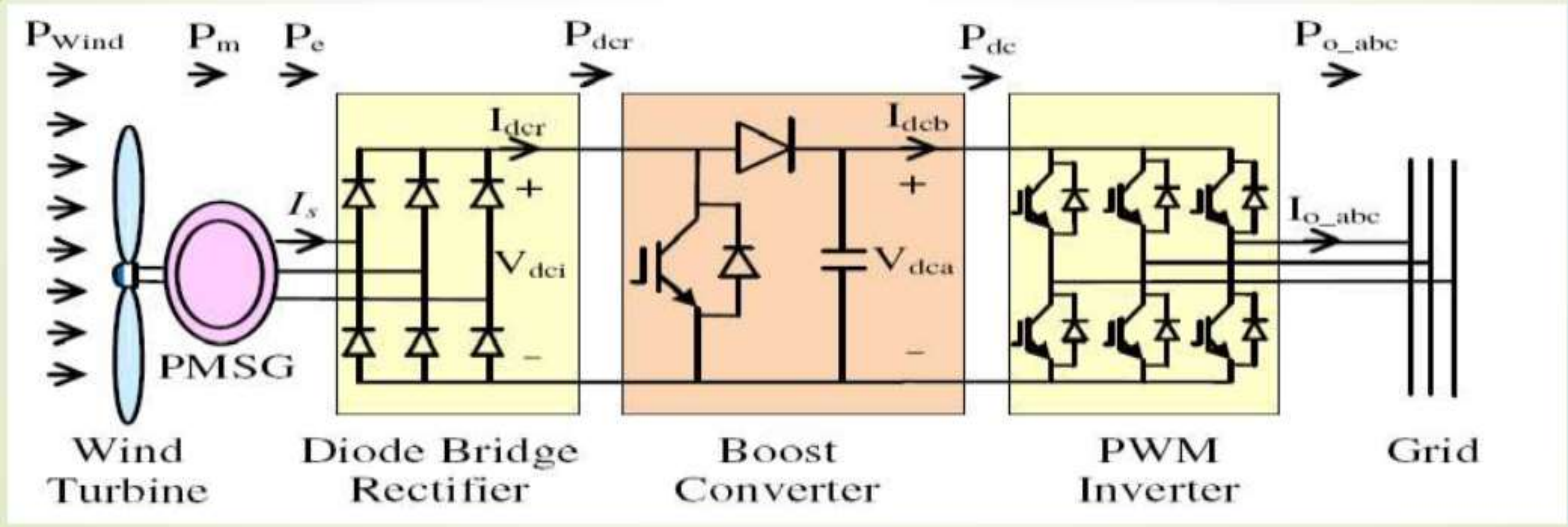
Wind Energy Storage

Today developing advanced, cost-effective storage technologies of electric energy still remains a challenge, which may limit the widespread application of wind energy. The technologies to convert wind energy into various forms of energies are

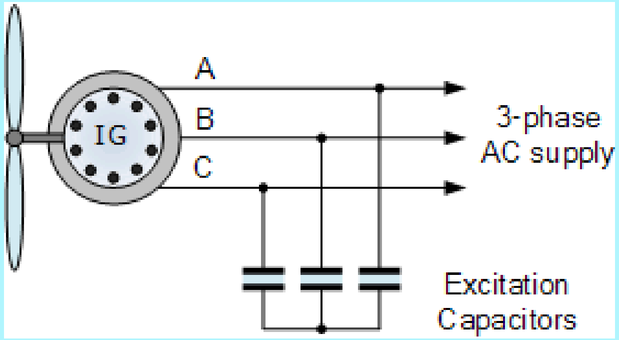
- Electrochemical energy in batteries and super capacitors
- Magnetic energy in superconducting magnetic energy storage (SMES)
- Kinetic energy in rotating flywheels
- Potential energy in pumped water at higher altitudes
- Mechanical energy in compressed air in vast geologic vaults
- Hydrogen energy by decomposing water

Wind Turbine Generation System





Wind Energy Electrical Generators

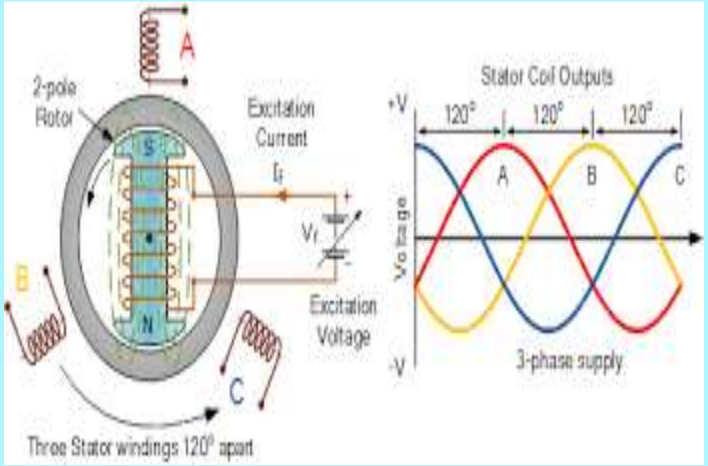


- Asynchronous Induction Generator
- Double Fed Induction Generator (DFIG)

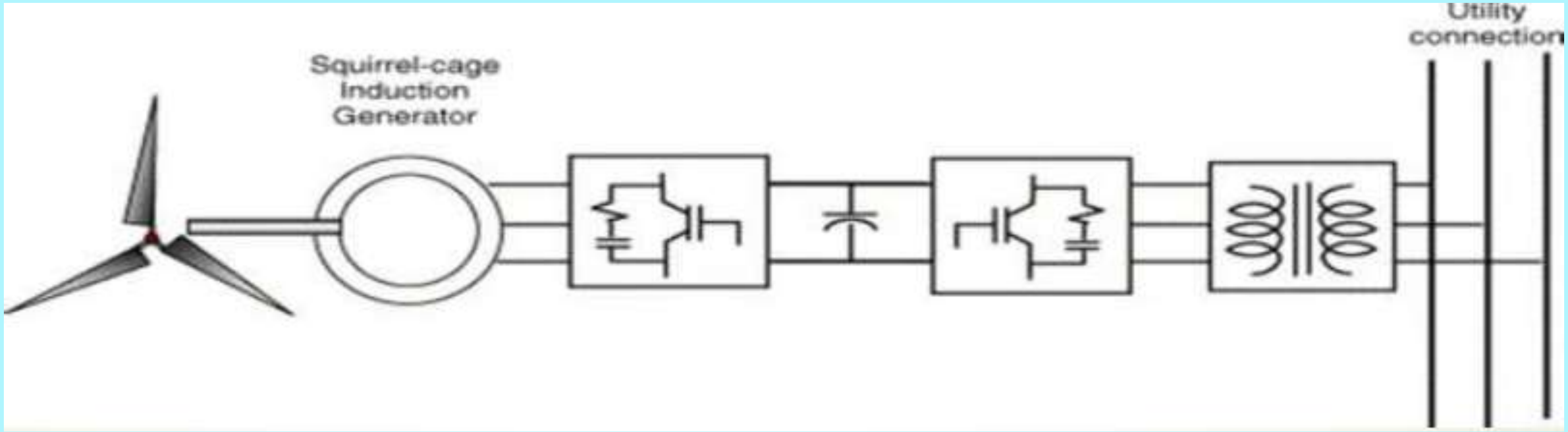
  Used for modern Large Wind Turbines

- Synchronize Generator
- Permanent magnet Generator

  Used for Small Wind Turbines

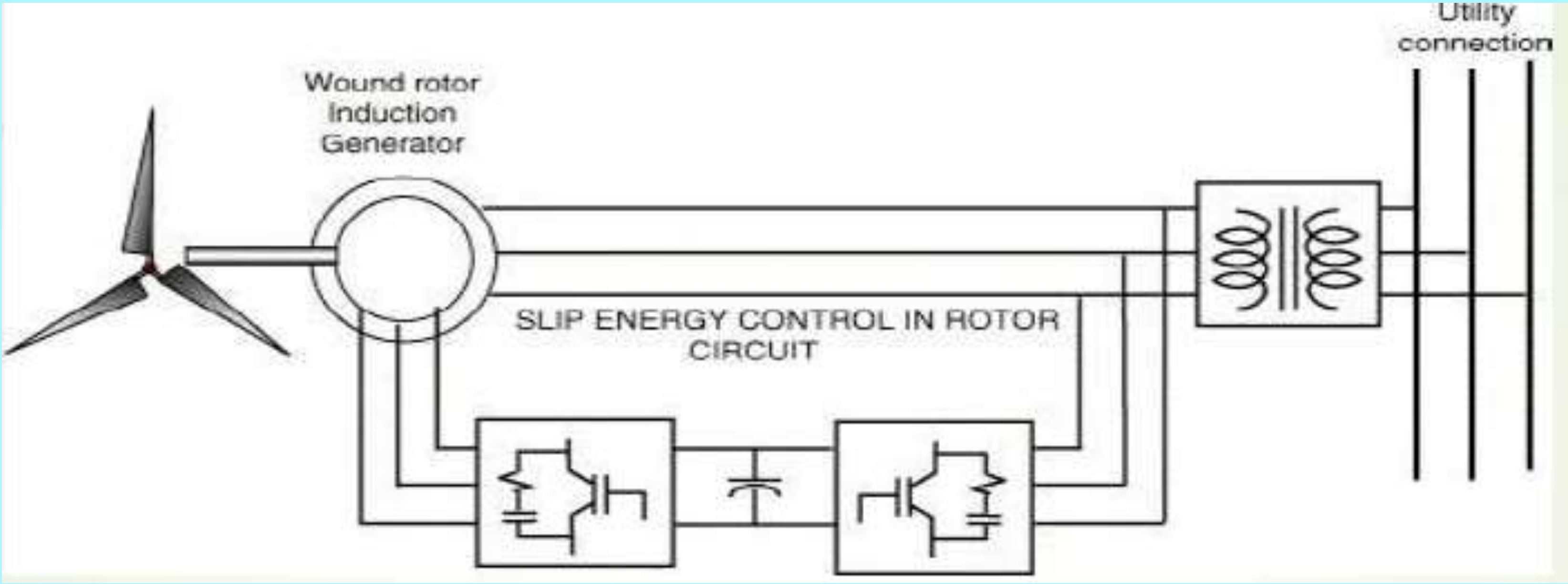


Squirrel Cage Induction Generators



- Stator of the SCIG is connected to grid through back to back power electronic converter bridges
- **Advantages**
  - To make best use of wind energy available
  - No need of capacitor bank
- **Disadvantage**
  - Expensive

Wound Rotor Induction Generators



Power Convertor size reduced by using it on rotor side of WRIG

- This is variable speed system using a wound rotor generator
- The power converter is now connected between the rotor and grid , so it needs to carry only the slip power.

Wound Rotor Induction Generators

Advantages

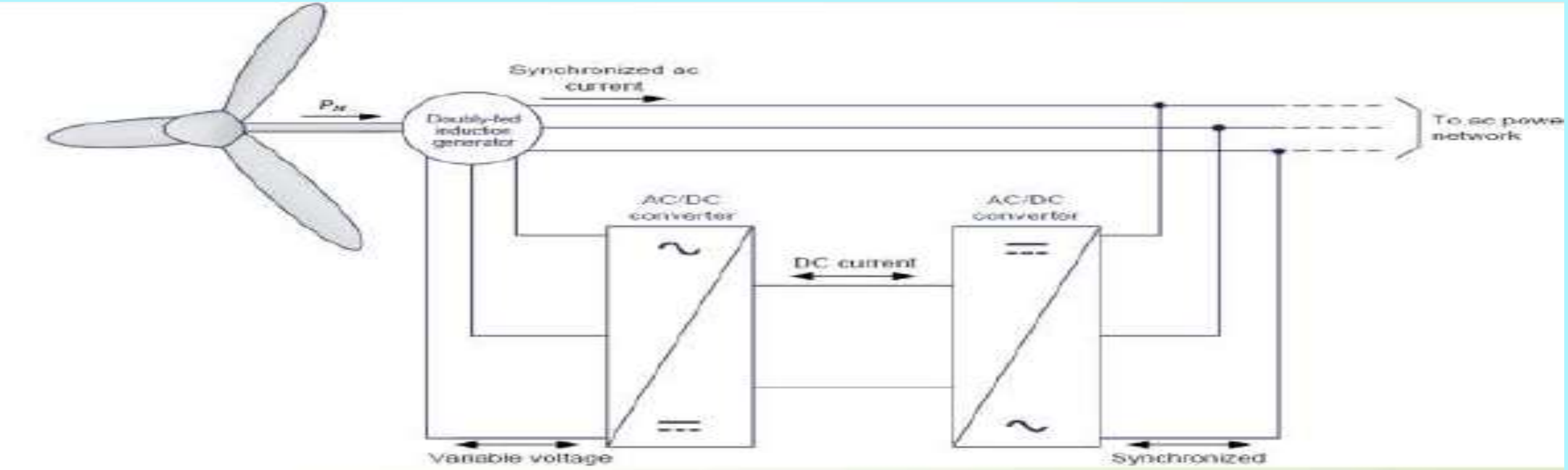
- For utility scale wind power generation it outweighs squirrel cage machine.
- Offers a lot of flexibility for wide range of speed control
- Used in high power applications in which a large amount of slip power could be recovered
- Speed of WRIM was changed by mechanically varying external rotor circuit resistance(simplest way)

Disadvantage

- This system is having low efficiency due to additional

loses in resistor connected in the rotor circuit.

Doubly Fed Induction Generators



Two power converter bridges connected back-to-back by means of a dc link can accommodate the bidirectional rotor power flow.

 The purpose of the grid side converter is to maintain the dc link voltage constant.

 It has control over the active and reactive power transfer between the rotor and the grid.

 The rotor side converter is responsible for control of the flux, and thus, the stator active and reactive powers .

Doubly Fed Induction Generators

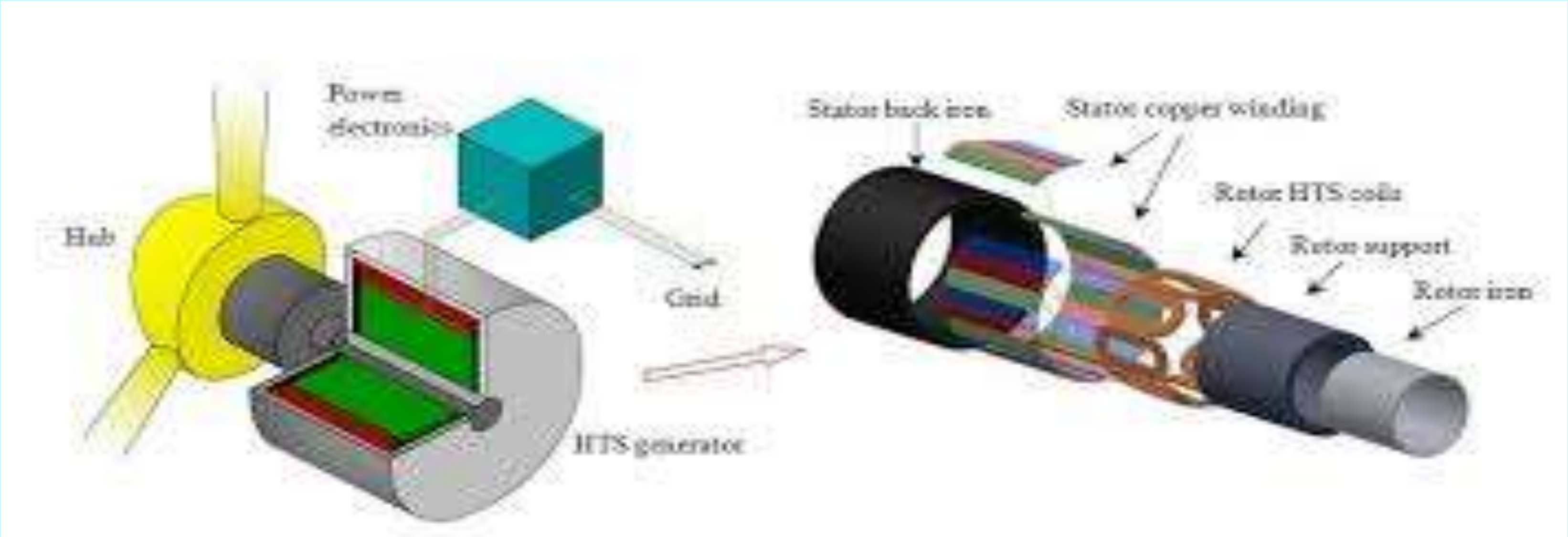
Advantages

- Operation at variable rotor speed while the amplitude and frequency of the generated voltages remain constant.
- Optimization of the amount of power generated as a function of the wind available up to the nominal output power of the wind turbine generator.
- Virtual elimination of sudden variations in the rotor torque and generator output power.
- Generation of electrical power at lower wind speeds.

Disadvantages

- Control of the power factor (e.g., in order to maintain the power factor at unity).
- Complicated and High Maintenance

HTS Wind Generators
(High Temperature Superconductivity)



- Homopolar HTSG
- Axial Bipolar HTSG
- Bipolar Linear HTSG
- Transversal Flux HTSG

HTS Wind Generators (High Temperature Superconductivity)

Advantages

- Increase machine efficiency beyond 99%, reducing losses by as much as 50% over conventional generators
- Energy savings
- Reduced pollution per unit of energy produced
- Lower life-cycle costs
- Enhanced grid stability
- Reduced capital cost
- Reduced installation expenses

Thank You