Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

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ELECTRICAL AND ELCTRONICS ENGINEERING

IVth YEAR / VIIIth SEMESTER

EE6009 – POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

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UNIT 04 – Analysis of Wind and PV Systems

How far that little candle throws his beams! So shines a good deed in a weary world.

--William Shakespeare

UNIT-4

- Stand alone operation of fixed and variable speed wind energy conversion systems and solar system
- Grid connection Issues
- Grid integrated PMSG, SCIG Based WECS
- grid Integrated solar system

Introduction to wind turbine

- Wind turbines are manufactured in a wide range of vertical and horizontal axis types.

- ***Smallest wind turbine :*** used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs.

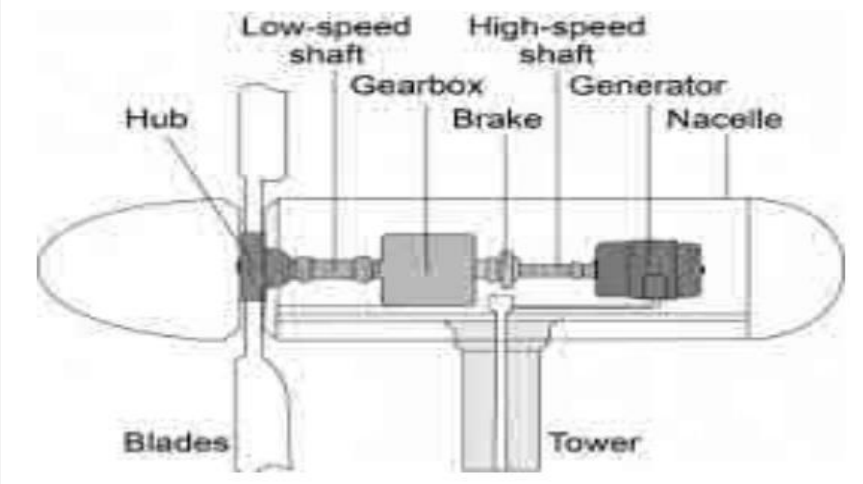
- ***Slightly larger turbine:*** used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.

- ***Large turbine:*** known as wind farms, are becoming an increasingly important source of intermittent renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

Types of wind turbine

- Horizontal axis wind turbine(HAWT)
- Vertical axis wind turbine(VAWT)

Horizontal axis wind turbine



- Horizontal axis wind turbines, also shortened to HAWT, has a similar design to a windmill; it has blades that look like a propeller that spin on the horizontal axis.

- Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind.

- Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind.

Advantages

- The tall tower base allows access to stronger wind in sites with wind shear.
- High efficiency since the blades always moves perpendicularly to the wind, receiving power through the whole rotation.
- In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle.

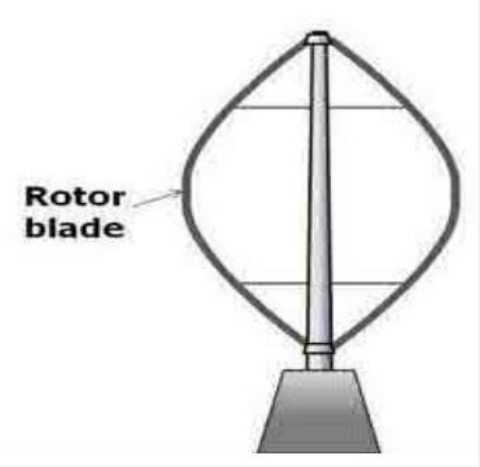
Disadvantages

- Massive tower construction is required to support the heavy blades, gearbox, and generator.
- Their height makes them obtrusively visible across large areas, disrupting the appearance of the landscape and sometimes creating local opposition.

Vertical Axis Wind Turbine

Vertical axis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically.

With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier.



The wind speed is slower at a lower altitude so less wind energy is available for a given size turbine.

The main drawback of a VAWT generally creates drag when rotating into the wind.

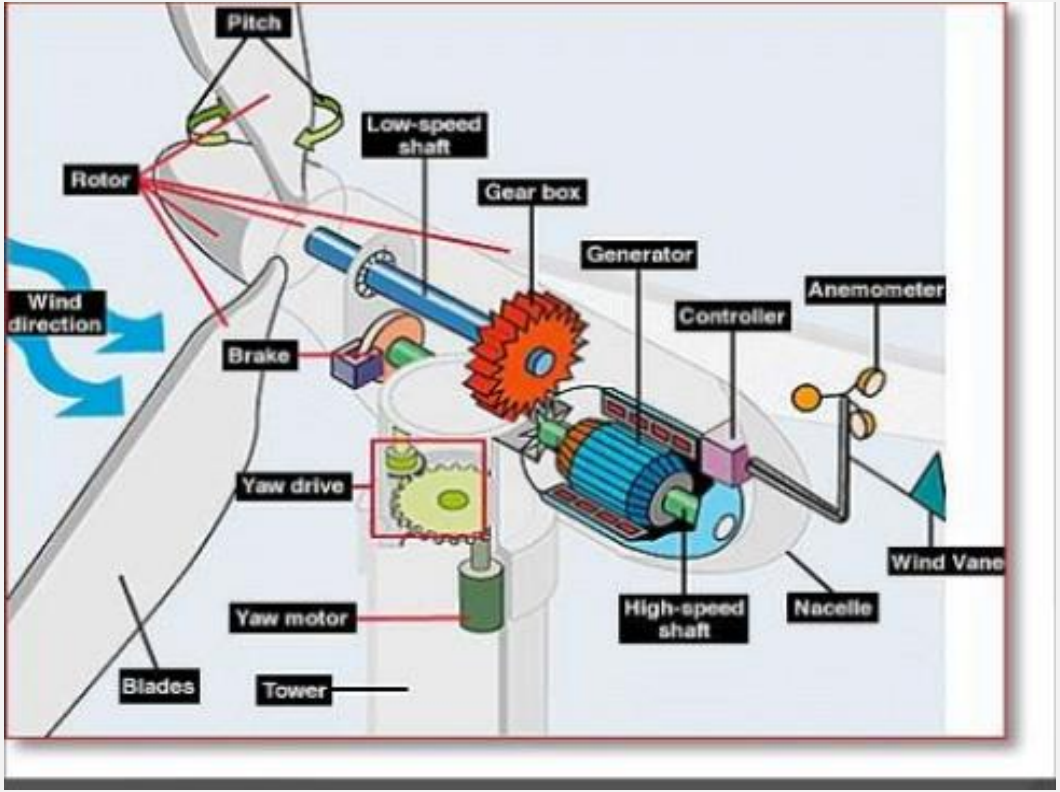
Advantages

- No yaw mechanisms are needed.
- VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.
- VAWTs have lower wind startup speeds than the typical the HAWTs

Disadvantages

- Having rotors located close to the grounds where wind speeds are lower and do not take advantage of higher wind speeds above.
- Most VAWTs have an average decreased efficiency from a common HAWT, mainly because of the additional drag that they have as their blades rotate into the wind.

Components of wind Turbine



Mechanical Components

- Tower
- Blades
- Hub
- Nacelle
- Generator
- Turbine brake
- Gearbox
- Yaw motor and drive
- Wind vane and Anemometer
- controller

Tower

The tower supports the other parts and holds them in the air. Thus, it must be structurally strong to withstand the weights of the components.

Blades

Blades are the parts of a wind turbine that catch the wind energy. Lift forces in the three blades give rise to a torque on the hub.

Hub

The hub is that part on which the blades are fitted and this hub is attached with the low speed shaft which is connected with gearbox.

Nacelle

The intermediate part between the rotor and the tower is the nacelle. It is a cover housing that houses all of the generating components in a wind turbine including the generator, gearbox, drive train and brake assembly.

Generator

An electric generator converts mechanical energy to electrical energy .It comes in different size which proportional to power.

Turbine brake

Brake is used to stop the turbine in emergency situation such as extreme gust events or over speed. It is a secondary means to hold the turbine at rest for maintenance.

Gear box

It converts the low speed shaft of rotor to a high speed shaft connected to generator. It made up of cast steel with one planetary two spur gear stages.

Yaw motor and drive

The yaw system of wind turbines is the component responsible for the orientation of the wind turbine rotor towards the wind.

Wind vane & Anemometer

An anemometer is used to measure the speed of wind

Wind vane is use to know the direction of air.

Controller

It is electronic device which take the signals from the anemometer and wind vane. On the base of these signals it give power to the yaw control motors and pitch control system.

Aerodynamic on airfoil

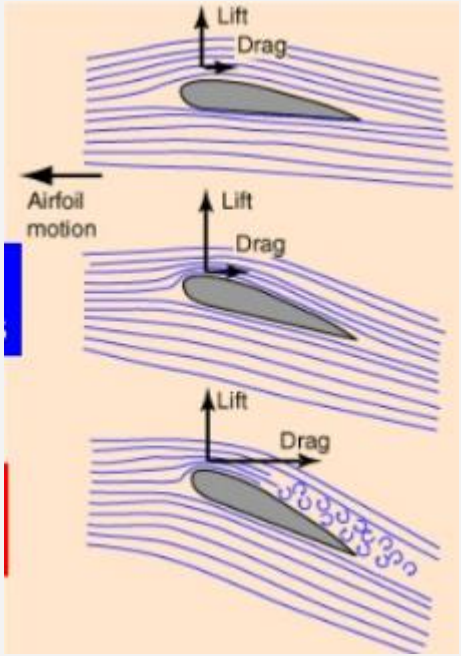
- Drag force
- Lift force

Lift force

The Lift force is perpendicular to the Direction of motion**.** When an object place In the wind mill it experiences forces on The body.

Drag force

The drag force is parallel to the parallel to The direction of motion. The force created Due to pressure difference between upper And lower surface of the blade.

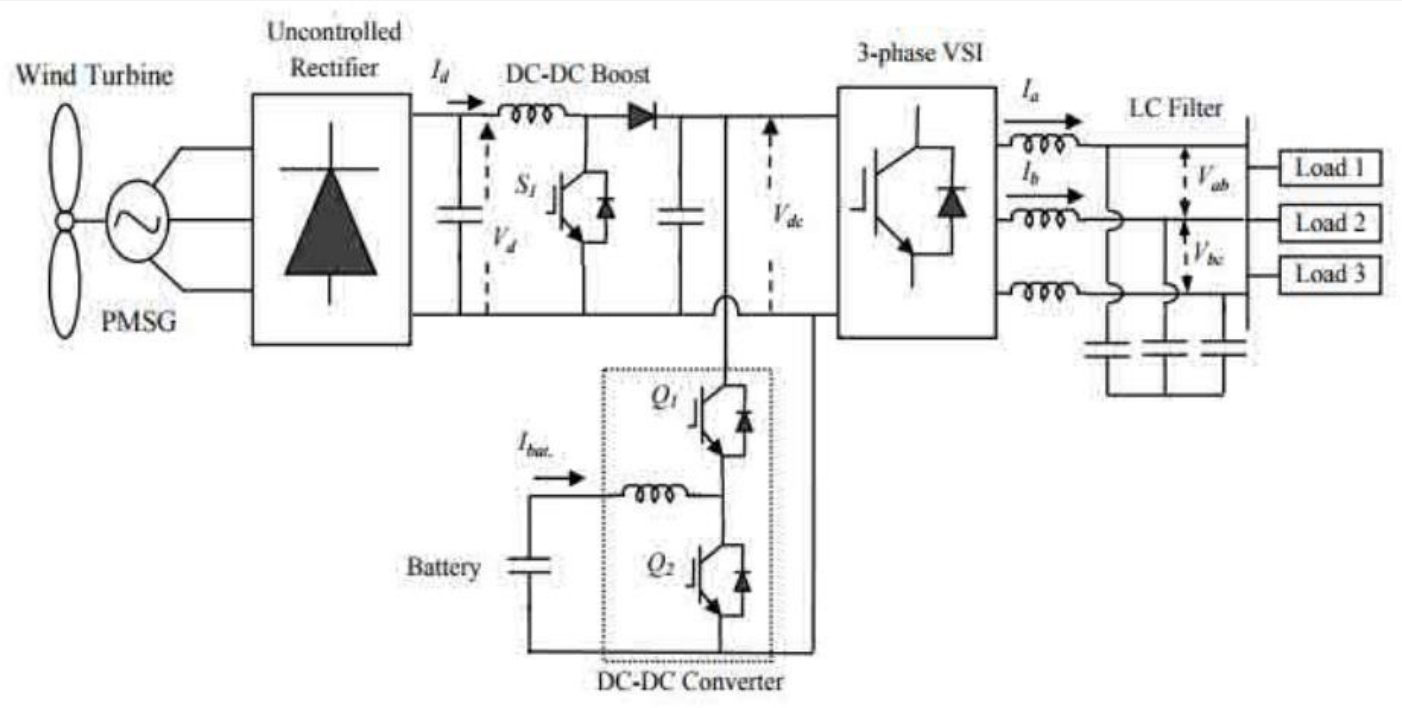


Configuration in WECS

Depending on electrical machines type, there are two configuration in WECS,

- Variable speed WECS
- Fixed speed WECS

PMSG BASED STAND-ALONE VARIABLE SPEED WIND ENERGY SUPPLY SYSTEM



- The system consists of Wind turbine, Permanent magnet synchronous generator (PMSG) which is directly driven by the wind turbine without using a gearbox, a single switch three phase mode rectifiers which consist of a three phase diode bridge rectifier, a DC-DC boost converter, batteries bank which is connected to the DC-link voltage through DC-DC bidirectional buck-boost converter and a three phase voltage source inverter connected to the load through LC filter.

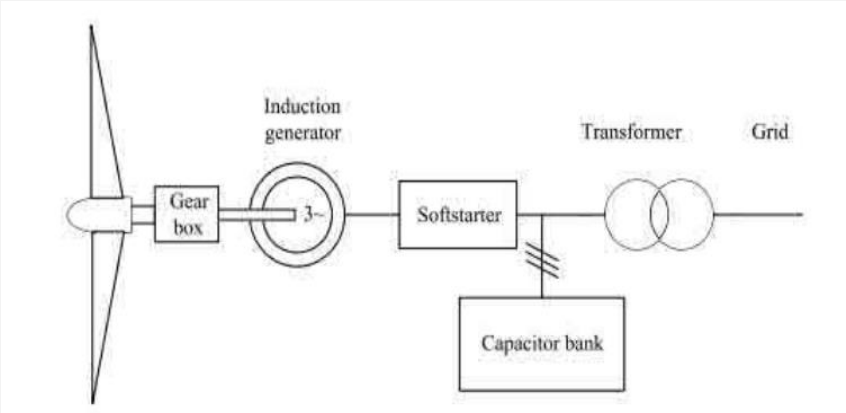
Mechanical power,

$$P_m = 0.5\rho A C_p u_w^3$$

Grid connection of wind turbines

Grid connected fixed speed WECS

- Fixed-speed WECS operate at constant speed. That means that, regardless of the wind speed, the wind turbine rotor speed is fixed and determined by the grid frequency.



- Fixed-speed WECS are typically equipped with squirrel-cage induction generators (SCIG), soft starter and capacitor bank and they are connected directly to the grid.

- Initially, the induction machine is connected in motoring regime such that it generates electromagnetic torque in the same direction as the wind torque.

- In steady-state, the rotational speed exceeds the synchronous speed and the electromagnetic torque is negative.

- This corresponds to the squirrel-cage induction machine operation in generation mode.

- SCIG are preferred because they are mechanically simple, have high efficiency and low maintenance cost. they are very robust and stable.

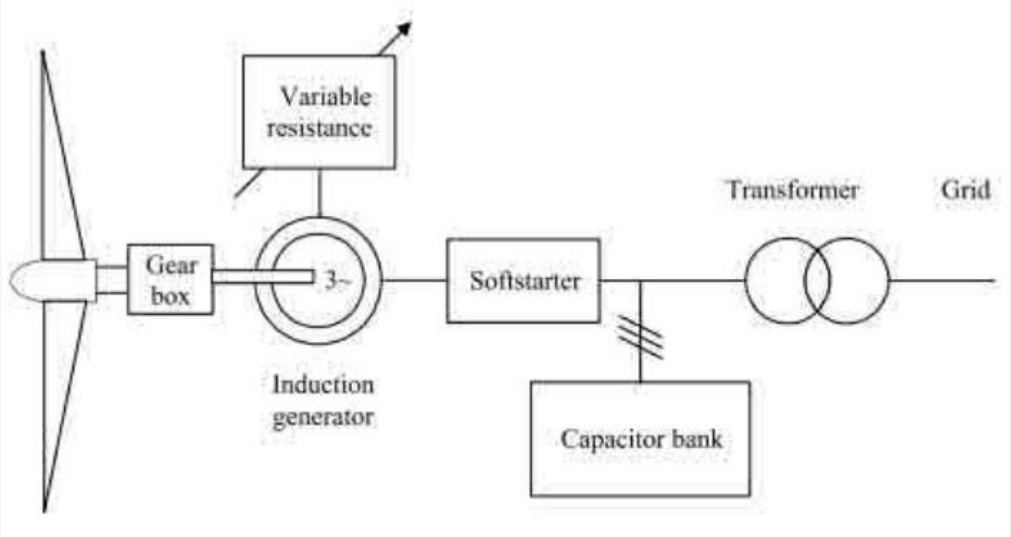
- One of the major drawbacks of the SCIG is the fact that there is a unique relation between active power, reactive power, terminal voltage and rotor speed.

- In order to limit the reactive power absorption from the grid, SCIG based WECS are equipped with capacitor banks.

- In order to increase the power efficiency, the generator of some fixed-speed WECS has two winding sets, and thus two speeds.

Grid connected variable speed WECS

The variable speed operation is possible due to the power electronic converters interface, allowing a full (or partial) decoupling from the grid.



- The doubly-fed-induction-generator (DFIG)-based WECS also known as improved variable-speed WECS, is presently the most used by the wind turbine industry.

- The DFIG having the stator windings connected directly to the three phase, constant-frequency grid and the rotor windings connected to a back-to-back (AC–AC) voltage source converter.

- Thus, the term —doubly-fedll comes from the fact that the stator voltage is applied from the grid and the rotor voltage is impressed by the power converter.

- The power electronics converter comprises of two IGBT converters, namely the rotor side and the grid side converter, connected with a direct current (DC) link.

- The main idea is that the rotor side converter controls the generator in terms of active and reactive power, while the grid side converter controls the DC-link voltage and ensures operation at a large power factor.

- DFIG-based WECS are highly controllable, allowing maximum power extraction over a large range of wind speeds.

- The active and reactive power control is fully decoupled by independently controlling the rotor currents.

Variable speed turbines vs Constant speed turbines

In constant-speed turbines, there is no control on the turbine shaft speed. Constant speed control is an easy and low-cost method, but variable speed brings the following advantages:

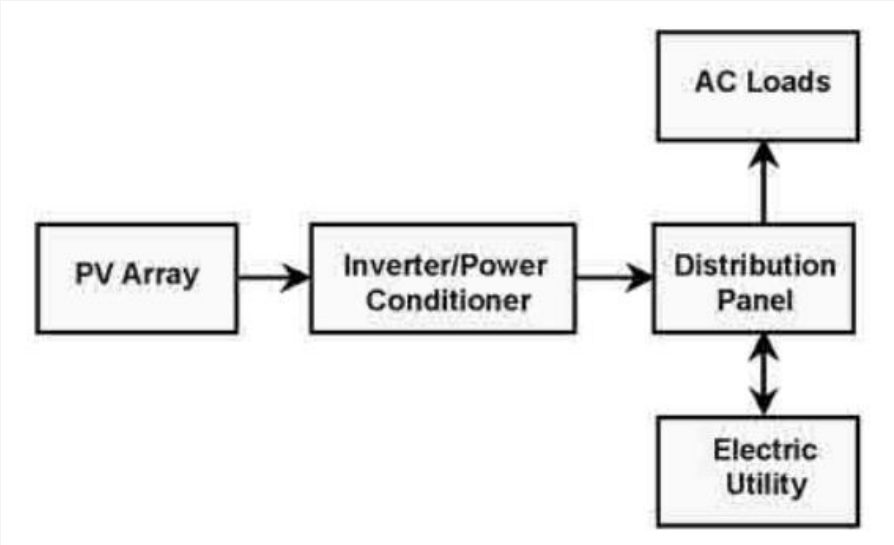
- Maximum power tracking for harnessing the highest possible energy from the wind
- Lower mechanical stress
- Less variation in electrical power
- Reduced acoustical noise at lower wind speeds.

Classification of Photovoltaic Power System

- Grid connected or utility connected systems
  - Centralized MPPT
  - Distributed MPPT
- Standalone systems

Grid connected Photovoltaic system

- Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid.



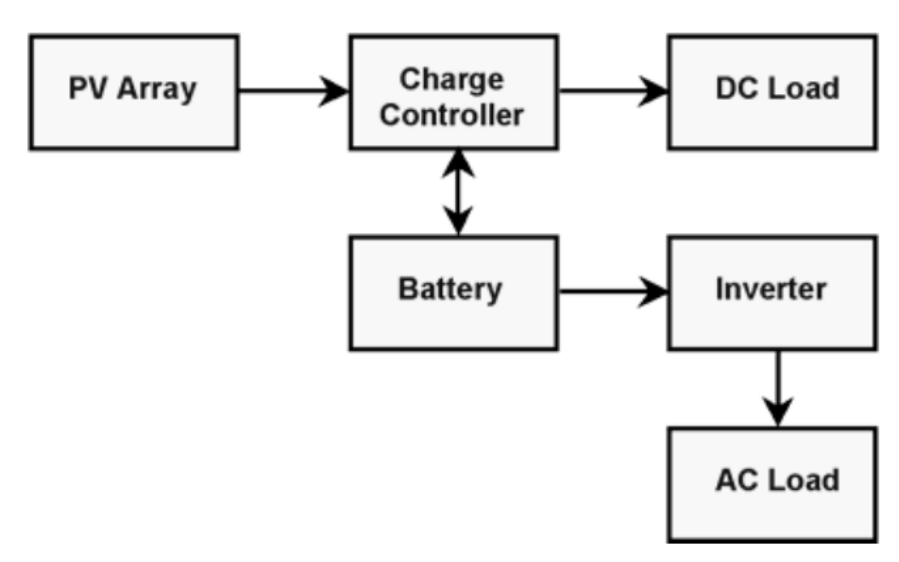
- The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU).

- The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized.

- A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance.

Stand alone Photovoltaic systems

- Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads.



- These types of systems may be powered by a PV array only, or may use wind, an engine-generator or utility power as an auxiliary power source in what is called a PV-hybrid system.

- The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load.

- A simple stand alone PV system is an automatic solar system that produces electrical power to charge banks of batteries during the day for use at night when the suns energy is unavailable.

Components

Batteries

- Batteries are an important element in any stand alone PV system but can be optional depending upon the design.
- Batteries are used to store the solar-produced electricity for night time or emergency use during the day.

Charge Controller

- A charge controller regulates and controls the output from the solar array to prevent the batteries from being over charged (or over discharged) by dissipating the excess power into a load resistance.

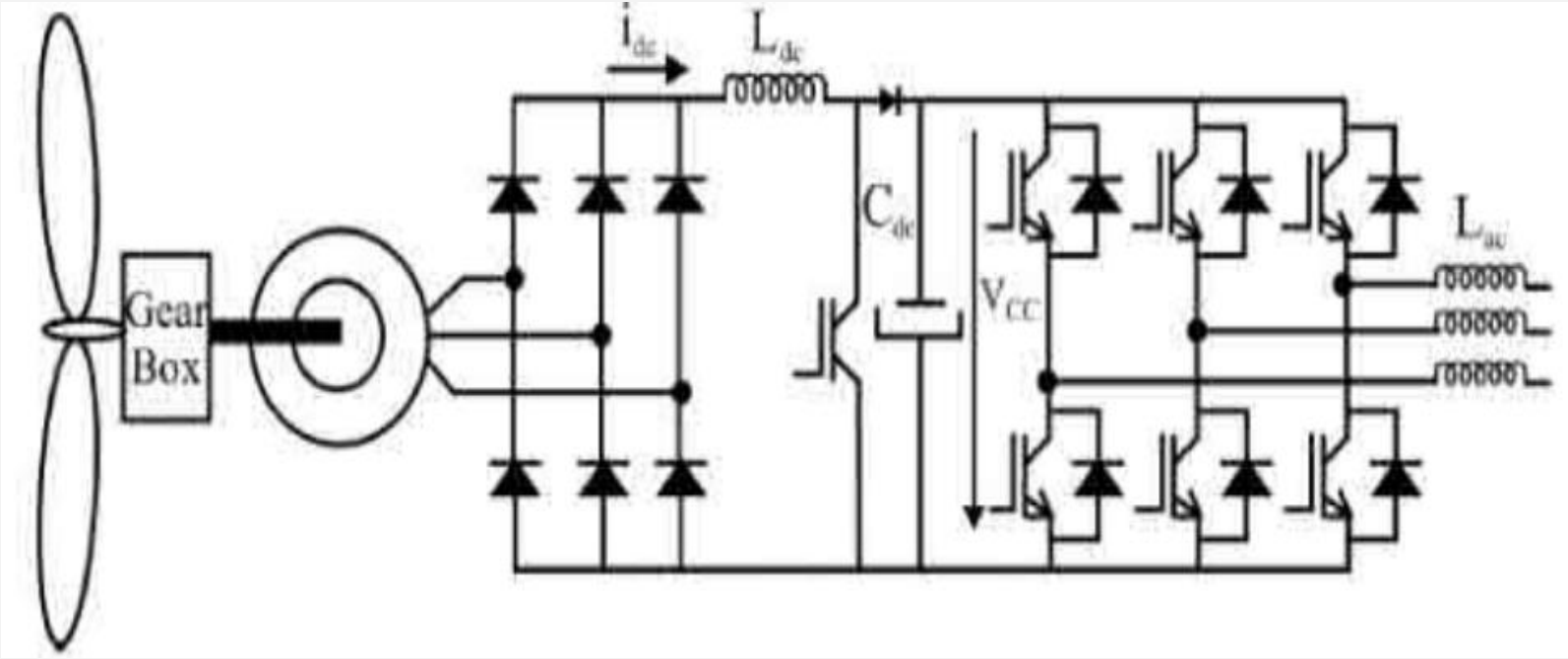
Fuses and Isolation switches

- These allow PV installations to be protected from accidental shorting of wires allowing power from the PV modules and system to be turned OFF when not required saving energy and improving battery life.

Inverter

- Inverters are used to convert the 12V, 24V or 48 Volts direct current (DC) power from the solar array and batteries into an alternating current (AC) electricity and power of either 120 VAC or 240 VAC for use in the home to power AC mains appliances such as TV‘s, washing machines, freezers, etc.

Grid Connected PMSG Based WECS



- The three-phase variable voltage, variable frequency output from the wind turbine is rectified using a diode bridge.
- With the change in the speed of the synchronous generator, the voltage on the DC side of the diode rectifier changes.
- To maintain a constant DC-link voltage of the inverter, a step-up chopper is used to adapt the rectifier voltage.
- The DC signal is then inverted through the use of semiconductor switches into a three-phase, 50 Hz waveform.

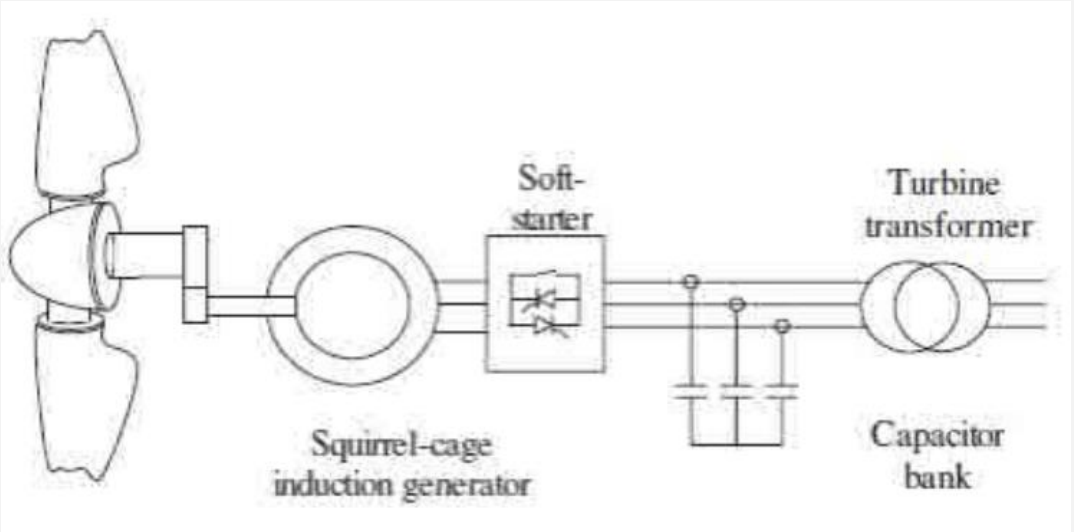
Based on the control design for the back-to-back PWM converter system, various advantages can be obtained such as:

- The line-side power factor is unity with no harmonic current injection
- Wind generator output current is sinusoidal
- There are no harmonic copper losses
- The rectifier can generate programmable excitation for the induction generator based system
- Continuous power generation from zero to the highest turbine speed is possible
- Power can flow in either direction, permitting the generator to run as a motor for start-up.

Grid connected SCIG based WECS

Fixed speed system

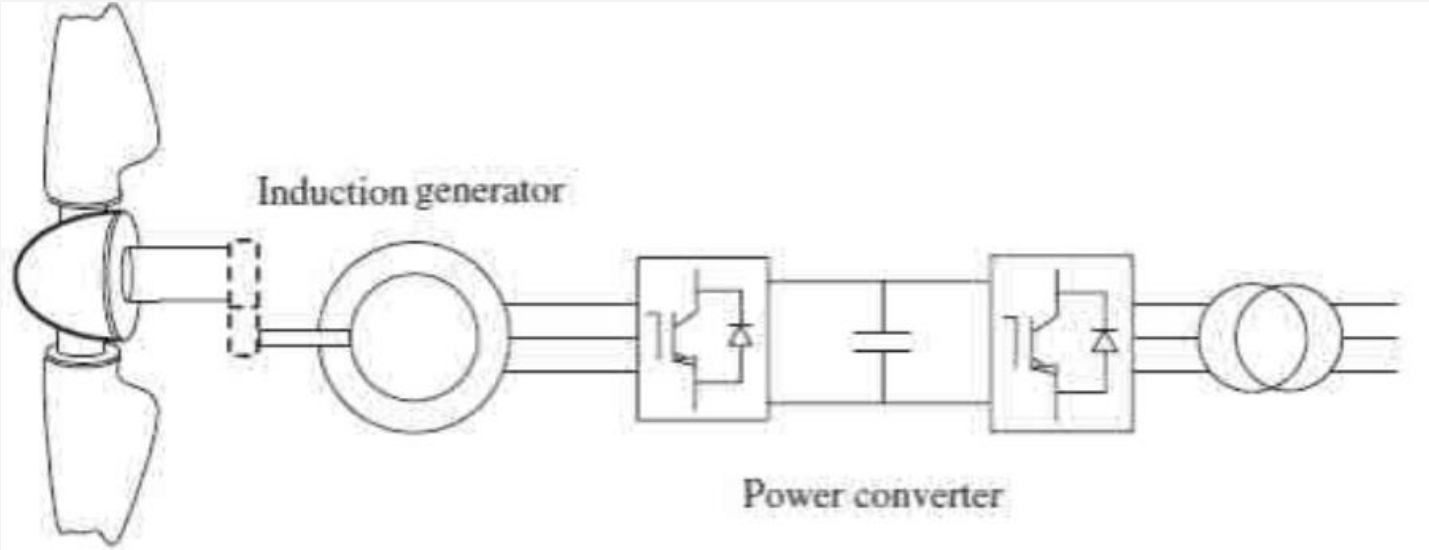
- Fixed-speed wind turbines are electrically fairly simple devices consisting of an aerodynamic rotor driving a low-speed shaft, a gearbox, a high-speed shaft and an induction generator.



- It consists of a squirrel-cage induction generator coupled to the power system through a turbine transformer.
- The generator operating slip changes slightly as the operating power level changes and the rotational speed is therefore not entirely constant.
- The operating slip variation is generally less than 1%, this type of wind generation is normally referred to as fixed speed.
- The function of the soft-starter unit is to build up the magnetic flux slowly and so minimize transient currents during energization of the generator.

Variable speed system

- This type of turbine may or may not include a gearbox and a wide range of electrical generator types can be employed, for example, induction, wound-rotor synchronous or permanent magnet synchronous.



Grid connected PV system

Connecting solar system to the grid

- These **Grid Connected PV Systems** have solar panels that provide some or even most of their power needs during the day time, while still being connected to the local electrical grid network during the night time.

- Solar powered PV systems can sometimes produce more electricity than is actually needed or consumed, especially during the long hot summer months.

- This extra or surplus electricity is either stored in batteries or as in most grid connected PV systems, fed directly back into the electrical grid network.

Grid connected net metering

- If during the billing period use or consume more electrical energy than generate, are billed for the net amount of electricity consumed as would be normally.

- If generate more solar energy than consume, are credited for the net amountll of electricity generated which may be either a reduction in monthly electricity bill or a positive payment.

- When installing a PV system, if net metering is available by local electricity company, it may be required to install a new second electrical meter instead of using a single electricity meter that spins in both directions.

Issues of Grid connected solar PV system

Problem concerned with power quality

- As the renewable DG‘s are integrated through a power electronic converter to the grid they usually inject harmonics into the system. which produce poor quality of power to be supplied to the customers.

Storage

- Due to the incorporation of renewable or PV source in the grid power path flow, the standard of the grid comes down. Introducing a battery to the grid connected PV systems invites issues of sizing and battery current and voltage control.

Protection issue

- Traditional power systems are protected by over current/over voltage relays and circuit breakers. But as energy conversion systems (solar) are introduced the protection of the network becomes more complex.

Reverse Power flow

- Conventional power systems possess unidirectional power flow. But as a renewable energy source is integrated to the conventional power system the power flow reversal takes place which alters the operation of protection circuits.

Lack of sustained fault current

- For the protection of the system from the fault current switch gear and circuit breakers are installed, which differentiates the fault current from the normal current. This differentiation is made with the significant increase in the fault current than the normal current.

Islanding

- Islanding is a unique problem of the grid connected PV system. Auto re-closure valve at the point of common coupling of the renewable generator to the grid is kept open offering the separation of the utility network with the grid.

Thank You