A Review on Wind TurbineGenerator Topologies

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***Abstract*—This paper presents a thought of the recent techniques used in wind energy conversion systems, their differentiation, and choice of generators. Additionally, the opposite crucial element within the WECS, the most objective of this paper is to survey the recent different methodologies utilized in the wind a generation process to offer high potency and higher performance in the wind generation process. Their square measure differing type of turbine ideas is developed. Currently, every day, the wind movement turns around game plan is received to be loads of price-aggressive, so correlations of varying generator framework's square measure important. To begin with, the progressive wind turbine units of estimation grouped .In this seminar the different recent wind technologies also included.**

Keywords—WECS; generator; wind energy; turbine; technologies

I. Introduction

Wind energy is green energy! Wind turbines use wind energy, which is created by atmospheric heating from the sun, to generate electricity. Using the advantages of wind energy we can convert the inexhaustible supply of wind to electricity without creating additional greenhouse gases and other pollutants.

Basic principle: conversion of kinetic energy into mechanical or electric Energy

Wind energy: Wind energy is the kinetic energy of air in motion, also called wind. Total wind energy flowing through an imaginary area *A* during the time *t* is:

$$E = \frac{1}{2}mv^2 = \frac{1}{2}(Avt\rho)v^2 = \frac{1}{2}A\rho t v^3 \ldots (1)$$

- Where ρ is the density of air; v is the wind speed; $Avt$is the volume of air passing through A (which is considered perpendicular to the direction of the wind); $Avt\rho$ is therefore the mass m passing per unit time. Note that $\frac{1}{2}\rho v^2$ is the kinetic energy of the moving air per unit volume.
- Power is energy per unit time, so the wind power incident on *A* (e.g. equal to the rotor area of a wind turbine) is:

$$P = \frac{E}{t} = \frac{1}{2}A\rho t v^3 \ldots (2)$$

- Wind power in an open air stream is thus *proportional* to the *third power* of the wind speed; the available power increases eightfold when the wind speed doubles. Wind turbines for grid electricity therefore need to be especially efficient at greater wind speeds.

The supply of power depends on the speed of the wind, and it is necessary to manage the whole unit against injury at higher wind speeds. The yield power from the wind turbines are regularly regulated by several ways, particularly stall administration (the razor sharp edge position is mounted to, on the other hand, stall of the wind appears on the cutting edge of higher wind speed) or pitch administration.

II. WIND ENERGY CONVERSION SYSTEM

Any device, such as a wind charger, windmill, or wind turbine, and associated facilities including the support structure of the system such as a tower that, converts wind energy to electrical energy [1].

A. Purpose

Regulations governing wind energy conversion systems are established to provide for appropriate locations for wind energy conversion systems, to ensure compatibility with surrounding uses, and to promote safe, effective and efficient use of wind energy conversion systems to increase opportunities for generation of renewable energy.

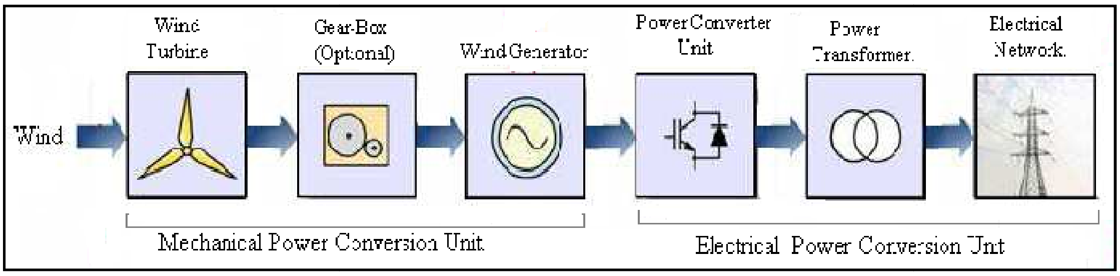

Fig. 1 wind energy conversion system

A contemporary turbine is supplied with a maximize electrical tool, the generator terminal voltage, frequently a Flat voltage underneath kilo volt, to a medium voltage around 20-30 kilo volt utilized for the local electrical Companionship at interim a wind stop (conveyance level). If the wind park is giant (above hundred kilowatts and up) and therefore, the distance to the electric power grid network is long, used tool might even be maximizing the Voltage between the power station to a high voltage from transmission level. The wind energy conversion systems are mainly classified according to their output power, speed, and type of generator used and the orientation of the turbine. This can be explained as below:

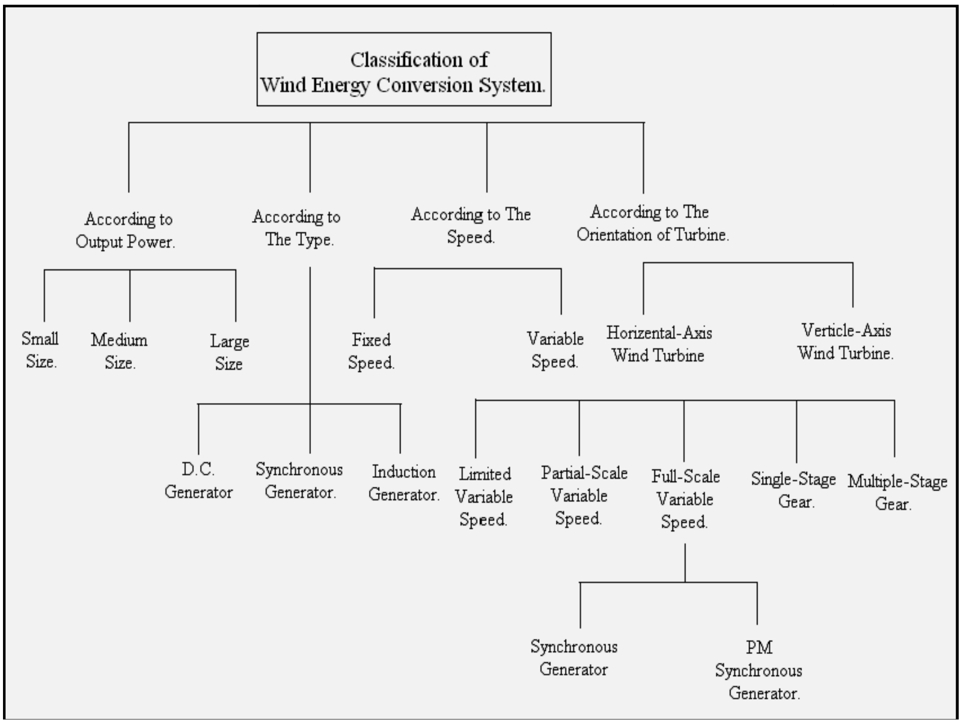

Fig. 2 classification of wind energy conversion system

B. Wind Energy Conversion System

Following square measure the most sorts of classifications of Wind Energy conversion systems keeping output electric power.

a. Little size (up to 2 kW):
Generally, these types of wind turbines are low power capacities, and it used for remote applications.

b. Medium Size (2-100 kW):
These sorts of wind turbines' square measure but one hundred kilowatt rated capability, and it is going to use for residences or native use.

c. Giant Size (100 kilowatt and up):
These sorts of wind turbines' square measure accustomed to generate power for distribution functions then it gives power in a central grid.

One of limiting factors in wind turbines lies in their generator technology. Traditionally, there are three main types of wind turbine generators (WTGs) which can be considered for the various wind turbine systems, these being direct current (DC), alternating current (AC) synchronous and AC asynchronous generators. In principle, each can be run at fixed or variable speed. Due to the fluctuating nature of wind power, it is advantageous to operate the WTG at variable speed which reduces the physical stress on the turbine blades and drive train, and which improves system aerodynamic efficiency and torque transient behaviors.

III. DC GENERATOR

In conventional DC machines, the field is on the stator and the armature is on the rotor. The stator comprises a number of poles which are excited either by permanent magnets or by DC field windings. If the machine is electrically excited, it tends to follow the shunt wound DC generator concept.

An example of the DC wind generator system is illustrated in Fig. 3.a. It consists of a wind turbine, a DC generator, an insulated gate bipolar transistor (IGBT) inverter, a controller, a transformer and a power grid. For shunt wound DC generators, the field current (and thus magnetic field) increases with operational speed whilst the actual speed of the wind turbine is determined by the balance between the WT drive torque and the load torque. The rotor includes conductors wound on an armature which are connected to a split-slip ring commentator. Electrical power is extracted through brushes connecting the commentator which is used to rectify the generated AC power into DC output. [2]

A. Disadvantages

- They require regular maintenance
- Relatively costly due to the use of commutators and brushes
- In general, these DC WTGs are unusual in wind turbine applications except in low power demand situations where the load is physically close to the wind turbine, in heating applications or in battery charging.

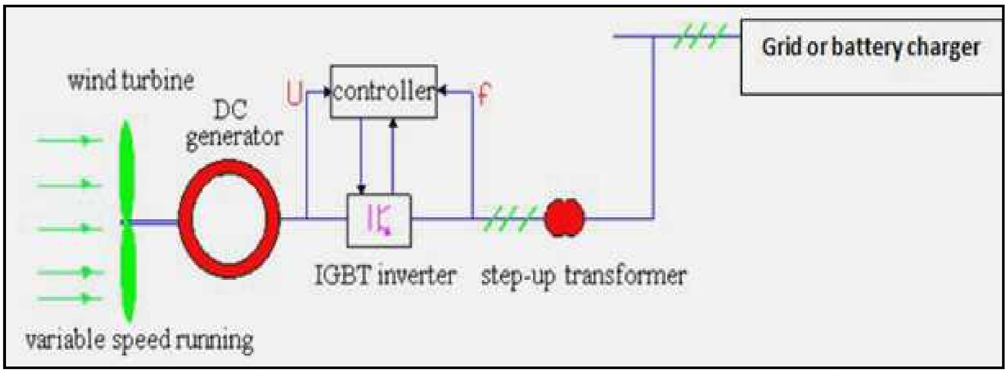

Fig. 3 dc generator wind turbine

B. Induction Generator

An induction generator is a type of electrical generator that is mechanically and electrically similar to an induction motor. Induction generators produce electrical power when their shaft is rotated faster than the synchronous frequency of the equivalent induction motor. Induction generators are often used in wind turbines and some micro hydro installations. Induction generators are mechanically and electrically simpler than other generator types. They are also more rugged, requiring no brushes or commutator.

Induction generators are not self-exciting, meaning they require an external supply to produce a rotating magnetic flux, the power required for this is called reactive current. The external supply can be supplied from the electrical grid or from the generator itself, once it starts producing power or can you can use a capacitor bank to supply it. The rotating magnetic flux from the stator induces currents in the rotor, which also produces a magnetic field. If the rotor turns slower than the rate of the rotating flux, the machine acts like an induction motor. If the rotor is turned faster, it acts like a generator, producing power at the synchronous frequency [2]. The common down side of using an induction generator in a wind turbine is gearing. Typically you need an induction motors to run 1500+ RPM to meet the synchronous so a gearing is almost always needed.

C. *Ac Synchronous Generators*

Synchronous generators square measure connected with a turbine its necessary controlled the fast rotor speed with relation to synchronous speed at turbulent winds. Since the early time of developing wind turbines, considerable efforts have been made to utilize three-phase synchronous machines. AC synchronous WTGs can take constant or DC excitations from either permanent magnets or electromagnets and are thus termed PM synchronous generators (PMSGs) and electrically excited synchronous generators (EESGs), respectively. When the rotor is driven by the wind turbine, a three-phase power is generated in the stator windings which are connected to the grid through transformers and power converters.

Disadvantages:

- Additionally synchronous generators needs drive train for versatile coupling, rather than this it additionally mount the gear case assembly on springs (or dampers) to soak up turbulence.
- However the synchronous generators square measure a lot of pricey than induction generators owing to smaller size ranges.
- One altogether the foremost edges of synchronous generator are that, it has equipped the reactive power whether or not it has required in power systems [2].

D. *Ac Asynchronous Generators*

Whilst conventional power generation utilizes synchronous machines, modern wind power systems use induction machines extensively in wind turbine applications. These induction generators falls into two types: fixed speed induction generators (FSIGs) with squirrel cage rotors (sometimes called squirrel cage induction generators-SQIGs) and doubly fed induction generators (DFIGs) with wound rotors.

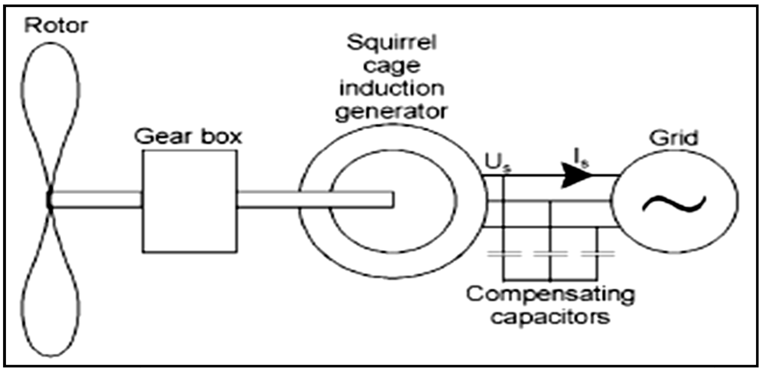

Fig.4 squirrel cage induction generator

- Clearly, fixed speed induction generators are limited to operate only within a very narrow range of discrete speeds.
- Other disadvantages of the machines are related to the machine size, noise, low efficiency and reliability.
- These machines have proven to cause tremendous service failures and consequent maintenance.
- Conventional, directly grid coupled squirrel cage induction generator.
- The slip, and hence the rotor speed of a squirrel cage induction generator varies with the amount of power generated.
- These rotor speed variations are, however, very small, approximately 1 to 2 per cent. Therefore, this wind turbine type is normally referred to as a constant speed or fixed speed turbine.
- Can run at two different (but constant) speeds by changing the number of pole pairs of the stator winding.

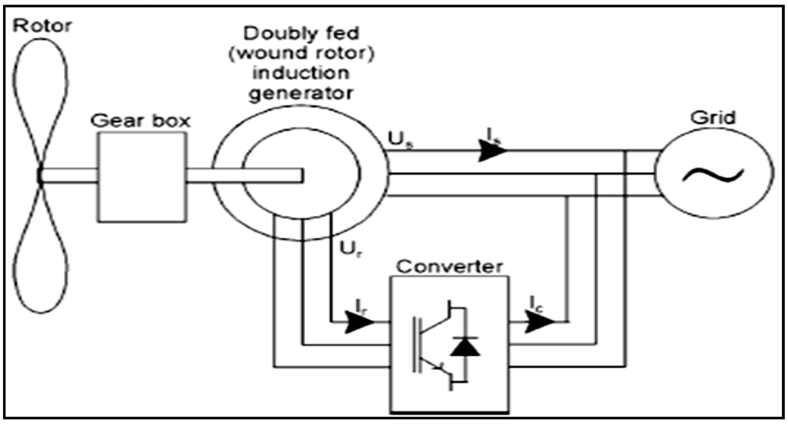

Fig.5 Doubly fed induction generator

1. Variable speed turbines (doubly fed induction generator)

Nowadays, over 85% of the installed wind turbines utilize DFIGs and the largest capacity for the commercial wind turbine product with DFIG has increased towards 5MW in industry. In the DFIG topology, the stator is directly connected to the grid through transformers and the rotor is connected to the grid through PWM power converters. The converters can control the rotor circuit current, frequency and phase angle shifts. Such induction generators are capable of operating at a wide slip range (typically ±30% of synchronous speed). As a result, they offer many advantages such as high energy yield, reduction in mechanical stresses and power fluctuations, and controllability of reactive power.

- To allow variable speed operation, the mechanical rotor speed and the electrical frequency of the grid must be De-coupled.
- In the doubly fed induction generator, a back-to-back voltage source converter feeds the three phase rotor winding.

In this way, the mechanical and electrical rotor frequency is decoupled and the electrical stator and rotor frequency can be matched, independently of the mechanical rotor speed.

2. Direct drive synchronous generator:

- In the direct drive synchronous generator, the generator is completely decoupled from the grid by a power electronics converter.

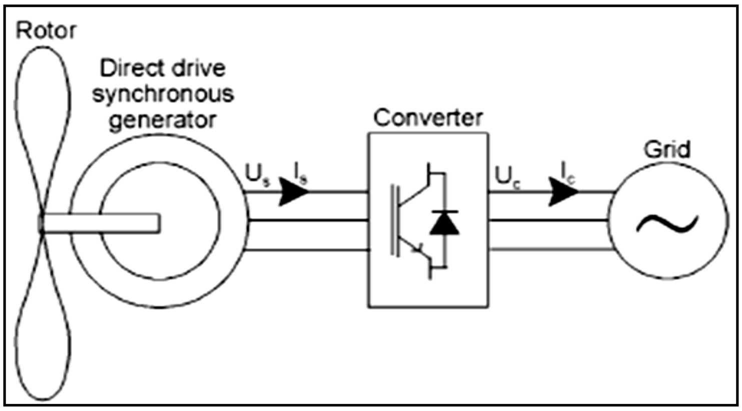

Fig 6:Direct drive synchronous generator

An Advantage of Different Types of Wind Generators:

Table I:An advantage of different types of wind generators

Type of Generator	Energy Yield	Cost	Reliability	Grid support Ability.	Technical Maturity
SCIG	Less	Less	Towering	Less	Towering
WRIG	Medium-Towering	Towering	Towering	Towering	Towering
DFIG	Medium-Towering	Medium	Medium	Medium	Towering
PMSG	Towering	Medium-Towering	Towering	Towering	Medium-Towering

IV.WIND SPEEDS

According to the motion speed of wind turbines differing types of wind generators topology mentioned in this paper.

A.Mounted (Fixed) Speed System

The fixed speed wind generator systems have been used with a multiple-stage gearbox and a SCIG directly connected to the grid through a transformer as illustrated in fig.4.a. Because the SCIG operates only in a narrow range around the synchronous speed, the wind turbine equipped with this type of generator is often called the fixed-speed wind generator system. Since the SCIG always draws reactive power from the grid, during the 1980s this concept was extended with a capacitor bank for reactive power compensation. Smoother grid connection was also achieved by incorporating a soft-starter. Furthermore, a pole-changeable SCIG has been used, which leads two rotation speeds.

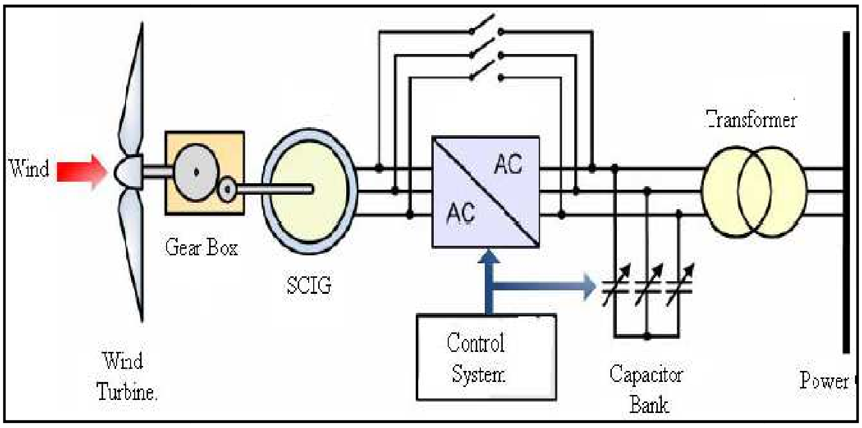

Fig.7 fixed speed wt connected directly to power grid with SCIG

Advantages:

- SCIG is robust, easy and relatively cheap for mass production.
- In addition, it enables stall-regulated machines to operate at a constant speed when it is connected to a large grid, which provides a stable control frequency

Disadvantages:

- A three-stage gearbox in the drive train is necessary for this wind turbine concept. Gearboxes represent a large mass in the nacelle, and also a large fraction of the investment costs.

The fixed speed concept means that wind speed fluctuations are directly translated into electromechanical torque variations, this causes high mechanical and fatigue stresses on the system (turbine blades, gearbox and generator) and may result in swing oscillations between turbine and generator shaft.

B.Variable-Speed Concept

1. Restricted (limited) Variable-speed system

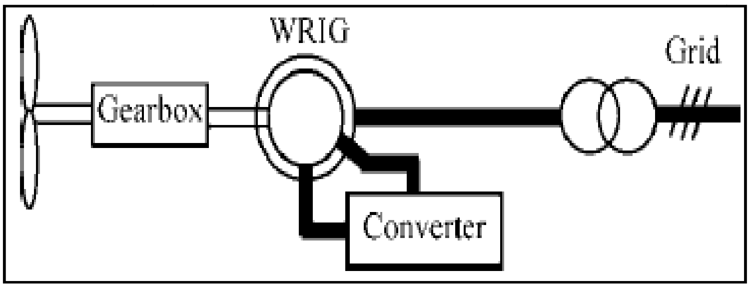

Fig.8 variable speed WT connected directly to power grid with DFIG

Limited variable speed construct is additionally known as because the 'Optislip' construct. Just in case of restricted variable speed, system usually the Wound rotor induction generator (WRIG) becomes employed. This wind turbine concept uses a wound rotor induction generator (WRIG) with variable rotor resistance by means of a power electronic converter and the pitch control method, as shown in above fig 4.b.

The stator of WRIG is directly connected to the grid, whereas the rotor winding is connected in series with a controlled resistor. Variable-speed operation can be achieved by controlling the energy extracted from the WRIG rotor; however, this power must be dissipated in the external resistor. With the increase in variable speed range, a higher slip means a high power extracted by the rotor, and the lower generator efficiency, so that the rating of the resistor must also be higher. Therefore the dynamic speed control range depends on the size of the variable rotor resistance, and the energy extracted from the external resistor is also dumped as heat loss in the controllable rotor resistance.A typical limited variable speed range is less than 10% above the synchronous speed.

2. Variable speed concept with a partial-scale power converter

This configuration is known as the DFIG concept, which corresponds to a variable speed wind turbine with a WRIG and a partial-scale power converter on the rotor circuit. The stator is directly connected to the grid, whereas the rotor is connected through a power electronic converter. This concept supports a wide speed range operation, depending on the size of the frequency converter. Typically, the variable speed range is +30% around the synchronous speed the rating of the power electronic converter is only 25–30% of the generator capacity, which makes this concept attractive and popular from an economic point of view. The largest capacity for the commercial wind turbine product with DFIG has been up to 5 MW from Repower.

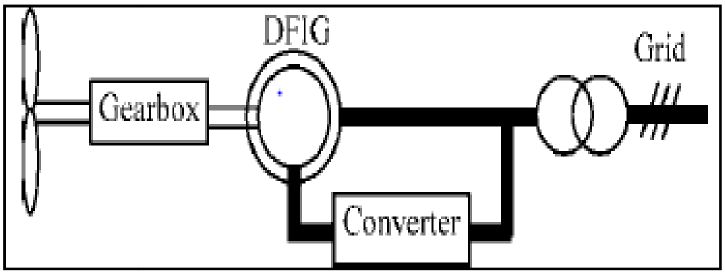

Fig.10 Variable speed concept with a partial-scale power converter

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Advantages:

- Compared with the opt slip concept, the rotor energy, instead of being dissipated, can be fed into the grid by the power electronic converter

Disadvantages:

- A multi-stage gearbox is necessary

- The slip ring is used to transfer the rotor power by means of a partial-scale converter, which requires a regular maintenance, and maybe result in machine failures and electrical losses
- Under grid fault conditions, on the one hand, large stator currents result in large rotor currents, so that the power electronic converter needs to be protected from destroy
- The corresponding control strategies may be complicated.

3. Variable speed direct-drive concept with a full-scale power converter

Compared with the variable speed concept with a partial-scale power converter, the full-scale power converter can perform smooth grid connection over the entire speed range. However, it has a higher cost and a higher power loss in the power electronics, since all the generated power has to pass through the power converter. Basically, types of direct-drive generators used in the market can be classified into the electrically excited synchronous generator (EESG) and the PMSG.

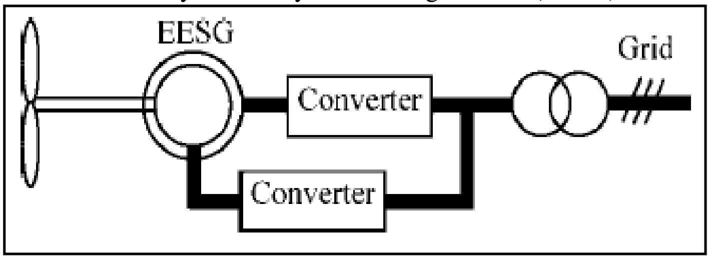

Fig.11 Electrically excited synchronous generator

The EESG is usually built with a rotor carrying the field system provided with a DC excitation. The stator carries a three-phase winding quite similar to that of the induction machine. The rotor may have salient poles or may be cylindrical. Salient poles are more usual in low-speed machines and may be the most useful version for application to direct-drive wind turbines

Advantages:

The amplitude and frequency of the voltage can be fully controlled by the power electronic at the generator side, so that the generator speed is fully controllable over a wide range, even to very low speeds.

- controlling the flux for a minimized loss in different power ranges it does not require the use of PMs, which would represent a large fraction of the generator costs, and might suffer from performance loss in harsh atmospheric conditions

Disadvantages:

- It is having heavy weight and expensive solution.

It is necessary to excite the rotor winding with DC, using slip rings and brushes, or brushless exciter, employing a rotating rectifier and the field losses are inevitable.

C. PM synchronous generator:

The scheme of a grid-connected PMSG for direct-drive wind turbines is shown in below fig 4.5

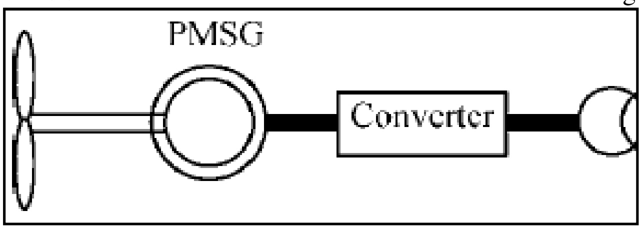

Fig.12 PM synchronous generator

Advantages:

- Higher efficiency and energy yield,
- No additional power supply for the magnet field excitation,
- Improvement in the thermal characteristics of the pm machine due to the absence of the field losses,
- Higher reliability due to the absence of mechanical components such as slip rings,
- Lighter and therefore higher power to weight ratio.

Disadvantages:

- High cost of PM material,
- Difficulties to handle in manufacture,
- Demagnetization of PM at high temperature.

1. Variable speed single-stage geared Concept with a full-scale power converter

In this scheme, a variable speed pitch control wind turbine is connected to a single-stage planetary gearbox that increases the speed by a factor of roughly 10 and a low-speed permanent-magnet generator. This concept, which was introduced as the Multi-blade, has gained the attention because it has the advantages of a higher speed than the direct-drive concept and a lower mechanical component than the multiple-stage gearbox concept.

2. Variable speed multiple-stage geared concept with a full-scale power converter

A PMSG system with a multiple gearbox is used in order to reduce the generator's volume and improve the generator efficiency in variable speed wind turbine concepts with a full-scale power converter. In the market, this configuration has been used in GE Multi-megawatt series.

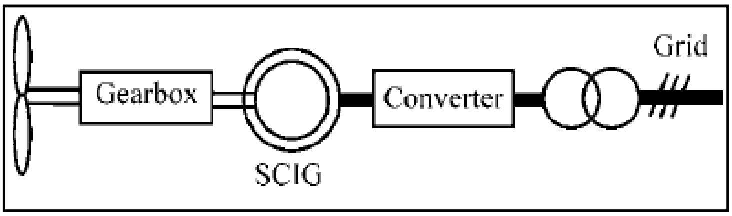

Fig.13 Variable speed multiple-stage geared concept with a full-scale power converter

Advantages:

- The generator has a better efficiency.
- The generator can be brushless.
- The grid-fault ride-through capability is less complex.

Disadvantages:

- Larger, more expensive converter (100% of rated power instead of 30%),

The losses in the converter are higher because all powers are processed by the power electronic converter.

V.TYPES OF WIND TURBINES

According to orientation, the turbine could also be classified into two sorts.

- Horizontal Axis wind turbines (HAWT)
- Vertical Axis wind turbines (VAWT)

A. Horizontal Axis Wind Turbines (HAWT)

A horizontal Axis Wind Turbine is the most common wind turbine design. In addition to being parallel to the ground, the axis of blade rotation is parallel to the wind flow.

- In this HAWT the rotating hub is parallel to the bearing of the wind. Horizontal axis turbine could even be classified relying on numbers used as single, double, multi-bladed and bicycle bladed.
- In keeping with the orientation of the blades with relation to wind, direction these could even is classified as up and down-wind

1. Up wind turbines

Some wind turbines are designed to operate in an upwind mode (with the blades upwind of the tower).

- Large wind turbines use a motor-driven mechanism that turns the machine in response to a wind direction.
- Smaller wind turbines use a tail vane to keep the blades facing into the wind.

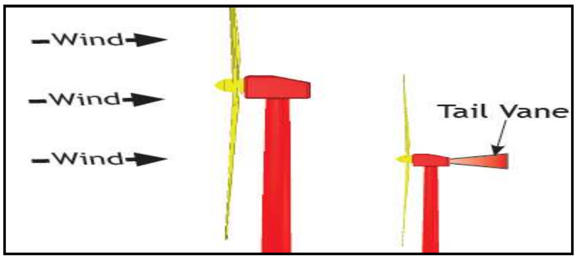

Fig. 14 Up wind turbines

The tail vanes and fantails square measure accustomed get forces within the wind itself. They passively alteration the direction of the turbine with relation to wind orientation while not mistreatment human or electric power.

2. Down wind turbines

Other wind turbines operate in a downwind mode so that the wind passes the tower before striking the blades. Without a tail vane, the machine rotor naturally tracks the wind in a downwind mode.
Tail vanes or fantasias do not require in Down-wind rotors. In the event of to a small extent downwind the sharpened pieces of steels square measure Cleared which supplies the rotating rotor the sort of shallow Cone with its peak at the tower.
Because of the coning of the Cutting edge that creates the rotor intrinsically, turn itself down wind.

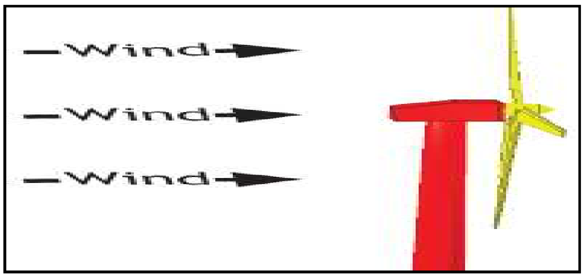

Fig. 15 Down wind turbines

3. HAWT advantages

The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up the wind speed can increase by 20% and the power output by 34%.

High efficiency, since the blades always move 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. Backtracking against the wind leads to inherently lower efficiency.

4. HAWT disadvantages

Massive tower construction is required to support the heavy blades, gearbox, generator and an additional yaw control mechanism to turn the blades toward the wind.

Downwind 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 generally require a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.

B. Vertical Axis Wind Turbines (VAWT)

The primary profits of VAWT over common place HAWT square measure that VAWT square measure Omni directional that is it affirms the wind from any heading. Those disentangle its style & kills the matter obligatory by turning mechanism compels on the rotor of common machines in light of the fact that the turbines yaw into the wind. The pivot of vertical pivot allows, mounting the generator & unit at the bottom level. On the opposite hand VAWT needs man wires attached to the support at higher level, The VAWT application is restricted for offshore sites.

1. VAWT advantages

- No yaw mechanism is needed because they have lower wind startup speeds than the typical the HAWTs.
- A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
- 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.

2. VAWT disadvantages

- 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.
- Having rotors located close to the ground where wind speeds are lower due and do not take advantage of higher wind speeds above.

C. INVELOX WIND POWER GENERATION TECHNOLOGY

Fig.16 Invelox wind power generation technology

Sheer wind, a wind power company from Minnesota, USA, has announced the results of tests it has carried out with its new Invelox wind power generation technology. The company says that during tests its turbine could generate six times more energy than the amount produced by traditional turbines mounted on towers. Besides, the costs of producing wind energy with Invelox are lower, delivering electricity with prices that can compete with natural gas and hydropower. **[6]** Tests have demonstrated that the system operating in natural wind speeds of 10mph is able to increase that speed to 40mph before it enters the turbine.

D. BLADELESS WIND TURBINE

Tunisian green energy startup Saphon Energy has created a new bladeless wind turbine which draws inspiration from the design of a ship's sails, and promises to convert the kinetic energy of the wind into electricity at up to double the efficiency – and half the cost – of a typical wind turbine. This is also avoiding the use of rotating blades, which can cause noise pollution and be harmful to birds.

Fig.17 Bladeless wind turbine

Tunisian green energy startup Saphon Energy has created a new bladeless wind turbine which draws inspiration from the design of a ship's sails, and promises to convert the kinetic energy of the wind into electricity at up to double the efficiency – and half the cost – of a typical wind turbine. This is also avoiding the use of rotating blades, which can cause noise pollution and be harmful to birds [6]. Dubbed the "Saphonian," in honor of an ancient wind divinity worshiped by the Carthaginian Mediterranean culture which predated modern Tunisia, the current iteration of bladeless wind turbine is the second prototype developed by the company thus far.The Saphonian turbine implements a patented system called "Zero-Blade Technology" in order to harness the wind's energy. This is said to involve channeling the wind in a back and forth motion, until it is converted into mechanical energy using pistons. The pistons then produce hydraulic pressure, which can be instantly converted to electricity via a hydraulic motor and a generator, or stored in a hydraulic accumulator.

E. WIND ENERGY SCENARIO IN INDIA

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world.[]In 2009-10 India's growth rate was highest among the other top four countries.

As of 31 Jan 2013 the installed capacity of wind power in India was 19779.15[2] MW. It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power.

CONCLUSION

The review on wind energy technologies is studied in this paper and the recent technologies on wind power systems, like Invelox wind power generation and bladeless wind turbine systems also studied. With the help of this review on wind energy we can develop the more technologies in future.

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