Wind Energy Background

Contents

Working Principle of Wind Turbine

Wind is air in motion. It is a form of solar energy. Solar radiation heats every part of the Earth?s surface unevenly due to irregularities and rotation of earth. The flow of wind patterns are modified by the earth's terrain, bodies of water, and vegetative cover. When air moves, causing wind, it has kinetic energy. The kinetic energy of wind can be captured by a wind turbine and converted to other forms of energy such as electricity or mechanical power.

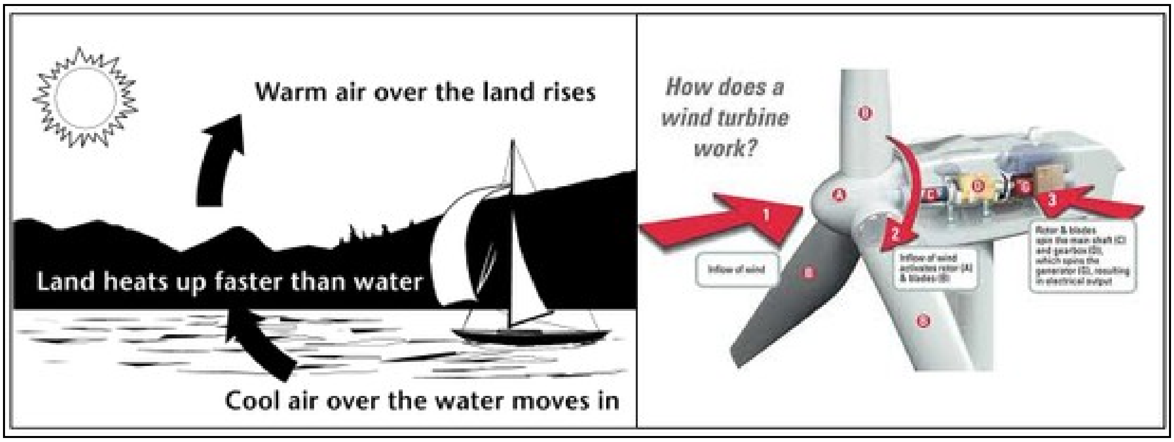


Fig 3 **Wind turbine principle**
Sources:Wind Energy Basics,How Wind Turbines Work

Horizontal Axis and Vertical Axis Wind Turbines

Wind turbines are mainly classified into two types based on the axis in which turbine rotates. They are Horizontal axis wind turbine(HAWT) and vertical axis wind turbine (VAWT). The table below presented, describes the advantages and disadvantages of HAWT's and VAWT's.

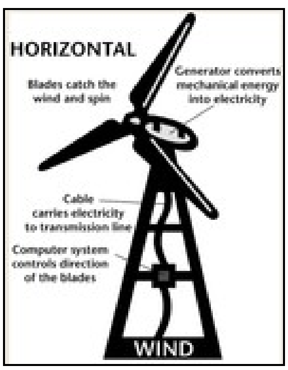
Horizontal axis wind turbines	Vertical axis wind turbines
• It is mounted on top of a tower ,requires huge towers leads to complex in operation, maintenance and high initial costs. • It operates only with upstream or down stream wind directions. • It can be constructed in off-shores. • It produces large amount of electricity with high efficiency.	• These are easy to build and maintain, safer, easier to transport and they can be mounted close to the ground. • These can handle much turbulence in wind than horizontal wind turbines. • Mostly it can be constructed with two blades • It operates with any direction of wind • Production of electricity is less due to low wind speeds near to ground
	

Fig 4(a)**Horizontal axis wind turbine**

Fig 4(b)**Vertical axis wind turbine**

Source:Different types of wind turbines

Horizontal Axis Wind Turbines

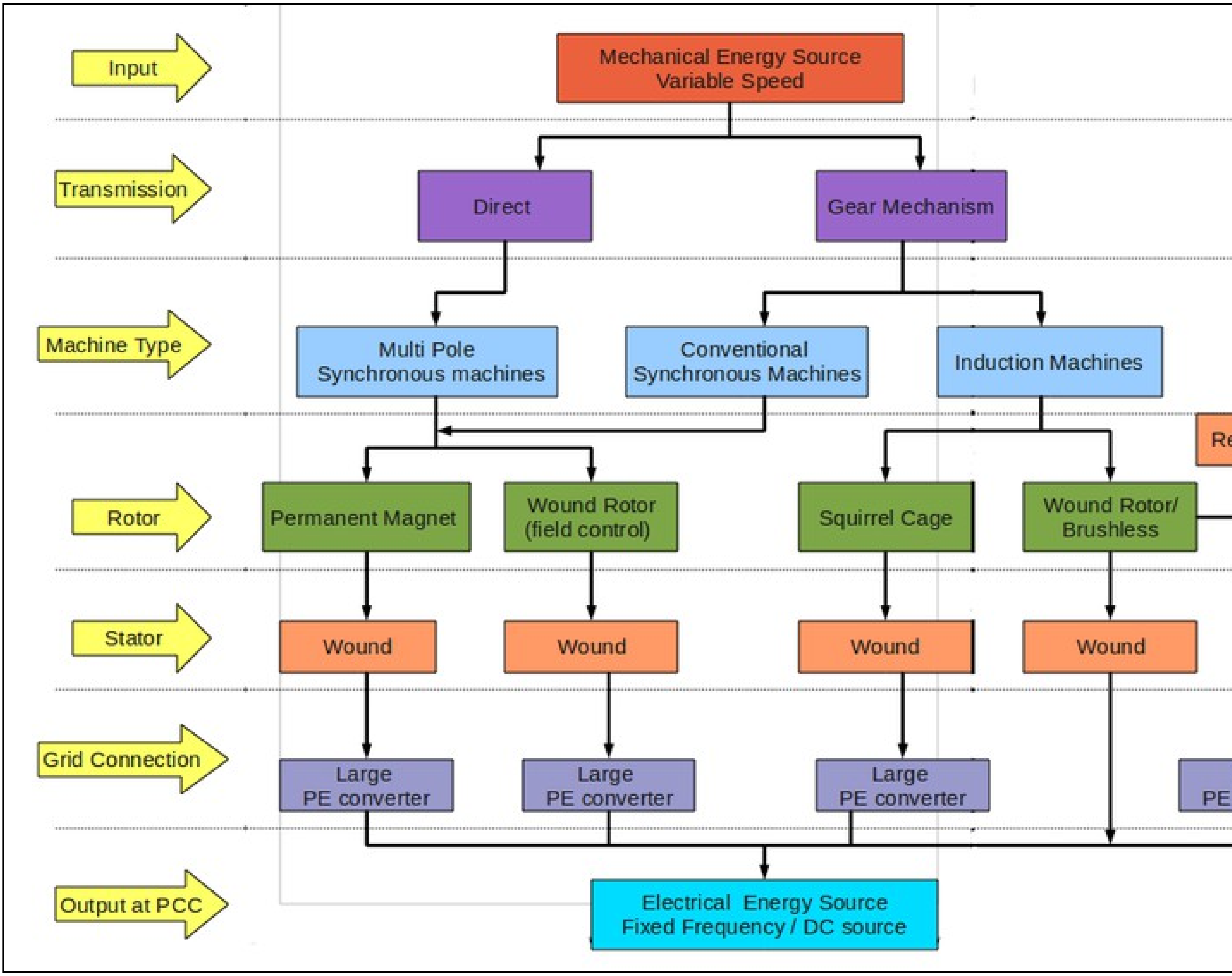


All grid-connected commercial wind turbines today are built with a horizontal axis type rotor which is installed on top of a tower. Most horizontal axis turbines built today are two- or three-bladed, although some have fewer or more blades. The purpose of the rotor is to convert the linear motion of the wind into rotational energy that can be used to drive a generator. Most of the systems have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Click on the link below to see detailed description about horizontal axis wind turbines.
Different Types and Parts of a Horizontal Axis Wind Turbines

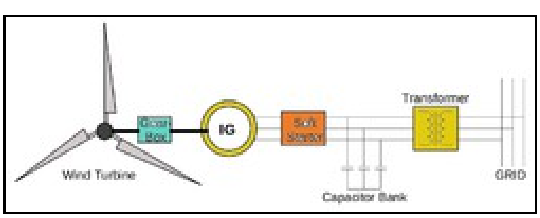
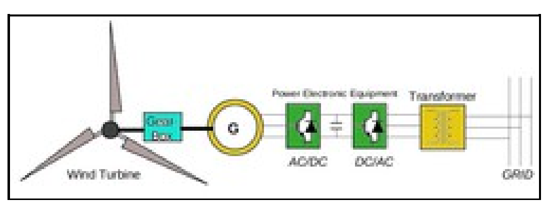
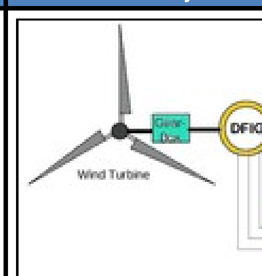
Electrical Generating Systems

The various types of electrical generating systems used in wind energy systems are shown in figure.



Source:Wind Turbine Generators

The most commonly used generator systems applied in wind turbines are are explained below.

	Fixed speed generating systems	Variable speed generating systems	Doubly fed inc
Structure			
Machines	SQIG	PMSG/WRSG/WRIG	DFIG
Advantages	* Simple and low cost * Low maintenance	* Complete control of real and reactive powers * High energy efficiency	* Reduced capacity conve * Decoupled control of act * Smooth grid connection
Drawbacks	* No control on real and reactive power * Less optimum power extraction capability * Poor power factor	* Additional cost of power electronics * Limited fault ride through capability	* Regular maintenance of * Limited fault ride-through

	* High mechanical stress on turbine mechanical components		

Source:Inside wind turbines

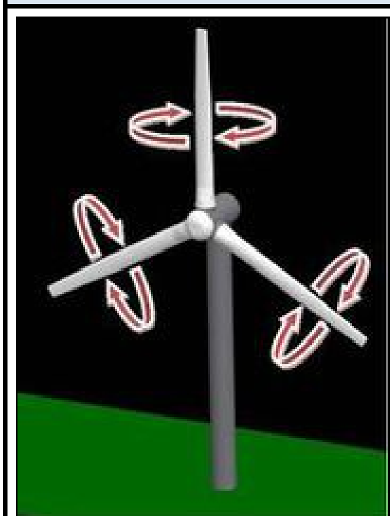
In this report, a comprehensive analysis of patent and non-patent literature is done with a focus on Doubly-fed induction generator systems.

Wind Turbine Control Systems

As the wind turbines increases in size and power, control systems plays a major role to operate wind turbines in safe region and also to improve efficiency and quality of power conversion. The main objectives of wind turbine control systems is

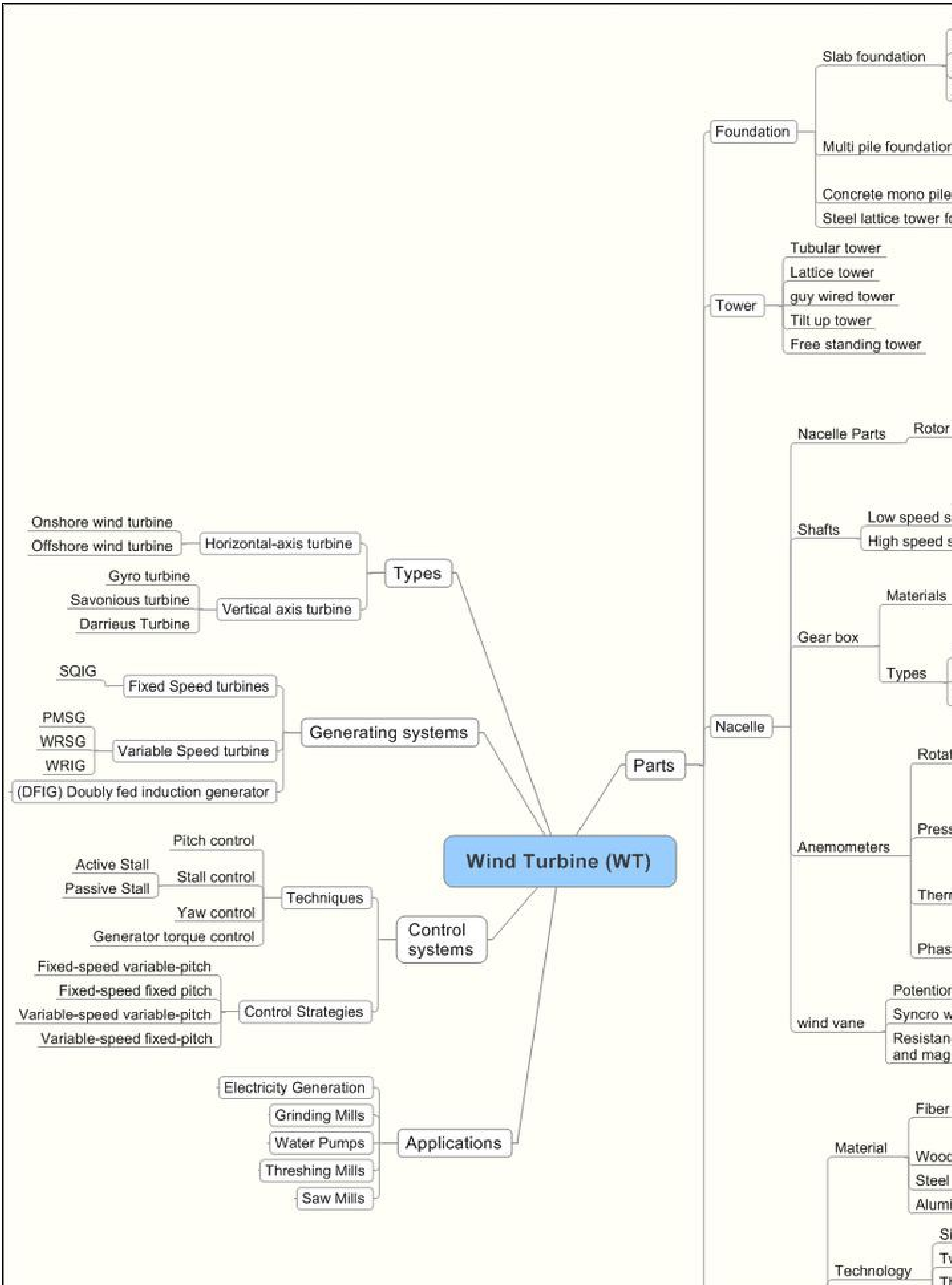
- *Energy capture* : Operating the wind turbine to extract maximum amount of energy considering safe restrictions like rated power, rated speed, cut-out wind speed etc.,
- *Mechanical loads*: protecting the systems from transient loads.
- *Power quality*: Conditioning the generated power with grid interconnection standards.

The various control techniques used in wind turbines are shown in table below

Control System	Pitch contol	Yaw control	Stall control	Generator torque control
Description	The rotation of horizontal axis wind turbine around its tower to orient the turbine in upwind or down wind direction. Source:Wind Turbine Control Methods	Stall control works by increasing the angle at which the relative wind strikes the blades (angle of attack). As the wind speed increases drag force on the blade increase and lift force gets reduces, thus finally reduces the speed of turbine.A fully stalled turbine blade, when stopped, has the flat side of the blade facing directly into the wind. Compare with furling. Source:Stall-control basics	As the aerodynamic torque control changes, rotor speed changes. it changes the output power frequency. A frequency converter is connected in between generator and the network to maintain generator power constant. SourceWind Energy Control	
 Fig 16(a) **Pitch control**	 Fig 16(b) **Yaw control**	NA	NA	

Taxonomy for Wind Turbines

A detailed taxonomy is presented which covers Parts, Types, Control Systems, Generating systems and Applications of wind turbines.



Wind Turbine (WT)
Types
Horizontal-axis turbine
Onshore wind turbine
Offshore wind turbine
Vertical axis turbine
Gyro turbine
Savonious turbine
Darrieus Turbine
Generating systems
Fixed Speed turbines
SQIG
Variable Speed turbine
PMSG
WRSG
WRIG
(DFIG) Doubly fed induction generator
Control systems
Techniques
Pitch control
Stall control
Active Stall
Passive Stall
Yaw control
Generator torque control
Control Strategies
Fixed-speed variable-pitch
Fixed-speed fixed pitch
Variable-speed variable-pitch
Variable-speed fixed-pitch
Applications
Electricity Generation
Grinding Mills
Water Pumps
Threshing Mills
Saw Mills
Parts
Foundation
Slab foundation
Tower
Tubular tower
Lattice tower
guy wired tower
Tilt up tower
Free standing tower
Nacelle
Nacelle Parts
Rotor
Shafts
Gear box
Materials
Types
Anemometers
wind vane
Material
Steel
Technology

IPC Classifications

A majority of patents describing wind turbines or wind energy are classified in the following IPC classifications.

S.NO	IPC Classification	Description
1	F03D	Machines or engines for liquids; wind, spring, or weight motors; producing mechanical power or a reactive propulsive thrust / **Wind motors**
2	F16C	Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general/ **Shafts; flexible shafts; elements of crankshaft mechanisms; rotary bodies other than gearing elements; bearings**
3	F16H	Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general / **Gearing**
4	F03B	Machines or engines for liquids; wind, spring, or weight motors; producing mechanical power or a reactive propulsive thrust / **Machines or engines for liquids**
5	H02K	Generation, conversion, or distribution of electric power / **Dynamo-electric machines**
6	H02P	Generation, conversion, or distribution of electric power / **Control or regulation of electric motors, generators, or dynamo-electric converters; controlling transformers, reactors or choke coils**
7	H02M	Generation, conversion, or distribution of electric power / **Apparatus for conversion between ac and ac, between ac and dc, or between dc and dc, and for use with mains or similar power supply systems; conversion of dc or ac input power into surge output power; control or regulation**
8	H02J	Generation, conversion, or distribution of electric power / **Circuit arrangements or systems for supplying or distributing electric power; systems for storing electric energy**
9	G06F	Computing; calculating; counting /**Electric digital data processing**
10	G05F	Controlling; regulating / **Systems for regulating electric or magnetic variables**
11	H02H	Generation, conversion, or distribution of electric power / **Emergency protective circuit arrangements**

Major Players

Major players in the Wind Energy sector include: General Electric, Vestas Wind Systems, Siemens AG, Mitsubishi Ltd, REPower Systems AG, Gamesa Innovation & Technology, Enercon, Nordex, Suzlon and Sinovel Wind Group Co. Ltd.

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