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Wind Energy: The Renewable Source of Energy

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Abstract—*Nowadays, it is well understood that the burning of fossil fuels in electric power station has a significant influence on the global climate due to greenhouse gases. In many countries, the use of cost- effective and reliable low-carbon electricity energy sources is becoming an important energy policy. Among different kinds of clean energy resources such as solar power, hydro power, ocean wave power and so on, wind power is the fastest growing form of renewable energy at the present time.Wind power is the second most important renewable source of electricity after hydropower. It is widespread but intermittent. Although the exploitation of wind can be traced back many centuries, the modern wind power industry started during the 1970s oil crisis. Most modern wind turbines are located on land but an increasing number are being built offshore, usually in wind farms. Since wind power is intermittent, it must be supported by other sources of electricity. Wind power can be cost effective in many situations but it has not yet achieved widespread grid parity with fossil fuels sources. The global wind generating capacity has grown rapidly during the first decade and a half of the twenty first century with the main growth areas in Europe, Asia and North America.*

1. INTRODUCTION

Because of the present-day energy demand and developing ecological awareness, there is a need to supplement energy demand with clean and renewable sources of energy. Humanity has utilized the wind as a source of energy for many years. Together with hydropower wind was the most used energy hotspot for quite some time. With the improvement of electrical designing and interest for power, towards the conclusion of the 19th century the first tests were completed on use of wind mills for creating power. In the continuous search of clean, safe and renewable energy sources, wind power, certainly is the most attractive solution. Wind power was used earlier for several centuries for propelling ships, driving wind mills, pumping water, irrigating fields and numerous other purposes. Wind is one of the potential renewable energy sources which can be harnessed in a commercial way and a detailed knowledge of wind characteristics is required for efficient planning and implementation of any wind engineering project.

Wind blows due to the warming and cooling of the Earth's atmosphere and the changes in temperature. In extreme cases the wind energy can be destructive in nature. Fortunately, most regions in the world experience moderate range of wind speeds that can allow human to extract energy from the wind. Wind results from air in motion. Air in motion arises from a pressure gradient. On a global basis one primary terracing function causing surface wind from the poles towards the equator is corrective circulation. Solar radiation heats the air near the equator, and this low-density heated air is bayed up. At the surface it is displaced by cooler, more dense higher-pressure air flowing from the poles. In the upper atmosphere near the equator the air thus tend to flow back towards the poles and away from the equator. The net result is a global corrective circulation with surface winds from North to South in the northern hemisphere.

The wind is basically caused by the solar energy predicting the Earth that is why wind utilization is considered a part of solar technology. A large wind farm may consist of several hundred individual wind turbines which are connected to the electric power transmission network.

Offshore wind farms can harness more frequent and powerful winds than are available to land based installations and have less visual impact on the landscape but construction costs are considerably higher. Small onshore wind facilities are used to provide electricity to isolated locations and utility companies increasingly produced by small domestic wind turbines. Wind energy is considered to be very clean chief important renewable energy source particularly for rural areas, farms, remote onshore and offshore installations away from main electrical grid.

The development of wind power in India began in 1990s, and has significantly increased in the last few years. Although a relative newcomer wind industry compared with Denmark for the United States, India is the fifth largest installed wind power station in the world. In 2009-10 station India's growth rate was highest among the other top 10 countries. As of 31st March 2011, the installed capacity wind power in India was16078 MW, mainly spread across Tamil Nadu (6007 MW), Maharashtra (2310.70 MW), Gujrat (2175.60 MW), Karnataka (1730.10 MW), etc.

The wind power industry is one of the fastest expanding industries as a result of the rapid growth of installed capacity. The wind power over the last 20-30 years has become a competitive technology for clean energy production. There is no reason why wind power should not become as important to the world's future energy supply as nuclear power is today. The question that has to be asked is how wind power will affect the whole electrical grid in particular the distribution network to which it is usually connected to. Nowadays wind power is fully established branch of the electricity market. When making decisions about new wind turbines placement the energy gain is not the only criteria to be considered during the planning phase; cost efficiency, the impact on the environment and the impact on the electric grid are some of the most important issues.

Unit ratings of wind turbine generators cover a wide range from 0.5 kilowatt to 14 kW. The broad classification is as follows:

i. Small: 1-15 kW
ii. Medium: 15-200 kW
iii. Large: 250-1000 kW
iv. Very Large: 1000-6000kW

2. HISTORICAL BACKGROUND

The wind has played a long and important role in the history of human civilization. The first known use ofwind dates back 5000 years to Egypt where boats used sails to travel from shore to shore. The first true windmill a machine with vanes attached to an access to produce circular motion may have been built as early as 2000 B.C. in ancient Babylon. By the 10th century A.D., windmills with wind catching surfaces as long as 16 feet and as high as 30 feet were grinding grain in the area now known as Eastern Iran and Afghanistan. Since early recorded history people have been harnessing the energy of the wind. Wind energy propelled boats along the Nile river as early as 5000 BC. By 200 B.C., simple wind mills in China for pumping water while vertical axis wind mills with woven reed sales for grinding grain in Persia and the middle East. In the 1930s and 1940s, hundreds of thousands of electricity producing wind turbines were built in the US. They had two or three thin blades which rotated at high speeds to drive electrical generators. These wind turbines provided electricity to farms beyond the reach of power lines and word typically used to charge storage batteries, operate radio receivers and power a light bulb or two. By the early 1950s, however, the extension of the central power grid to nearly every American household,via the rural Electrification Administration, eliminated the market for these machines. Wind turbine development lay nearly government for the next 20 years.

3. BASIC PRINCIPLES OF WIND ENERGY CONVERSION

3.1 Nature of The Wind

The circulation of air in the atmosphere is caused by the non-uniform heating of the Earth's surface by the sun. The air immediately above a warm area expands; it is forcedupwards by cool, denser air which flows in from surrounding areas causing a wind. The nature of the terrain, the degree of cloud cover and the angle of the sun in the sky are all factors which influence this process. In general, during the day the air above the land mass tends to heat up more rapidly than the air over water. In coastal regions this manifests itself in a strong onshore wind. At night the process is reversed because the air goes down more rapidly over the land and the breeze therefore blows off shore. Flow or air(wind) results in flow of mass. Flowing mass has kinetic energy. Hence wind is a natural source of kinetic energy. Energy in the wind can be converted into useful mechanical energy by means of wind turbine, windmill, sails of ships etc.

Winds are natural phenomena in the atmosphere and has two different origins:

i. Planetary winds are brought about by day by day rotation of the earth around its polar axis and unequal temperatures between polar regions and tropical areas.
ii. Local winds are brought on by unequal warming and cooling of ground surfaces and ocean or lake surfaces throughout day and night.

3.2 The Power of The Wind

Wind is the movement of air from an area of high pressure to an area of low pressure. In fact, wind exists because the sun unevenly hits the surface of the earth. Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air like a sail or propeller, can extract part of the energy and convert it into useful work. Three factors determine the output from a wind energy converter

i. The wind speeds
ii. The cross section of wind swept by rotor
iii. The overall conversion efficiency of the rotors transmission system and generator or pump

The power in the wind can be computed by using the concept of kinetics. The windmill works on the principle of converting kinetic energy of the wind into mechanical energy. We know that power is equal to energy per unit time. The energy available is the kinetic energy of the wind.

3.3 Site Selection Process

The power available in the wind increases rapidly with the speed hence wind energy conversion machines should be located especially in those areas where the winds are strongest and persistent. The following guidelines have been designed to install a wind turbine:

i. Turbines work at best when on high exposed sites. Coastal sites are especially good
ii. Town centers and highly populated residential areas are usually not suitable sites for wind turbines
iii. Avoid roof mounted turbines as there is no guarantee that these devices will not damage your property through vibration

iv. The further the distance between turbine and power requirement the more power will lose in the cable
v. Turbulence disrupts the air flow which can wear down the blades and reduce the life cycle of the turbine
vi. Smaller turbines require an average wind speed of over 4.5 meter per second to produce an efficient level of electricity
vii. Require planning permission before you can install your wind turbine
viii. If the location is next to listed building in a conservation area or in an area of natural beauty my experience difficulties when trying to obtain planning permission.

4. WIND ENERGY CONVERSION SYSTEM

The natural wind as an energy source is extremely variable. In order to protect the energy output of a wind energy conversion system there has been considerable interest in finding a suitable statistical model of wind speed frequency distribution in the last few years. Traditional windmills were used extensively in the middle ages to mill grain and lift water for land drainage and watering cattle. Wind energy converters are still used for these purposes today in some parts of the world but the main focus of attention now lies with their use to generate electricity. Differential heating of the Earth's surface by the sun causes the movement of large air masses on the surface of the earth, i.e. the wind. Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. Wind power generation has experienced a tremendous growth in the past decade and has been recognized as an environmentally friendly and economically competitive means of electric power generation. The fuel mix for the world's electricity generation in 1999 indicates that fossil fuels accounted for 62% while renewable resources including hydropower, wind and solar etc., accounted for 20.2%. The term windmill still widely used to describe wind energy conversion systems. Wind energy conversion systems are more correctly referred to as WECS, aero generators, wind turbine generators or simply wind turbines. By addition of the electrical generator and other blocks the wind energy is converted into electrical energy and is used locally for various purposes.

4.1 Lift and Drag

The basis for wind energy conversion is lift and drag forces. The extraction of power and hence energy from the wind depends on creating certain forces and applying them to rotate a mechanism. There are two primary mechanism for producing forces from the wind.

Drag forces in the direction of the air flow and lift forces perpendicular to the air flow. Either or both of these can be used to generate the forces needed to rotate the plates of a wind turbine. Lift forces are produced by changing the velocity of the air stream flowing over other side of the lifting surface. In other words, any change in velocity generates a pressure difference across the lifting surface. This pressure difference produces a force that begins to act on the high-pressure side and moves towards the low-pressure side of the living surface which is called an airfoil. A good airfoil has a lift or drag ratio in some cases it can generate lift forces perpendicular to the airstream direction that are 30 times as great as the drag force parallel to the flow. For efficient operation, of wind turbine blade needs to function with as much lift and as little drag as possible because track dissipates energy.

4.2 Drag Based Wind Turbine

In drag-based wind turbines, the force of the wind pushes against a surface, like an open sail. In fact, the earliest wind turbines dating back to ancient Persia used this approach. The Savonius rotor is a sample drag based windmill that you can make at home. It works because the drag of the open, or concave, face of the cylinder is greater than the drag on closed or convex section.

4.3 Lift Based Wind Turbines

More energy can be extracted from wind using lift rather than drag, but this requires special is saved airfoil surfaces, like those used on airplane wings. The airfoil shape is designed to create a differential pressure between the upper and lower surfaces, leading to a net force in the direction perpendicular to the wind direction. Rotors of this type must be carefully oriented (the orientation is referred to as the rotor pitch) to maintain their ability to harness the power of the wind as wind speed changes.

5. BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEM

Greenhouse gas production has been one of the crucial and inevitable global challenges, especially for the last two decades as more evidences on global warming have been reported. This has drawn increasing attention to renewable energies including wind energy, which is regarded as a relative leave mature technology. It recorded 159 GW for the total wind energy capacities in 2009, which is the highest capacity among the existing renewable energy sources with excluding large scale hydro power generators. Also, its annual insulation growth rate marked 31.7% in 2009 with its growth rate having been increasing for the last few years, which indicates that wind energy is considered one of the fastest growing and attractive renewable energy sources. The increasing price competitiveness of wind energy against other conventional fossil fuel energy sources such as coal and natural gas is another positive indication on wind energy. Therefore, a vast amount of researches on WECS have been and is being undertaken intensively. WECS consists of three major aspects aerodynamic mechanical and electrical. The electrical aspect of WECS can further be divided into three main components, which are wind turbine generators (WTGs),power electronic converters (PECs)and the utility grid. Summary of the system operation is as follows., Aero turbines convert energy in moving air to rotary mechanical energy. Pitch control and yaw control are required only in case of horizontal or wind axis machines for proper operation.

6. CLASSIFICATION OF WEC SYSTEMS

6.1 Horizontal Axis machines

Horizontal Axis machines are manufactured very widely. The axis of rotation is horizontal and the air turbine plane is vertical facing the wind. The three-blade version is the most essential all over the world for unit ratings from 15 KW to 3 MW. Horizontal Axis wind turbines have their axis of revolution even to the ground and just about parallel to the wind stream. Most of the commercial wind turbines fall to this class. Horizontal Axis machines have some unique preferences for example low cut in wind pace and simple rolling. All in all, the indicate generally high-power coefficient. However, the generator and gearbox of these turbines are to be set over the tower which makes its plan more unpredictable and expensive. An alternate impediment is the requirement for the tail or yaw had to turn the turbine towards wind.

There are many types of horizontal axis wind turbine:

i. Rotor with reversal blades
ii. Several rotors installed on one tower to reduce the cost of tower on the condition of a certain output power
iii. Tapered hood to ensure thatwhen the gas flow goes through the horizontal axis in a centralized or decentralized way in order to increase or decrease the speed
iv. Some with whirlpool shaped by the horizontal axis winter wind around the rotor to centralize the wind and raise the speed of the gas flow.

Size is only one design consideration for wind turbines. The number of turbine blades where is between wind machines, along with the blade's aerodynamic properties such a taper, twist and cross-sectional shape. Other advances in wind turbine technology continue today, leading to more powerful and more efficient wind turbines which will be used to power more of the world in coming years. Some of the main design considerations are outlined below:

- The blades of wind turbine rotor are made from wood, metal or composites of several materials. But at present carbon fibers are used which are lightweight and flexible with immense strength.
- Wind turbines have been built with up to six propellers type blades but two and three bladed propellers are most common.
- Wind turbine blades have an airfoil type cross section and a variable pitch. Better performance of windmill is obtained when the blades are narrower at the tip than at the root.
- The area of the wind streams swept by the wind turbine is maximum when blades face into the wind. This is achieved by control arrangement in which when the wind direction changes a motor rotates the turbine slowly about the vertical axis so as to face of the blades into the wind.
- The horizontal wind turbines are mounted on towers and there are wind forces on the tower.
- Airfoils wind turbine cutting ages have an airfoil short cross segment and variable pitch. For the proficient energy extraction cutting edges of current wind turbine are made with airfoil sections. The airfoils utilized for the prior days wind turbines were of flight airfoils under the NACA (National Advisory Committee for Aeronautics) arrangement.

6.2 Vertical Axis machines

The axis of rotation is vertical and the blades may also be vertical and are built commercially by a few manufacturers. The sails or blades may also be vertical as on the ancient Persian wind mills or nearly so as on the modern Darrieus rotor machine. Two types of designs are commercially successful. The wind turbines mounted with the axis of rotation in vertical position have the accompanying notable favorable circumstances like:

i. They are omnidirectional. They do not need the complete yaw control. This type of wind mill captures wind in any direction because their operation is independent of wind direction.
ii. They require less structural support because heavy components like gear generators are located at the base level.

The following are two types of vertical wind rotor:

6.2.1 Savonius Rotor

Savonius wind turbines are vertical Axis wind turbines, or VAWT, and are used foe wind force conversion into torque through the rotation of the main shaft. Savonius wind turbines are mainly operate on the drag of the aerofoils by their opposite directions and their interaction with the wind movement and works like a cup anemometer. This wind turbine was invented by engineer Sigurd Johannes Savonius in the year of 1920. This machine has become popular, since it requires a relatively low velocity winds for operation. The fundamental characteristic of this turbine is that, it is self-beginning, has low speed and low productivity.

6.2.2 Darrieus Rotor

This machine was invented originally and patented in 1925 by G.J.M. Darrieus, a French engineer and his concept has recently been given serious consideration once again. The Darrieus rotor is a vertical axis wind turbine (VAWT) with two or more cutting ages having an aerodynamic airfoil. The plates are typically twisted into a chain and associated with the center at the upper and easier side both the closure of sharpened pieces of steels are joined to a vertical shaft. Hence, energy in the sharpened steel because of wind rotation is pure tension. This gives a solid ness to help withstand the wind strengths it encounters and the sharpened pieces of steel are made lighter than in the propeller sort.

➢ **Characteristics of Darrieus Rotor**

i. Self-starting
ii. High speed
iii. High efficiency
iv. Potentially low capital cost

➢ **Advantage of Darrieus Rotor**

i. The rotor shaft is vertical. Therefore, it is possible to place the load, like a generator or a centrifugal pump at the ground level. As the generator housing is not rotating, the cable to the load is not twisted and no brushes are required for large twisting angles.
ii. The rotor can take wind from every direction.
iii. The visual acceptation for placing of the windmill on a building might be larger than for and horizontal axis windmill.
iv. Airfoil rotor fabrication costs are expected to be reduced over conventional rotor blade costs.
v. the major advantage of this design is that the rotor blades can accept the wind from any direction.

➢ **Disadvantages of Darrieus Rotor**

i. The angle of attack varies strongly and therefore the lift, the drag varies strongly too.
ii. Because the blade load is fluctuating strongly,this result, especially for a two-blade rotor in strong fluctuating loads on the tower and the foundation.
iii. Starting torque coefficient is zero and at low tip speed ratios it is given negative. Therefore, a special motor is required to start the rotor.
iv. It is difficult to protect the rotor against high wind speeds. Turning the rotor out of the wind is not possible.
v. A very large bending moment is created in the rotor shaft, if it is not supported at the top because supported the top requires a large, wide guiding.
vi. For a traditional Darrieus rotor with blades bent into a chain line, the upper and lower parts of the blade don't contribute to the torque or even have a negative torque because the local radius and therefore the tip speed ratio is too small.

7. ENVIRONMENTAL ASPECTS

Wind turbines are not without environmental impact and their operation is not entirely risk free. Following are the main issues pertaining to a wind turbine are as follows:

i. Bird and bat deaths: Turbines are proven to kill birds and bats. Bird and bad debts are one of the most controversial biological issues related to wind turbines. Turbines are proven to disrupt wild animals and their natural habitats.
ii. Weather and climate change: Wind farms may affect weather in their immediate vicinity. Spinning wind turbine rotors generate a lot of turbulence in the air. This turbulence increases vertical mixing of heat and water vapor that affects the Meteorological conditions downwind. Overall wind farms lead to a slight warming at night and slight cooling during the daytime.
iii. Noise: Like all mechanical systems wind turbines produce some noise when they operate. Most of the turbine noise is marked by the sound of the wind itself and turbines run only when the wind blows revolving blade generates noise which can be heard in the immediate vicinity of the installation.
iv. Other concerns: Unlike most other generation technologies wind turbines do not use conversion to generate electricity and hence don't produce air emissions. The only potentially toxic or hazardous materials are relatively small amounts of lubricating oils and hydraulic and insulating fluids therefore contamination of surface or ground water or soil is highly suspected.The primary health and safety considerations related to blood movements and the presence of industrial equipment in areas potentially accessible to the public.

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