

Wind Turbines: A Sustainable Electricity Generation from the Kinetic Power of the Wind

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Abstract

Wind turbines are used to generate electricity from the kinetic power of the wind. A wind turbine is a device that converts kinetic energy from the wind into electricity. Wind turbine systems for homes are one of the more cost effective forms of generating electricity from a renewable energy source if you have the right site. It has a lower impact on the environment and climate, reduces dependence on fossil fuel imports and increases security of energy supply. In this paper we will discuss about the working of wind turbines and how it has become one of the most sustainable renewable energy resources for electricity generation.

Keywords: *Kinetic Power, Wind Turbines, Renewable energy resources, Electricity Generation*

I. INTRODUCTION

In recent years, wind energy has become one of the most economical renewable energy technology. Today, electricity generating wind turbines employ proven and tested technology, and provide a secure and sustainable energy supply. At good, windy sites, wind energy can already successfully compete with conventional energy production [1]. Many

countries have considerable wind resources, which are still untapped.

The technological development of recent years, bringing more efficient and more reliable wind turbines, is making wind power more cost-effective. In general, the specific energy costs per annual kWh decrease with the size of the turbine

notwithstanding existing supply difficulties.

Many African countries expect to see electricity demand expand rapidly in coming decades. At the same time, finite natural resources are becoming depleted, and the environmental impact of energy use and energy conversion has been generally accepted as a threat to our natural habitat. Indeed these have become major issues for international policy. [2]



Fig 1: Wind Turbines

Many developing countries and emerging economies have substantial unexploited wind energy potential. In many locations, generating electricity from wind energy offers a cost-effective alternative to thermal power stations. It has a lower impact on the environment and climate, reduces dependence on fossil fuel imports and increases security of energy supply [3].

Wind turbine systems for homes are one of the more cost effective forms of generating electricity from a renewable energy source

if you have the right site. In general terms, a site that has at least a half-acre of open land and average of 10 mph (16km/h) or higher winds is a good candidate for a wind turbine installation.

It is possible to have a system that only gets its power from wind, however, many people combine getting power from a wind turbine with getting power from a solar electric system. The two technologies are often complimentary: when there's little sun (e.g. during the winter or when it's overcast), there's often more wind and vice versa.

The most commonly used wind turbines for homes are usually not very large - ranging from 3 feet (~1 meter) to 6 feet (~2 meters) in diameter. There are also some like the Bergey Excel which are as large as 22 feet (6.7 meters) in diameter and used for more energy consumptive homes or businesses.

The blades of a wind turbine turn between 13 and 20 revolutions per minute, depending on their technology, at a constant or variable velocity, where the velocity of the rotor varies in relation to the velocity of the wind in order to reach a greater efficiency.

Most of the small wind turbines that are available for use with individual homes and business produce no more noise than the wind would whispering through the leaves of a tree. Small wind turbines have also been shown to hurt fewer birds than glass patio doors that are so common on many US homes.

For many years now, developing countries and emerging economies have been faced with the challenge of meeting additional energy needs for their social and economic development with obsolete energy supply structures. Overcoming supply bottlenecks through the use of fossil fuels in the form of coal, oil and gas increases dependency on volatile markets and eats into valuable foreign currency reserves. At the same time there is growing pressure on emerging newly industrialized countries in particular to make a contribution to combating climate change and limit their pollutant emissions.

In the scenario of alternatives, more and more developing countries and emerging economies are placing their faith in greater use of renewable energy and are formulating specific expansion targets for a 'green energy mix'. Wind power, after having been tested for years in industrialized countries and achieving

market maturity, has a prominent role to play here. In many locations excellent wind conditions promise inexpensive power generation when compared with costly imported energy sources such as diesel. Despite political will and considerable potential, however, market development in these countries has been relatively slow to take off. There is a shortage of qualified personnel to establish the foundations for the exploitation of wind energy and to develop projects on their own initiative. The absence of reliable data on wind potential combined with unattractive energy policy framework conditions deters experienced international investors, who instead focus their attention on the expanding markets in Western countries.

It is only in recent years that appreciable development of the market potential in developing countries and emerging economies has taken place. The share of global wind generating capacity accounted for by Africa, Asia and Latin America reached about 20% at the end of 2008, with an installed capacity of 26 GW. This is attributable above all to breathtaking growth in India and China: these two countries alone are responsible for 22 GW. This proves that economic use of wind energy in developing countries and

emerging economies is possible, and also indicates that there is immense potential that is still unexploited [4].

II. HOW WIND TURBINES WORKS

Wind power involves converting wind energy into electricity by using wind turbines. A wind turbine usually has 3 propellers-like blades called a rotor. The rotor is attached to a tall tower. On average wind towers in residential settings are about 20m high. The reason why the tower is so tall is because winds are stronger higher from the ground and there's less of a buffeting effect.

The terms "wind energy" and "wind power" both describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy from the wind into mechanical power. This the terms "wind energy" and "wind power" both describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy from the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

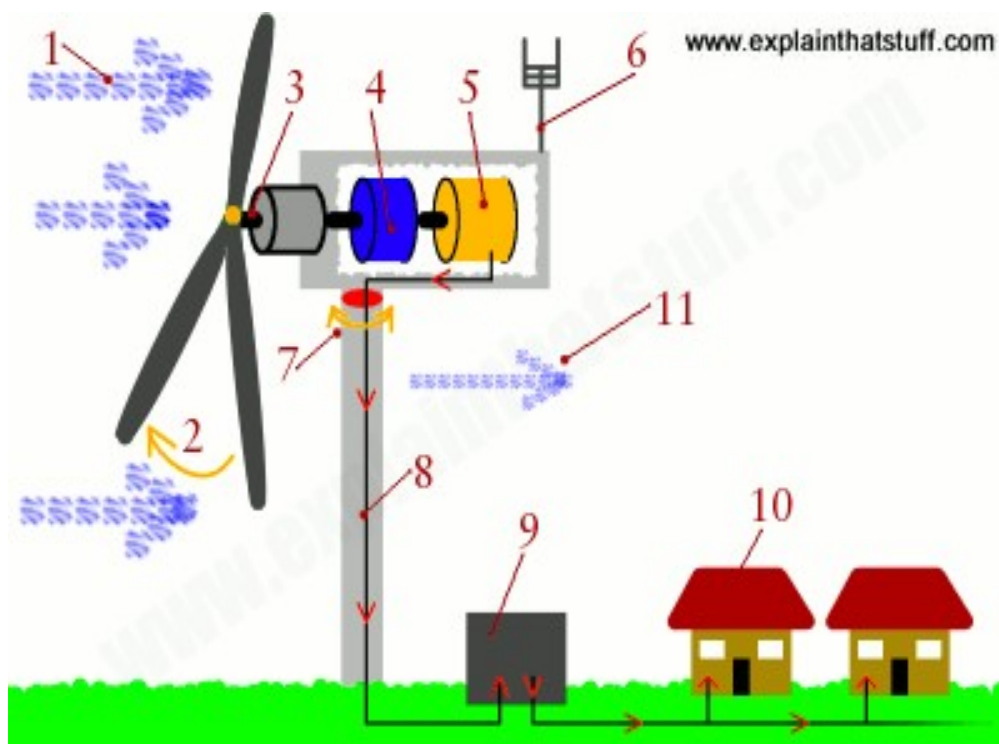


Fig 2: Working of Wind Turbines

- 1) Wind (moving air that contains kinetic energy) blows toward the turbine's rotor blades.
- 2) The rotors spin around, capturing some of the kinetic energy from the wind, and turning the central drive shaft that supports them. Although the outer edges of the rotor blades move very fast, the central axle (drive shaft) they're connected to turns quite slowly.
- 3) In most large modern turbines, the rotor blades can swivel on the hub at the front so they meet the wind at the best angle (or "pitch") for harvesting energy. This is called the pitch control mechanism. On big turbines, small electric motors or hydraulic rams swivel the blades back and forth under precise electronic control. On smaller turbines, the pitch control is often completely mechanical. However, many turbines have fixed rotors and no pitch control at all.
- 4) Inside the nacelle (the main body of the turbine sitting on top of the tower and behind the blades), the gearbox converts the low-speed rotation of the drive shaft (perhaps, 16 revolutions per minute, rpm) into high-speed (perhaps, 1600 rpm) rotation fast enough to drive the generator efficiently.
- 5) The generator, immediately behind the gearbox, takes kinetic energy from the spinning drive shaft and turns it into electrical energy. Running at maximum capacity, a typical 2MW turbine generator will produce 2 million watts of power at about 700 volts.
- 6) Anemometers (automatic speed measuring devices) and wind vanes on the back of the nacelle provide measurements of the wind speed and direction.
- 7) Using these measurements, the entire top part of the turbine (the rotors and nacelle) can be rotated by a yaw motor, mounted between the nacelle and the tower, so it faces directly into the oncoming wind and captures the maximum amount of energy. If it's too windy or turbulent, brakes are applied to stop the rotors from turning (for safety reasons). The brakes are also applied during routine maintenance.
- 8) The electric current produced by the generator flows through a cable

running down through the inside of the turbine tower.

- 9) A step-up transformer converts the electricity to about 50 times higher voltage so it can be transmitted efficiently to the power grid (or to nearby buildings or communities). If the electricity is flowing to the grid, it's converted to an even higher voltage (130,000 volts or more) by a substation nearby, which services many turbines.

- 10) Homes enjoy clean, green energy: the turbine has produced no greenhouse gas emissions or pollution as it operates.

- 11) Wind carries on blowing past the turbine, but with less speed and energy (for reasons explained below) and more turbulence (since the turbine has disrupted its flow).

III. TYPES OF WIND TURBINES

Horizontal and Vertical Axis Wind Turbine



Fig 3: Vertical and horizontal axis turbines used for residential electricity generation

a) Wind comes from atmospheric changes: changes in temperature and pressure make the air move around the surface of the earth. All of which is triggered by the sun. So in a way, wind energy is another form of solar power.

b) A wind turbine captures the wind to produce energy. The wind makes the rotor spin; as the rotor spins, the movement of the blades drives a generator that creates energy. The motion of the blades turning is kinetic energy. It is this power that we convert into electricity.

IV. WIND TURBINE FEATURES

How do wind turbines produce energy? The functioning of a wind turbine can be explained in function of the following phases:

a) Automatic orientation

The wind turbine is automatically oriented to take maximum advantage of the kinetic energy of the wind, from the data registered by the vane and anemometer that are installed at the top. The nacelle turns around a crown located at the end of the tower.

b) Turning of the blades

The wind makes the blades turn, which start to move with wind speeds of around

3.5 m/s and provide maximum power with a wind speed 11 m/s. With very strong winds (25 m/s), the blades are feathered and the wind turbine slows down in order to prevent excessive voltages.

c) Gearbox

The rotor (unit of three blades set in the hub) turns a slow axis that is connected to a gear box that lifts the turning velocity from 13 to 1,500 revolutions per minute.

d) Generation

The gearbox transfers its energy through a fast axis that is connected to the generator, which produces the electricity.

e) Evacuation

The energy generated runs through the inside of the tower to the base. From there, the energy runs over an underground line to the substation, where its voltage is raised in order to inject it into the electrical grid and distribute it to the points of consumption.

f) Monitoring

All of the critical functions of the wind turbine are monitored and supervised from the substation and the control center in order to detect and resolve any incidents.

ADVANTAGES & DISADVANTAGES

a) Advantages

The advantages of wind energy are more apparent than the disadvantages. The main advantages include an unlimited, free, renewable resource (the wind itself), economic value, maintenance cost, and placement of wind harvesting facilities.

- First and foremost, wind is an unlimited, free, renewable resource. Wind is a natural occurrence and harvesting the kinetic energy of wind doesn't affect currents or wind cycles in any way.
- Next, harvesting wind power is a clean, non-polluting way to generate electricity. Unlike other types of power plants, it emits no air pollutants or greenhouse gases.
- The wind turbines harmlessly generate electricity from wind passing by. Wind energy is far more ecofriendly than the burning of fossil fuels for electricity.
- Once turbines and energy centers have been installed, the cost of maintaining turbines and generating wind power is next to nothing.
- Another advantage of wind power is the ability to place turbines wherever

necessary. After performing research and finding areas that have adequate wind, experts may place the turbines in desired areas. These areas are usually unpopulated (offshore wind turbines, for example). In fact, offshore winds tend to blow harder and more uniformly than on land, providing the potential for increased electricity generation and smoother, steadier operation than land-based wind power systems. Fig. 4 shows offshore wind turbines harvesting energy.



Fig. 4: Offshore wind turbines in the Irish Sea (Source: Wikimedia Commons)

b) Disadvantages

The two major disadvantages of wind power include initial cost and technology immaturity.

Firstly, constructing turbines and wind facilities is extremely expensive. High cost of energy can, in part, be addressed directly with technology innovations that

increase reliability and energy output and lower system capital expenses. Offshore wind energy produces more energy than onshore wind energy, but costs much more to establish. The primary costs of wind turbines include construction and maintenance.

The second disadvantage is technology immaturity. New technology is needed to lower costs, increase reliability and energy production, solve regional deployment issues, expand the resource area, develop infrastructure and manufacturing facilities,

and mitigate known environmental impacts. Therefore, one may argue that implementation of wind energy must be delayed until technological advancements are made.

Other disadvantages include:

- **Aesthetic impact:** Many people are concerned with the visual effects that wind turbines have on the beautiful scenery of nature. They believe that giant wind turbines distract viewers from the beautiful surroundings. Fig. 5 shows just how big wind turbines can be.



Fig. 5: Turbine blade convoy passing through Edenfield, England (Source: Wikimedia Commons)

- **Wildlife:** Wind turbines may be dangerous to flying animals. Many birds and bats have been killed by flying into the rotors. Experts are now conducting research to learn more about the effects that wind turbines have on marine habitats.
- **Remoteness of location:** Although this may be an advantage (placing wind turbines in desolate areas, far away from people), it may also be a disadvantage. The cost of travel and maintenance on the turbines increases and is time consuming. Offshore wind turbines require boats and can be dangerous to manage.
- **Noise:** Some wind turbines tend to generate a lot of noise which can be unpleasant
- **Safety at Sea:** In the darkness/at night it may be difficult for incoming boats to see wind turbines thus leading to collisions.

VI. LIMITATIONS

a) No electricity when there is any wind

The limitation of wind power is that no electricity is produced when the wind is not blowing. Thus, it cannot be used as a dependable source of base load power.

Utilities and merchant generators will not invest huge sums of money into a technology that does not work when the wind is not blowing.

b) Wind Turbines Killing Migrating Birds

It has been estimated that about 45,000 birds (golden eagles, kestrels and red-tailed hawks) have been killed over the past twenty years by the whirling blades of wind turbines. Past attempts to reduce bird kills have included painting the tips of turbine blades to try to make them more visible to birds and installing screens around generators. These measures have failed to substantially lower the number of bird deaths.

CONCLUSION

In recent years, wind energy has become one of the most economical renewable energy technologies. Today, electricity generating wind turbines employ proven and tested technology, and provide a secure and sustainable energy supply. The technological development of recent years, bringing more efficient and more reliable wind turbines, is making wind power more cost-effective.

The advantages of wind energy are more apparent than the disadvantages. The main

advantages include an unlimited, free, renewable resource (the wind itself), economic value, maintenance cost, and placement of wind harvesting facilities. We should build wind turbines where there is too much of wind, like near sea so there will be 24 hours electricity and the problem of electricity will be solved and also there will be fewer birds near sea so the problem of killing birds will also be solved.

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