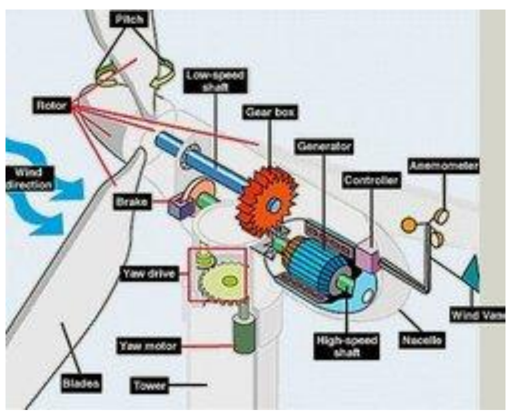
Wind power

Ardrossan windfarm, Scotland. Source: Environmental Protection Agency

Wind power is the conversion of natural air flow in the Earth's atmosphere to useful mechanical or electrical energy. With the world's oil supply slowly diminishing and recognition of air pollution impacts associated with coal-fired power plants, renewable energy is a desirable alternative. Wind power is one form of renewable energy that could potentially reduce the world dependence on fossil fuels.

Wind power is considered renewable energy because it utilizes an atmospheric resource of kinetic energy that is driven by the ongoing power of the sun. However, there are significant drawbacks to wind power, chiefly among which are: (a) undependable feeding of power to the grid due to vicissitudes in winds; (b) consumption of considerable amounts of real estate for installation; and (c) significant impacts on biota including turbine killing of considerable numbers of birds and bats.



Wind turbine components. Source: Wind Energy Development Programmatic EIS Information Center, Argonne National Library

Wind turbines convert kinetic to mechanical energy that a generator then uses to produce electrical energy. The two main types of wind turbines manufactured and used by commercial companies today are vertical- and horizontal-axis turbines. The more common type for wind turbines and wind farms is the horizontal-axis turbine.

Montana DNRC employees stand next to one of the propellers for the wind turbines. Source:Montana Department of Natural Resources and Conservation

Horizontal-axis turbines are characterized by having a shaft and generator within a nacelle along with a rotor having typically two or three blades. The nacelle is typically fixed on a yaw ring near the apex of a large concrete or steel tower. Also within the nacelle of upwind turbines are the yaw motor and drive and a brake. The yaw drive is needed to rotate the blades to face into the wind, independent of the wind direction.

Various mechanisms, including blade pitching, are employed in order to control the blade rotation speed. The brake may be applied mechanically or electrically to stop the rotor during emergencies or when the wind reaches speeds upwards of fifty miles per hour. The rotor connects the blades to the shaft, which rotates and drives the generator that normally produces 50 or 60-cycle alternating current electricity, depending upon the electrical standards within the particular country. Wind turbines are also equipped with an anemometer to measure wind speeds and a vane that measures wind direction, both of which are connected to an internal controller. The chief optimization criterion is the maintenance of an optimal attack angle, which angle is reckoned by the wind vector with respect to the blade plane; this criterion is termed the optimum tip speed ratio.

Physics of wind energy

Wind turbine blades work in the manner of airfoils. This is the same concept utilized by airplane wings. The blades have a curved surface, which creates a pressure difference between the two sides that produces lift, and therefore rotation. Blades are also twisted to optimize the angle of attack from blade tip to blade root. For many turbine designs, blades begin to rotate when the a wind ambient wind speed attains a threshold value of about four meters per second. When the generator is operating at its maximum rated power, control mechanisms (passive or active) limit power to this maximum even in strong wind regimes.

The total energy fluxing through an imaginary vertical plane can be represented by the kinetic energy:

$$E = \tfrac{1}{2}\, m \cdot v^2 = \tfrac{1}{2}\,(A \cdot v \cdot t \cdot \rho)\, v^2$$

Where m is the mass of air per unit of time, A is the area intercepted by the turbine, v is the wind velocity, ρ is the air density, and t is the elapsed time. Since the power generated is energy per unit time, the wind power produced is:

$$P = E/t = \tfrac{1}{2}\, A \cdot \rho \cdot v^3$$

Thus wind power varies as the cube of wind velocity. Tower heights are dependent on blade diameters; longer blades and taller towers generally produce more electricity, since higher velocity winds generally occur aloft. Even though taller towers produce more electricity they are more expensive to manufacture and construction is more difficult. For example, A 1.5 megawatt model typically may have 40 meter long blades with a 70 meter high tower. This equates to a total hardware height of 110 meters.

History

Using the wind for power is not a new idea. Centuries ago people harvested the wind with sails to power their boats and ships. In circa 500 AD the Persians built vertical-sail windmills called Panemones that were used to grind grain and pump water. The Chinese were the next to build windmills for the same reasons in 1219 AD. The windmills in China were similar because they were built by Persians brought to China by Genghis Khan.

Some of the first horizontal-access windmills were built in Western Europe, including the Wrawby Post Mill located in North Lincolnshire, England, which was built in 1790. It is now used for educational purposes as well as being a local tourist attraction. Some of the most famous windmill manufacturers are the Dutch. In the late 1300s they began building post mills. The post mill dynamic is similar to the modern-day yaw drive. The top portion of the mill has to be physically turned so the blades are oriented into the wind to harvest the most energy.

The first patented wind turbine for generation of electricity was developed by Scottish academic Professor James Blyth in the year 1891. However it was the Danish scientist, Poul la Cour (1846-1908), who is considered a pioneer of electricity-generating wind turbines of commercial significance. His formal training was in meteorology, yet he was concerned with the storage of energy, specifically to power a light used in a local school, which led him to conduct experiments in a self built wind tunnel. He first produced electricity using a windmill in 1892. He was also was the founder of the Society of Wind Electricians in 1905 and published the world's first journal of wind electricity. In the early twentieth century over one hundred Danish utility companies had wind turbines due mainly to his research and hard work. Further advancements were made by the Dutch during the World Wars to combat widespread energy shortages. They are still considered today to be at the forefront of wind technology.

The United States joined the rest of the world in respect to wind power in the mid nineteenth century, and Daniel Halladay is most noted for his contributions. The Connecticut resident's company manufactured windmills for the American West to pump water to livestock and provide railroads with water. As Americans moved west, railroads used the windmills more to pump water for their steam engines. Wind technology continued to grow in America. In the late 1800s individuals were able to purchase windmills to aid in many farm chores including cutting wood and pumping water. In 1888 Charles F. Brush added to the wind power movement. He built an enormous windmill in his backyard that was used to power a light in his basement. It turned a direct current generator, which consequently produced a very small amount of electricity.

In the mid 1900s windmills were no longer needed due to the widespread distribution of electricity. America did not again visit the subject with such passion until the nineteen seventies at the beginning of the Arab Oil Embargo.

Benefits of wind power

A wind farm. Source: Wind Energy Development Programmatic EIS Information Center, Argonne National Library

The concept of renewable energy often sparks considerable debate, and wind power is in the middle of it. Wind is advantageous since it is a free, virtually inexhaustible resource that does not produce air pollution during its transformation from kinetic energy into electrical energy. Wind power reducescarbon emissions relative to fossil fuels, since, as wind power enters a grid system, marginal generation from fossil fuel combustion is lessened. Wind is generally found all across the globe, even if its useful threshold may be absent in certain seasons or times of day. Over time and due to continued advances in technology, the cost of production and utilization has decreased dramatically making it a much better alternative than its more expensive counterpart ofsolar energy.

Wind power is also a way to produce energy from an area while leaving parts of the land open, as opposed to large scale solar arrays, which may effectively destroy large areas of natural habitat. The majority of a wind turbine is above the ground surface, therefore taking up vertical air space and not valuable horizontal pasture lands. This makes it an investment for farmers who live and work in the open plains, increasing their profits while still allowing their livestock to graze.

Wind power also benefits communities. In the areas where wind farms are installed, jobs in construction, operation, and maintenance are sometimes created. Schools and other public services also profit from increased property taxes.

Furthermore, wind power is efficient for remote areas where it would be expensive to connect to an already existing power grid. Turbines can instead be installed to efficiently power an area at a more reasonable cost to consumers. And finally, if the turbine must be taken down there is less lasting effect on the environment than from the installation of large scale solar arrays, which arrays typically destroy most of the natural habitat.

Disadvantages of wind power

Although wind is available at a given geographical location throughout many times of the year, wind speeds vary, often over very short time scales (e.g. seconds or minutes) This gustiness places wind power at a disadvantage since it is not consistent. Therefore, wind power generation must always be supplemented by other sources of energy, in order to compensate for the time intervals when the wind is lacking which could include anything from other sources of renewable energy if available to a coal-fired power plant.

Manufacturing companies and investors claim their wind turbines blend into the surroundings and add to the landscape, although this is not a view shared by many people living near the large turbines. Turbines are often considered to be a visually undesirable feature that ruin a natural landscape. Some farmers and others whose land is home to the turbines and wind farms feel their views are tainted by the large, gray monstrosities that litter the sky. Besides being an eyesore some consider them to contribute to noise pollution. This noise can come from the blades as they pass through the air as well as the gearbox and generator located in the nacelle. Modern wind turbines are generally quieter than the earliest models; nevertheless, siting of a windfarm within several kilometres of sensitive receptors (such as residences or schools) can pose a significant adverse impact from noise intrusion. One reason for this outcome is that siting of most windfarms is conducted in relatively un-industrialized settings, where ambient sound levels are typically low.

Finally, what is considered to be the biggest problem is the number of turbines required to produce enough >electricity for an entire community. One or two wind turbines are not sufficient to produce large quantities of electricity. A town would need many turbines in a few nearby wind farms to fully rely on wind power whenever possible. And even then, as stated before, other electrical sources would need to be available when wind energy could not be used.

Wind turbine fire. Source: Moorsyde Action Group

There are also risks associated with wind power, specifically the turbines themselves. Lightning and overheating of the generator have caused fires in nacelles that eventually destroyed the entire turbine. There is also concern with bird deaths because of the placement of turbines in their migratory pathways. These risks have been, and can continue to be reduced with further research and improved placement of the turbines.

The future

Wind power has a place in the world's energy future. For instance, in 2008, more new wind turbines were installed in the United States than any other country in the world; Germany and Spain, on the other hand, still have the largest cumulative installed base. Six percent of the United States is considered to be suitable wind areas, from a power generation viewpoint, by the National Wind Technology Center: however, this amount of potential real estate is greatly diminished, when using siting decisions that consider bird migration corridors and raptor hunting areas. Research is also being done on the storage of wind energy and connecting it to existing power grids, in addition to improving materials and design. Advancement in all of these areas could lead to a decrease in the manufacturing and production costs associated with wind energy technology.

Offshore windfarms have been developed in coastal waters of Europe, particularly in Denmark, Scotland and Germany as well as in near-shore waters of the USA. An event took place on March 31, 2007 when the State Environmental Board of Massachusetts approved an offshore wind farm near Cape Cod. This project could consist of 130 turbines over a twenty-five mile radius area off the cost of Nantucket Sound. The farm would then produce seventy-nine percent of the electricity for the local area, and is predicted to be operational for twenty years.

References and further reading

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