Wind turbine power generation

Smaller wind turbines are used for applications such as battery charging and remote devices such as traffic warning signs. Larger turbines can contribute to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.[3]

Wind power first appeared in Europe during the Middle Ages. The first historical records of their use in England date to the 11th and 12th centuries; there are reports of German crusaders taking their windmill-making skills to Syria around 1190.[8] By the 14th century, Dutch windmills were in use to drain areas of the Rhine delta. Advanced wind turbines were described by Croatian inventor Fausto Veranzio in his book Machinae Novae (1595). He described vertical axis wind turbines with curved or V-shaped blades.

In Denmark by 1900, there were about 2500 windmills for mechanical loads such as pumps and mills, producing an estimated combined peak power of about 30 megawatts (MW). The largest machines were on 24-metre (79 ft) towers with four-bladed 23-metre (75 ft) diameter rotors. By 1908, there were 72 wind-driven electric generators operating in the United States from 5 kilowatts (kW) to 25 kW. Around the time of World War I, American windmill makers were producing 100,000 farm windmills each year, mostly for water-pumping.[15]

A forerunner of modern horizontal-axis wind generators was in service at Yalta, USSR, in 1931. This was a 100 kW generator on a 30-meter (98 ft) tower, connected to the local 6.3 kV distribution system. It was reported to have an annual capacity factor of 32 percent, not much different from current wind machines.[citation needed]

In the autumn of 1941, the first megawatt-class wind turbine was synchronized to a utility grid in Vermont. The Smith-Putnam wind turbine only ran for about five years before one of the blades snapped off.[17] The unit was not repaired, because of a shortage of materials during the war.[18]

The first utility grid-connected wind turbine to operate in the UK was built by John Brown & Company in 1951 in the Orkney Islands.[13][19]

It has been argued that expanding the use of wind power will lead to increasing geopolitical competition over critical materials for wind turbines, such as rare earth elements neodymium, praseodymium, and dysprosium. However, this perspective has been critically dismissed for failing to relay how most wind turbines do not use permanent magnets and for underestimating the power of economic incentives for the expanded production of these minerals.[24]

Wind Power Density (WPD) is a quantitative measure of wind energy available at any location. It is the mean annual power available per square meter of swept area of a turbine, and is calculated for different heights

above ground. Calculation of wind power density includes the effect of wind velocity and air density.[25]

Wind turbines are classified by the wind speed they are designed for, from class I to class III, with A to C referring to the turbulence intensity of the wind.[26]

The maximum theoretical power output of a wind machine is thus 16/27 times the rate at which kinetic energy of the air arrives at the effective disk area of the machine. If the effective area of the disk is A, and the wind velocity v, the maximum theoretical power output P is:

Efficiency can decrease slightly over time, one of the main reasons being dust and insect carcasses on the blades, which alter the aerodynamic profile and essentially reduce the lift to drag ratio of the airfoil. Analysis of 3128 wind turbines older than 10 years in Denmark showed that half of the turbines had no decrease, while the other half saw a production decrease of 1.2% per year.[33]

In general, more stable and constant weather conditions (most notably wind speed) result in an average of 15% greater efficiency than that of a wind turbine in unstable weather conditions, thus allowing up to a 7% increase in wind speed under stable conditions. This is due to a faster recovery wake and greater flow entrainment that occur in conditions of higher atmospheric stability. However, wind turbine wakes have been found to recover faster under unstable atmospheric conditions as opposed to a stable environment.[34]