Windmill power generation

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Wind power is the use of wind energy to generate useful work. Historically, wind power was used by sails, windmills and windpumps, but today it is mostly used to generate electricity. This article deals only with wind power for electricity generation.Today, wind power is generated almost completely with wind turbines, generally grouped into wind farms and connected to the electrical grid.

Wind power is one of the lowest-cost electricity sources per unit of energy produced. In many locations, new onshore wind farms are cheaper than new coal or gas plants.[9]

Regions in the higher northern and southern latitudes have the highest potential for wind power.[10] In most regions, wind power generation is higher in nighttime, and in winter when solar power output is low. For this reason, combinations of wind and solar power are suitable in many countries.[11]

The global wind kinetic energy averaged approximately 1.50 MJ/m2 over the period from 1979 to 2010, 1.31 MJ/m2 in the Northern Hemisphere with 1.70 MJ/m2 in the Southern Hemisphere. The atmosphere acts as a thermal engine, absorbing heat at higher temperatures, releasing heat at lower temperatures. The process is responsible for the production of wind kinetic energy at a rate of 2.46 W/m2 thus sustaining the circulation of the atmosphere against friction.[14]

The total amount of economically extractable power available from the wind is considerably more than present human power use from all sources.[18] The strength of wind varies, and an average value for a given location does not alone indicate the amount of energy a wind turbine could produce there.

To assess prospective wind power sites, a probability distribution function is often fit to the observed wind speed data.[19] Different locations will have different wind speed distributions. The Weibull model closely mirrors the actual distribution of hourly/ten-minute wind speeds at many locations. The Weibull factor is often close to 2 and therefore a Rayleigh distribution can be used as a less accurate, but simpler model.[20]

A wind farm is a group of wind turbines in the same location. A large wind farm may consist of several hundred individual wind turbines distributed over an extended area. The land between the turbines may be used for agricultural or other purposes. A wind farm may also be located offshore. Almost all large wind turbines have the same design -- a horizontal axis wind turbine having an upwind rotor with 3 blades, attached to a nacelle on top of a tall tubular tower.

Transmission system operators will supply a wind farm developer with a grid code to specify the requirements for interconnection to the transmission grid. This will include the power factor, the constancy of frequency,

and the dynamic behaviour of the wind farm turbines during a system fault.[32][33]

Offshore wind power is wind farms in large bodies of water, usually the sea. These installations can use the more frequent and powerful winds that are available in these locations and have less visual impact on the landscape than land-based projects. However, the construction and maintenance costs are considerably higher.[35][36]

As of November 2021, the Hornsea Wind Farm in the United Kingdom is the largest offshore wind farm in the world at 1,218 MW.[37]

Wind power resources are not always located near to high population density. As transmission lines become longer, the losses associated with power transmission increase, as modes of losses at lower lengths are exacerbated and new modes of losses are no longer negligible as the length is increased; making it harder to transport large loads over large distances.[39]

When the transmission capacity does not meet the generation capacity, wind farms are forced to produce below their full potential or stop running altogether, in a process known as curtailment. While this leads to potential renewable generation left untapped, it prevents possible grid overload or risk to reliable service.[40]