WEEK 2: WIND ENERGY AND TURBINE

Electricity produced from the wind produces no CO_2 emissions and therefore does not contribute to the greenhouse effect. Wind energy is relatively labor intensive and thus creates many jobs. In remote areas or areas with a weak grid, wind energy can be used for charging batteries or can be combined with a diesel engine to save fuel whenever wind is available. Moreover, wind turbines can be used for the desalination of water in coastal areas with little fresh water, for instance the Middle East. At windy sites the price of electricity, measured in $/kWh, is competitive with the production price from more conventional methods, for example coal fired power plants.

One of the drawbacks of wind energy is that wind turbines create a certain amount of noise when they produce electricity. In modern wind turbines, manufacturers have managed to reduce almost all-mechanical noise and are now working on reducing aerodynamic noise from the rotating blades.

Another disadvantage is that wind energy can only be produced when nature supplies sufficient wind. However, for most countries, which are connected to big grids and can therefore buy electricity from the grid in the absence of wind.

The wind turbine captures the wind’s kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture.

Numerous wind turbines are installed at one site to build a wind farm of the desired power generation capacity. Obviously, sites with steady high wind produce more energy over the year.

Wind turbines convert the kinetic energy of the air particles to the mechanical or electrical form. Turbine blades are the main tools to realize this conversion.

The efficiency of the conversion depends on the followings:

Meteorological data, Topography of the site, Blade profiles, Number of blades, Tower height.

Speed and Power Relations

- The kinetic energy in air of mass m moving with speed V is given by the following in joules:

$$\text{kinetic energy} = \frac{1}{2} m V^2$$

- The power in moving air is the flow rate of kinetic energy per second in watts:

$$\text{power} = \frac{1}{2}(\text{mass flow per second}) V^2$$

- If

P= mechanical power in the moving air (watts),

ρ = air density (kg/m^3),

A= area swept by the rotor blades (m^2), and

V= velocity of the air (m/sec),

- then the volumetric flow rate is AV, the mass flow rate of the air in kilograms per second is ρAV, and the mechanical power coming in the upstream wind is given by the following in watts:

$$P = \frac{1}{2}(\rho A V) V^2 = \frac{1}{2} \rho A V^3$$

- This is the power in the upstream wind.

- It varies linearly with the density of the air sweeping the blades and with the cube of the wind speed.
- The blades cannot extract all of the upstream wind power, as some power is left in the downstream air that continues to move with reduced speed.

References:

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