Renewable Energy

Third lecture Asst prof. Dr. Rudainah Ali

**Wind Energy**

now we study the technology for harnessing the resource for mechanical work (e.g. water pumping) and for electricity (often just called ‘power’). Wind turbine electricity generators, abbreviated to ‘wind turbines’, are the dominant machines, manufactured worldwide with capacities ranging from tens of watts to approaching ten megawatts, with diameters of about 1 m to about 150 m. Nevertheless, in some areas, mechanical-only machines are still vital for water pumping. Today wind turbines are accepted as ‘mainstream power generation’ for the utility grid networks of countries with wind power potential (e.g. in Europe, the USA, and parts of India and China). One of the main challenges with wind power is its intermittence and high variability, which requires systematic adjustments in operation as well as strategies to integrate the wind power into the grid.

Wind results from expansion and convection of air as solar radiation is absorbed on Earth. On a global scale these thermal effects combine with dynamic effects from the Earth’s rotation to produce prevailing wind patterns. The kinetic energy stored in the winds is about 0.7 × 1021 J, and this is dissipated by friction, mainly in the air but also by contact with the ground and the sea.

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Wind speed varies significantly with time over periods from seconds to seasons and years, and over distances ~1 km, especially in hilly terrain. Therefore it is important to make measurements at the nominated site at several heights for at least 12 months and compare these with official meteorological data and wind atlas information. The information enables the prediction of power generation from nominated turbines for the site.

A major design criterion for turbines is the need to protect the machine against damage in very strong and turbulent winds, even though such gale-force winds are relatively infrequent. Wind forces tend to increase as the square of the wind speed and the amplitude of turbulent variation increase similarly. Therefore fatigue damage may occur, especially related to the blades and drive train; so wind speed variation of one minute and less must be understood across the area of turbine rotor. Fortunately there are other industries and services that need to know about wind conditions and so information can be shared; this includes

meteorological services, agriculture, aircraft and airports, building and bridge construction, and road safety.

Wind turbines only operate where and when it is windy. Air is transparent to solar radiation and so is not heated until the radiation is absorbed in the ground and the ground heats the air above. The heated air near the ground expands, becomes less dense and rises through the colder air above. The

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heating effect is strongest near the Equator. This causes looped convection currents in the lower atmosphere there are a multitude of other effects with significant seasonal, regional and local variation

*(a) Effect of oceans and continents*

Solar radiation heats land quickly but oceans slowly; however, the thermal capacity of ocean near-surface water is large and so contrasts with continental

land mass. The relative effects are seasonal as solar inclination and other effects change through the year. Extreme winds occur in hurricanes (tropical cyclones) and monsoons as moisture, mostly taken from the ocean, condenses to water (rain) with the release of latent heat. Similar effects, but less extreme, occur in all cyclonic weather as air not only circulates, but moves upwards and downwards.

*(b) Effects of land shape*

The *complex terrain* of hills and mountains deflects and concentrates air

movement, with significant effect on wind. Daily variation of such winds

occurs due to uneven solar absorption and height differences, and with

concentration, as in valleys. Movement of air over mountains may lead

to deposition of rain on windward sides and air warmed by its increasing

pressure on the leeward side

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*(c) Effects by season and time*

In the great majority of locations, average wind speed and direction depend on the season in the year, and in many locations on the time of the day. Meteorological services know these effects well and can make reasonably reliable forecasts. However, there is almost complete ignorance about predicting variation from year to year, which for wind power can cause significant variation affecting the economics of installations.

Such comprehensive knowledge is needed to be able to choose productive wind turbine sites and to predict wind conditions and hence wind-generated power variation.

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TURBINE TYPES AND TERMS

The names of different types of wind turbine depend on their constructional geometry, and the aerodynamics of the wind passing around the blades; also called airfoils or aerofoils., the relative motion of air with a turbine blade section is essentially the same as with an airplane wing section. Fig. 1 shows a blade section of a horizontal axis wind turbine blade; the same principles apply to vertical axis turbines. For Fig. 1(c) imagine yourself looking down on a section of a vertical blade as it rotates. The section is rotating approximately perpendicular to the distant oncoming wind of speed u0. Because of its own movement, the blade section experiences oncoming air at relative velocity *v*r. The comparison can be made with an airplane wing section by turning the page so Fig. 1(c) has the relative air speed *vr* horizontal. As the air is perturbed by the blade, a force acts which is resolved into two components:

• The *drag force F*D is the component in line with the relative velocity *vr*.

• The *lift force FL* is the component perpendicular to *F*D*.* The use of the

word ‘lift’ does not mean that *F*L is necessarily upwards, and derives

from the equivalent force on an airplane wing

**Wind power technology**

The rapid growth of worldwide turbine power generation capacity is increase between 2000 and 2010, the average annual growth rate was 27% (compound), which is remarkably high. Since about 2002, much additional generation capacity is being installed at sea in offshore wind farms where the depth is < ~50m. Our analysis in succeeding sections outlines basic wind turbine theory; a key aspect is to determine dimensionless scaling factors which are so

important in engineering (e.g. for applying the results of experiments on physical models of a wind tunnel to the design and operation of very large structures). For instance, see §8.3; a turbine intercepting a cross section A of wind of speed u0 and density r produces power to its rated maximum according to