AVAILABILITY OF WIND ENERGY AND ITS ESTIMATION

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Summary

In common with most other renewable resources, wind energy, in being driven by differential heating of the earth's surface, has its primary source in the sun. Although atmospheric circulation and wind flows have thermal origins, the pattern is heavily influenced by global rotational inertial effects and by local geographical features. Different dominant driving forces exist at different points on the globe, and local flow disturbance caused by topography and obstacles nearly always provides additional micro effects.

As is the case for many renewables, wind energy is highly variable in strength. Wind speed is seldom constant and distinct patterns of variation in mean wind speed can nearly always be discerned on time scales of minutes, days and seasons. On a second-by-second basis large variations in wind speed can be expected and since power is proportional to the cube of the speed, this can give rise to highly erratic power production. Despite its variability, wind can be well described statistically and mature techniques exist whereby wind characteristics can be measured or modelled with reasonable accuracy and presented in a standard way. This in turn assists greatly in the selection of suitable sites for exploitation of wind energy.

In siting wind turbine developments, there are a number of obvious, simple rules. Winds at elevated locations are stronger than winds at sea-level. Winds accelerate over hill-top features. Winds off-shore are stronger and less turbulent than sea-level winds on-shore. In selecting appropriate sites, other factors, technical, financial and environmental factors, must also of course be considered.

1. The Sun as the Wind Driver

The primary cause of atmospheric circulation is the differential heating of the earth's surface by the sun. At the warm equatorial regions, air is heated and resulting buoyancy causes the air to rise. In the absence of additional effects, the air would migrate in the upper atmosphere to the colder polar regions where it would cool and descend, subsequently flowing at a lower level back to the equator where the circulation would be repeated.

This pattern is distorted however by the rotation of the earth from west to east. Rotation produces inertial forces which cause the winds to be deflected laterally (the so-called Coriolis effect) which in turn produce, in a rather complex manner, discrete circulatory cells over the polar and tropical regions (Figure 1). In the equatorial regions the circulation (termed Hadley circulation) is less affected by Coriolis effects and essentially continues to follow a general pattern of polarward migration in the upper atmosphere and migration towards the equator in the lower atmosphere. The associated surface winds are mainly easterlies (i.e. from the east). Nearer to the poles a much more complicated flow pattern emerges. The predominant phenomenon is that of waves of rising and falling air which circulate laterally around the globe (Rossby circulation), with relatively high associated wind speeds. Near to the poles and as in the tropics, prevailing surface winds are also generally of an easterly nature, whereas in the middle latitudes of both hemispheres, westerlies predominate.

Further complications to this already complex flow pattern occur due to the inhomogeneous thermal capacity of the surface of the earth, specifically between large land and water masses. Physical flow blockage by large mountain ranges provide an additional source of interference with atmospheric movement.

In middle latitudes, such as over Europe, the passage of high and low pressure systems dominates the weather. High and low pressure systems are produced by the thermally driven downward and upward motions of the atmosphere which are respectively associated with convergence and dispersion of air in the upper atmosphere. Pressure system wind flows are also subject to Coriolis forces, the net result being that winds are found to flow in spirals around rather than towards or away from the centre of weather systems. This effect is modified in the lower atmosphere by viscous, surface shear forces. The extent of the shearing action defines the so-called Surface Boundary Layer. This varies in depth but typically accounts for only the bottom 1 km of the 11 km deep troposphere. For wind energy purposes, it is what goes on within this boundary layer which is of primary interest, although the higher level and less variable geostrophic winds are useful for reference.

General large-scale atmospheric circulation is clearly very complex, but smaller scale local effects also play a very important role in determining the wind climate of a particular location.

Typical local effects include the Mistral winds in France where close alignment of the Rhône valley to the predominant isobaric direction produces considerable wind funnelling. Worldwide, in mountainous regions, thermal gradients which change in accordance with time of day lead to so-called anabatic and katabatic winds which in turn produce highly predictable winds in the valleys. Also in coastal regions, different thermal capacities of land and sea masses produce strong onshore and offshore winds that again depend upon the time of day.

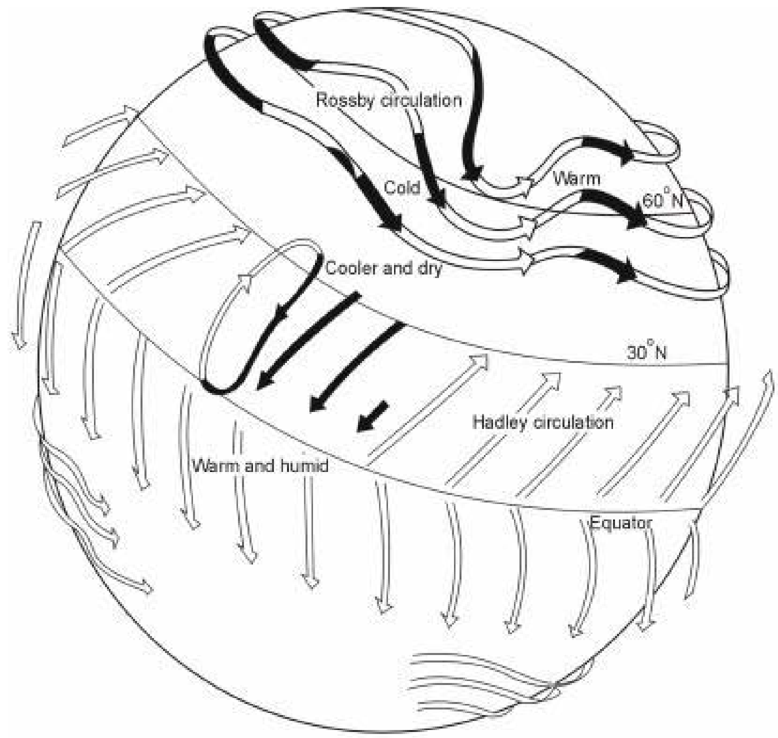

Figure 1. Major atmospheric circulations (after World Meteorological Office technical note 175, 1981).

Different parts of the globe are dominated to different degrees by such effects, and it is important to understand their relative importance when assessing the potential of a wind energy development. In California where wind driven electricity production on a large scale first took place, the anabatic/katabatic effects are very strong. In the North of Europe, where major wind energy markets have emerged, the winds are predominantly the result of wind flows around large scale weather systems, whereas in the South of Europe, where wind could provide a major contribution to the energy demand associated with desalination, local thermal effects may be dominant and can produce considerable predictability to the daily pattern of wind energy availability.

Nevertheless wind flows, even at the macro scale are clearly very complex, particularly in mid latitudes and accurate prediction more than a few days ahead is normally very difficult.

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