GLOSSARY

A

Active Stall Another term for pitch-to-stall WT power control (see Pitch Regulation).

Air Density The power output of a WT at a given wind speed increases with increasing air density, ie. the mass of the air per cubic metre of space at the WT location.

Anemometer An instrument for measuring wind speed. Ultrasonic, laser, hot wire and cup varieties are available: cup anemometers (consisting of a number of cups attached to an axle) are almost invariably used throughout the wind industry. Good quality anemometers are vital for accurate wind resource assessment.

Angle of Attack The angle between the oncoming wind and the blade chord.

Aspect Ratio The ratio of the characteristic chord of the blade to its length.

Auxiliary Costs Costs other than those of the turbine itself, ie. foundation, grid-connection, electrical installation, road construction, consultancy, financial charges, etc.

Availability The availability of a WT describes the amount of the time that it is actually functional, not out of order or being serviced. Clearly, the higher the availability the better.

B

Betz Limit The theoretical limiting efficiency of a WT (typically about 59%).

Blade The blades of a WT are the wing-like structures attached to the hub. A blade is very similar in look and function to an aeroplane wing - air flow past the blade generates aerodynamic lift which, in the case of a WT, causes the rotor to spin and makes power generation possible. Most modern electricity-generating WTs have three blades (the so-called "Danish concept"). However, many two-bladed examples also exist, and even one-bladed designs have been known. Rotors for water pumping and battery charging may have many more blades to allow them to function in low winds.

Blade Element-Momentum Theory (BEM) An aerodynamic theory linking the drag and lift forces experienced by each section of a WT blade to the change in momentum of air passing through the rotor disc.

Blade Passing Frequency The frequency at which the blades of a WT pass the tower. For a three-bladed WT, this will be three times the rotational frequency.

Boundary Layer The layer of the atmosphere in which interaction with the Earth's surface influences air flow patterns. The thickness of the boundary layer varies between about 100 m on clear nights with low wind speeds to 2 km on fine summer's days.

C

Carbon Dioxide (CO_2) CO_2 is "a naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance" (IPCC, 2001; p.70).

Capacity Credit A WT can only produce when the wind blows and, therefore, it is not directly comparable to a conventional power plant. The capacity credit is the percentage of conventional capacity that a given turbine can replace. A typical value of the capacity credit is 25% (see Capacity Factor), ie. 100 MW of wind power is assumed to replace 25 MW of conventional fossil fuelled capacity.

Capacity Factor The amount of energy a WT actually produces in a year, divided by the amount of energy if could theoretically produce if it were to run at its rated power 24 hours a day, 365 days a year. The capacity factor is expressed as a percentage; for a typical WT installation it is around 25%-30% (although it can get up to 50%).

Capital Costs The total investment cost of the turbine, including auxiliary costs.

CENELEC The European Committee for Electrotechnical Standardisation, a non-profit technical organisation composed of the National Electrotechnical Committees of 23 European countries. CENELEC's mission is to prepare voluntary electrotechnical standards to help develop the Single European Market/European Economic Area for electrical and electronic goods and services, so removing barriers to trade, creating new markets and cutting compliance costs.

Certification Authority An organisation which checks the designs of WT manufacturers and issues an independent assessment, often called a certificate. The most prominent are Det Norsk Veritas and Germanischer Lloyd.

Climate Change Defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability

observed over comparable time periods" (IPCC, 2001; p. 71).

Control Strategy Modern WTs feature computer control (the controller) whereby the computer will execute a given control strategy, telling the WT how to behave under different conditions. Examples of components of a control strategy would be the cut-in and cut-out wind speeds, when the WT should cut out in low, falling wind speeds and when it should cut back in at high, falling wind speeds when it has already cut out (see Hysteresis). Depending on the type of WT (fixed/variable speed, pitch/stall-regulated), there will be other more complicated logic in the control strategy.

Controller The computer equipment that monitors the turbine and controls its operation.

Coriolis Force A virtual force experienced by a body relative to a rotating body as it moves outward from the centre of rotation. For example, the Coriolis force causes air flowing southwards in the northern hemisphere to veer westwards relative to the rotating globe below; hence it has a huge influence on the behaviour of the atmosphere. It is a consequence of the principle of conservation of angular momentum (but should be distinguished from gyroscopic effects).

Coriolis Parameter A parameter describing the strength of the Coriolis force at any point on the globe, featuring in the log law.

Costs of Generated Wind Power See Levillised Costs.

Cut-In and Cut-Out Wind Speeds A WT is usually programmed only to start operating above a particular wind speed (the cut-in wind speed) and to stop operating when the wind speed exceeds another particular wind speed (the cut-out- wind speed). There is very little energy available below the cut-in wind speed, making operation of the WT unviable or impossible. Above the cut-out wind speed (typically 25 m/s) the loads on the WT could cause damage if it did not shut down. Though such high-speed winds are clearly very energetic, they are experienced so rarely at most locations that very little energy is wasted by cutting out at these speeds.

D

Data Logger The electronic equipment used to record the output of anemometers, wind vanes and other instruments (eg. air temperature and pressure gauges) at a monitoring station. Some data loggers store data on site, others are able to relay it to distant computer systems.

Dinotail An "add-on" device sometimes attached to a stall-regulated turbine blade which enhances the lift on a section. It extends backwards from the trailing edge and looks rather like a dinosaur tail.

Direct-Drive A new generation of WTs has recently emerged where the rotor is connected directly on a single shaft to a special high-torque, low speed generator without the use of a gear box. Such WTs are generally variable speed and feature power electronic converters to convert the frequency of the generated power to the grid frequency. Direct-drive WTs offer higher efficiency and lower noise levels due to the absence of a gear box, but the complex generator and power electronics may make them more expensive.

Direct Employment Direct employment is the total number of people (skilled, unskilled and self-employed) employed in companies belonging to a specific sector, ie. WT manufacturing.

Discount Rate The interest rate used to calculate the present-day cost of turbine installations.

Diurnal A term describing a daily frequency, ie. a period of 24 hours. Some weather effects occur on a diurnal basis, associated with the daily heating and cooling of the Earth's surface.

Doubly Fed Induction Generator (DFIG) The DFIG provides the operational advantages of an induction and a synchronous machine. It offers variable speed operation and the advantage of reactive power control. This is achieved by injecting appropriate currents into the rotor circuit of a wound rotor induction generator. Control of the frequency of the injected currents provides variable speed control of the machine, whereas manipulation of the magnitude and phase of the rotor currents provide power factor control.

Dynamic Stall As WT blades rotate, they experience constantly changing angles of attack due to wind shear and yaw. Under these conditions, a phenomenon known as dynamic stall (as opposed to static stall) occurs. The angle of attack will increase beyond the point at which the blade would normally have stalled in a quasi-static situation in a wind tunnel, but the delayed stall is very sudden and hard when it occurs at some large angle of attack, causing large loads in the blades and significant fatigue.

E

Edgewise Used to define the direction in an axis set in the rotating blade. Edgewise motion is motion in the plane of rotation and is perpendicular to flatwise motion.

Efficiency In general of any component, this describes the amount of energy coming out of the component as a percentage of the energy put into it. For a WT, it describes the amount of active electrical power generated as a percentage of the wind power incident on the rotor area (see also Betz Limit).

Emissions Defined by the UN (2002) as "the discharge of pollutants into the atmosphere from stationary sources such as smokestacks, other vents, surface areas of commercial or industrial facilities and mobile sources, for example, motor vehicles, locomotives and aircraft". With respect to climate change, emissions refer to "the release of greenhouse gases into the atmosphere over a specified area and period of time" (IPCC, 2001; p. 72).

Energy Pay-Back Period The amount of time it takes for a WT to generate as much energy is required to make the WT in the first place, install it, maintain it throughout its lifetime and, finally, scrap it(typically two to three months at a site with reasonable wind exposure).

Experience Curve The curve relates the cumulative quantitative development of a product with the development of the specific costs. Thus, the more that is produced of a product, the more efficient the production process and the cheaper it becomes.

External Costs Those costs incurred in activities which may "cause damage to a wide range of receptors, including human health, natural ecosystems and the built environment" (European Community, 1994), and yet are not reflected in the price paid by consumers.

F

Fatigue The phenomenon by which a repeated loading and unloading of a structure causes its various components to gradually weaken and eventually fail. Owing to the highly repetitive nature of WT operation, fatigue is a serious issue.

Feather Blade feathering is possible on WTs with adjustable pitch. The blades are rotated so the chord is pointing upwind which, when the blade is in motion, gives a negative angle of attack which will rapidly slow the rotor to a standstill. This effect can be used to assist WT cut-out in very high winds and as an emergency brake. In very high winds, if the WT can be parked with the blades feathered, this will reduce the loads on the whole WT.

Fixed Speed A fixed speed WT will, once started, always rotate at the same speed, regardless of the wind speed. As power must be injected at a constant frequency onto the grid, operating at a fixed speed simplifies the generator and power electronic requirements for the WT considerably, making it cheaper. However, as the WT will only be able to operate at maximum efficiency at one particular wind speed, fixed speed WTs are around 10% less efficient than variable ones. A compromise is to use a WT that can operate at two different fixed speeds.

Flatwise Used to define the direction in an axis set in the rotating blade. Flatwise motion is motion perpendicular to both the plane of rotation and to edgewise motion.

Forced Yaw See Motor Yaw.

Free Stream Used to describe wind conditions at a location in the absence of the WT.

Free Yaw Rotating WT rotors will tend to align themselves to face the oncoming wind (even upwind rotors will do this). A WT which allows this natural tendency to align the rotor is known as a free yaw WT. This mode of operation is not popular in large WTs due to the possibility of damage from gyroscopic forces. Also, rotors will not recover from positions of large yaw misalignment, for example after periods of calm or sudden large changes in wind direction.

Friction Velocity A parameter featuring in the log law.

Fuel Cycle The impacts of power production are not exclusively generated during the operation of the power plant, but also in the entire chain of activities needed for the electricity production and distribution, such as fuel extraction, processing and transformation, construction and installation of the equipment as well as the disposal of waste. These stages, which constitute the chain of electricity production and distribution, are known as the fuel cycle.

Full Load Hours The turbine's average annual production divided by its rated power. The higher the number of full load hours, the higher the turbine's production at the chosen site.

G

Gearbox The gearbox in a WT is used to convert the low speed, high torque rotation of the rotor to a high speed, low torque rotation suitable for driving the generator to produce alternating current at the correct grid frequency. Not all modern WTs have gearboxes (see Direct Drive).

Generator (Synchronous, Induction) The generator is the piece of electrical machinery that actually converts the rotating motion of the rotor into alternating current electrical power. Most fixed (or partially variable) speed WTs have induction generators, whereas variable speed WTs have synchronous generators. The principle components of a generator are the rotor and the stator.

Geostrophic Wind Winds higher in the atmosphere driven purely by temperature and pressure differences within the atmosphere, and unaffected by the surface of the Earth.

Glass-Reinforced Plastic (GRP) The material from which most WT blades are made. GRP consists of a web of glass fibres set into solid plastic (polyester is often used).

Greenhouse Gas "Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds. Entirely human made greenhouse gases in the atmosphere such as halocarbons and other chlorine- and bromine-containing substances are dealt under the Montreal Protocol. Beside carbon dioxide, nitrous oxide and methane, the Kyoto protocol deals with the greenhouse gases sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons" (IPCC, 2001; p. 74).

Grid-Connected A WT is said to be grid-connected when its output is channelled directly into a national electric grid or the like (see also Stand-Alone).

Grid Reinforcement A weak grid can be reinforced by uprating its connection to the rest of the grid. The cost of doing this may fall to the wind farm developer.

Gurney Flaps Aerodynamic devices which are used to enhance lift on a stall-regulated blade.

Gyroscopic Effects A rotating WT rotor will experience gyroscopic forces if direction of the axis of rotation is shifted (stemming from the principle of conservation of angular momentum). If the rotor is allowed to yaw in an uncontrolled manner, these forces can cause large loads in the WT, potentially causing failures.

H

Harmonic Ideally, the alternating electrical signal output by any device onto the electrical grid should be perfectly sinusoidal in form. A regular, non-sinusoidal signal can be made up of sinusoidal components at integer multiples of the so-called base frequency. These higher frequency components are known as harmonics, and whilst they make music sound nice, they cause problems in electrical networks (see Power Quality). The sinusoidal output from a power electronic converter (PEC) is digitally synthesised and hence is not a perfect sinusoid. Older PECs would inject significant harmonics on to the electrical grid; more modern ones do not.

High-Speed Shaft In WTs featuring gearboxes, the high-speed shaft is the shaft connecting the gearbox to the generator. This shaft also features lower torques.

High Voltage Direct Current (HVDC) It is proposed that in linking offshore wind farms to land by buried cable, HVDC links will be used instead of alternating current power transmission.

Hill Effect Wind speeds up as it passes over the top of hills, making hilltops good sites for WTs. Note, however, that in extreme cases negative wind shear may occur (ie. the wind closer to the ground on the hilltop is faster than that higher up) and complex hilly terrain may cause additional turbulence and flow separation.

Horizontal Axis Wind Turbine (HAWT) A generic description of the propeller-type WTs seen throughout the world (see also Vertical Axis Wind Turbine).

Hub The hub of a WT is the rotating component to which the blades are fixed.

Hub Height The height of the rotor axis above the ground.

Hysteresis In general, this term describes a process that does not proceed in the same way when run in different directions; a simple example would be that you do not get the same amount of energy out of an elastic band when you allow it to relax as when you stretch it (some energy goes to heat the elastic band). Hysteresis is often used in wind energy to describe the way in which, whilst a WT may cut out when the wind speed reaches 25m/s, it will not cut back in again until the wind speed drops below (for example) 23m/s. There is also a hysteresis loop involved in blade behaviour in dynamic situations (see Dynamic Stall).

I

Impact Pathway Approach The impact pathway approach developed by ExternE establishes the effects and spatial distribution of the burdens from the fuel cycle to find out their final impact on health and the environment. Subsequently, the economic valuation assigns the respective costs of the damages induced by a given activity.

Indirect Employment Refers to those employed in sectors and activities supplying intermediate products/components to, for example, WT manufacturers. Indirect employment includes employment throughout the production chain.

Induced Velocity The change in the velocity of the wind caused by the presence of a WT blade.

Input-Output The national accounts of a country's or region's economic transactions keep track of all the inputs and outputs between economic sectors.

Insulated Gate Bipolar Transistor (IGBT) The IGBT has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET. IGBTs are used in power switching applications where high current handling and ease of control are desired.

Intermedial Load Intermedial load refers to those electricity generation technologies contributing to satisfy the demand in a range between base load and peak load of the electricity system. A generating unit that normally operates at a constant output (amount of electricity delivered) for several hours, eg. during a year, take all or part of the base load of a system. In contrast, a peak load unit is only used to reach specific peak periods of a few hours when the demand is high.

International Standards Organisation (ISO) ISO is a federation of national standards bodies from around 150 different countries. Established in 1947, it is non-governmental organisation with a mission broadly to promote the development of standardisation with the objective of facilitating international trade. ISO standards are prefixed with ISO (eg. ISO 9000).

Inverter A power electronic device used to convert direct current to alternating current. An inverter will often form part of the power electronics used with variable speed WTs, along with a rectifier.

Investment Cost of Turbine The cost of the turbine itself, including transport from the factory to the place where the turbine is erected.

Islanding The phenomenon by which a piece of the electrical network which has become disconnected from the rest of the network (for instance due to a lightning strike on an overhead pylon) continues to function, as the power sources on that section of the grid (for example a wind farm) continue to supply the loads. Islanding is a serious problem that can result in danger to personnel and damage to equipment; a number of safeguards are used to try to prevent it.

L

Laminar Laminar air flow is where layers of air moving at different speeds slide smoothly across one another without mixing, for example around the leading edge of an unstalled WT blade.

Leading Edge The blunter edge of a WT blade; this edge is the one that moves forwards through the oncoming wind.

Learning Rate A learning curve parameter. The learning rate is estimated on available data for WTs; it tells you the achieved reduction in specific product costs. Thus, if the learning rate is 15%, then costs are assumed to be reduced by this percentage when total installations of WTs are doubled.

Levellised Costs The present-day average cost per kWh produced by the turbine over its entire lifetime, including all costs (investments, reinvestments and operation and maintenance costs). The levellised costs are calculated using the discount rate and the turbine lifetime.

Lift Defined as the force experienced by a body in an airflow perpendicular to the direction of the airflow.

Log Law The log law is a parameterised mathematical equation used to describe the increase in wind speed with height above ground in the surface layer (see also Wind Shear). The equation includes the surface roughness of the ground and the Coriolis parameter.

Logger See DataLlogger.

Low Speed Shaft This connects the rotor to the gearbox in WTs featuring gearboxes. It is a high-torque shaft.

M

Measure, Correlate and Predict (MCP) To produce a confident prediction of how much energy a proposed wind

farm will produce, many years of wind data from the site would be necessary. As there is usually only a year or maybe two of data from the site available, the MCP process is adopted instead. The data measured at the site itself is correlated with data for the same period of time from a nearby meteorological station, and this correlation is then applied to the remainder of the data from the station to produce a synthetic long-term set of wind data for the wind farm site. This long-term data is then taken to be indicative of the likely future wind climate at the site and used to predict the future energy output of the wind farm.

Meteorological Mast The tall, thin, guyed pole upon which instruments such as anemometers and wind vanes are mounted when conducting wind resource measurements.

Meteorological Station A long-term installation for measurement of various properties of the atmosphere, wind speed, direction, air temperature and pressure, precipitation, insolation. etc. It is often possible to buy many decades worth of hourly data from these installations, and this can be used in combination with considerably shorter periods of more detailed 10-minute measurements made at the proposed site of a new wind farm to produce good estimates of how much energy a new wind farm could produce in the long term. This is done by the measure, correlate predict process.

Monopile A means of securing offshore WTs by boring a deep hole in the seabed and hammering a large pile into the hole, to which the WT is attached.

Motor Yaw The opposite of free yaw. In a motor yaw, WT electrical motors are used to precisely control the orientation of the nacelle and rotor and to prevent free yawing motion. The WT control system will decide in which direction to point the nacelle based on wind direction data averaged over a few minutes. Also known as forced yaw.

Multiplier/Multiplicator An employment multiplicator, for example, measures the direct and indirect employment effect of producing €1 million worth of output from the WT manufacturing sector. Basically, this assumes that it is valid to multiply total WT manufacturing in euros with a factor giving the necessary employment to produce this output. Series of multipliers for historic national account statistics exist.

N

Nacelle The nacelle of a WT is the enclosed volume mounted on top of the tower, containing the gearbox, generator and yaw drive, among other things.

Nitrogen Oxide (NO_X) According to the United Nations (2002), NO_X is a "product of combustion from transportation and stationary sources. It is a major contributor to acid depositions and the formation of ground-level ozone in the troposphere. It is formed by combustion under high pressure and high temperature in an internal combustion engine. It changes into nitrogen dioxide in the ambient air and contributes to photochemical smog".

O

Offshore Wind speeds are typically higher and turbulence lower offshore. Combined with reduced visual impact to sensitive landscapes this has meant that interest in building offshore wind farms has increased in recent years.

Operation and Maintenance Costs (O&M) The cost of repairs to, and servicing of, WTs throughout their lives.

Overspeed Protection Devices fitted to the WT to prevent the rotor from accelerating to dangerous speeds should a failure (generator, gearbox) occur in the WT. Such devices include tip brakes and shaft brakes.

P

Park Effect The effect whereby WTs positioned together in large wind parks each produce less energy than they would if in the same position on their own, due to the wind shadows of the other WTs in the park.

Pitch To control the power output and to assist in starting and stopping, the blades of some WTs can be rotated about their longitudinal axes by hydraulic activators. This motion of the blade is known as pitching. The angle that the blade chord makes with the rotor disc is the pitch.

Pitch Regulation Once the rated wind speed has been reached, a WT will be unable to make use of all of the wind energy incident on the rotor plane and must shed some. A pitch-regulated WT will do this either by pitching the blades to reduce the angle of attack and thus the torque and power captured (in pitch-to-feather machines) or by pitching the blades to increase the angle of attack

to cause sections of the blade to stall (in pitch-to-stall-machines).

Pole Switching A means by which a generator can be made to operate at two different rotational frequencies.

Pollutant Defined as a "substance that is present in concentrations that may harm organisms (humans, plants and animals) or exceed an environmental quality standard. The term is frequently used synonymously with contaminant" (United Nations, 2002).

Power Curve A plot of power output vs. wind speed, characteristic of a particular WT model and configuration.

Power Electronic Converter (PEC) A PEC is necessary on fully variable-speed machines in order to convert the frequency of the generated power from whatever it is being generated at to the grid frequency. This is achieved by first rectifying then inverting the signal to the required frequency. Older PECs generate problematic levels of harmonics, newer ones less so.

Power Law An approximation used as an alternative to the log law for approximating the wind speed at a particular height in the surface layer.

Power Quality Utilities are committed to supplying electricity within narrow bands of frequencies and voltages and with defined low levels of harmonics to consumers: this is described as the power quality. They are thus concerned that any generating device attached to their networks should inject power of sufficiently high quality. Variable speed and stall-regulated machines will smooth over the effects of wind gusts, but the presence of power electronic converters may increase the injection of harmonics onto the network.

Prevailing Wind Direction The direction from which the wind comes for the largest proportion of the time.

Pressure Face The side of a WT blade upon which the air flow around the blade causes a pressure rise.

Principal Component Analysis A particular way of fitting a curve through a set of data points which minimises the fitting error.

Productivity Productivity is used here as employees per output unit in fixed prices. The 2% increase in productivity used as a basic assumption implies that 2% less people are needed to produce the same output every year. If additional cost reductions of turbines are assumed, this must partly be attributed to additional productivity increases further reducing the need for employees.

Profile (Blade) The blade profile describes the shape you would see if you were to take a slice through the blade. It has a profound effect on the behaviour of the blade. There are a large number of standard profiles in use, described by names such as "NACA4412" which indicate the shape family and proportions of the blade.

Progress Ratio This ratio is related to the learning rate so that if the learning rate is 15%, then the progress ratio is 85% (progress ratio is 100% minus learning rate).

R

Rated Capacity Refers to the nameplate capacity that shows how much the turbine can produce when running at full load.

Rated Power The maximum power output possible from the WT. This is dictated by the generator size and loads that the WT can bear. Choice of rated power for a site is a balance dictated by the amount of energy available in the wind at different wind speeds and the cost of increasingly large and powerful WTs.

Rated Wind Speed The minimum wind speed at which a WT will generate its rated power.

Reactive Power If the voltage and current signals in an electrical network are not in phase, the out-of-phase component gives rise to reactive power flow. Reactive power cannot be used, but still causes losses in an electrical network, hence its flows should be minimised. Induction generators consume reactive power, and the network operator may wish to be compensated for the losses this causes. Synchronous generators can be made to consume or produce reactive power as desired, which may be of use to the network operator.

Rectifier A power electronic device used to convert alternating current into direct current. A rectifier will often form part of the power electronics used with variable speed WTs, along with an inverter.

Re-Energisation When a body of air has decelerated and is moving slowly (for example in a WT wake or towards the trailing edge of a blade), turbulent mixing with neighbouring fast-moving airflows can re-energise the body of air, reaccelerating it.

Reference Site A chosen location with known wind conditions. The reference site is used to compare efficiency and power production of different turbines.

Reinvestments When a larger and more costly part of the turbine has to be replaced, eg. a gearbox or a blade.

Root The root of the blade is the section nearest the hub. Rotor The rotor is the combination of the hub and blades. This term is also used to describe the rotating part of an electrical generator. The design of a generator rotor depends on the type of generator in question.

Rotor Area See Swept Area.

Rotor Disc The rotor disc is the imaginary circular surface swept out by the rotor blades as they rotate.

Roughness Class A classification system for the roughness of different surfaces. Examples include: landscape with many trees and buildings (class 3-4); sea surface (class 0); concrete runway (class 0.5). Tables of roughness classes for different surfaces are available.

Roughness Length The distance above ground level at which the wind speed should theoretically be zero, due to the roughness of the surface at that point.

S

Scale Parameter A parameter describing the height of a Weibull distribution.

Sea Breeze In the first half of the day as the land heats up, wind will tend to blow off the sea onto the land as heated air above the land rises (a weaker land breeze also occurs in the evening).

Separation An airflow is said to become separated from the object around which it is moving when the flow ceases to follow the contours of the body but instead features turbulent mixing and flow reversal close to the surface.

Shadow Flicker If a WT comes between an observer and the sun, the observer will experience a flickering as the light passes between the rotating blades of the WT; this can be very distracting. Wind farms should be planned to avoid causing shadow flicker at nearby residences, and wind farm design software can assist in doing this.

Shaft Brake A braking mechanism to stop the rotation of the WT by arresting the motion of one of the shafts in the WT. As the high speed shaft has much lower torque, a lighter and cheaper brake can be used if it is positioned on this shaft. However, should the gearbox fail, the high-speed shaft brake will be unable to stop the WT rotor.

Shape Parameter A parameter describing the variation of a Weibull distribution about the mean.

Shear Air in contact with the ground is not moving: air at high altitudes is moving at high speeds. The gradual increase of wind speed with increasing altitude is knows as wind shear, and is particularly relevant over the area of a typical WT blade.

Slip In induction generators, the slip is the difference in angular velocity between the rotor and the rotating magnetic field, expressed as a fraction of the angular velocity of the rotating magnetic field.

Soft-Start If an induction generator is started by connecting it directly to the grid, it will initially draw a large current as the generator is magnetised; this large current could cause voltage drops in the local network. To avoid this, a soft-start unit regulates the amount of current drawn by the generator, allowing it to magnetise more slowly and preventing voltage dips on the network.

Soft Tower A soft tower has a natural frequency lower than the blade passing frequency but greater than the rotational frequency of the WT.

Soft-Soft Tower A soft-soft tower has a natural frequency lower than the rotational frequency of the rotor.

Solidity The frontal area of the blades on a WT divided by the total swept area, expressed as a percentage.

Squirrel Cage A description of the rotor of an induction generator.

Stability The stability of the boundary layer above the Earth's surface can be described as stable, neutral and unstable. Stable conditions, when the surface of the Earth is cooling, are characterised by little vertical mixing of the air.. Unstable conditions occur when the Earth's surface is heated and more vertical mixing occurs. Neutral conditions lie somewhere in between. We are largely concerned with conditions of neutral stability in wind energy.

Stall Above a particular angle of attack, the air flow around the suction face of a blade will become separated. Once this happens, the drag on the blade will increase dramatically and the lift will fall. The stalled section of blade ceases to function as an efficient aerofoil.

Stall Delay It is observed that sections of rotating WT blade close to the hub stall at higher angles of attack than would normally be expected. The reason for this is uncertain.

Stall Regulation The blades on a stall-regulated- WT cannot be pitched. To achieve control of power captured above rated wind speed, the blades are carefully designed

so that they progressively stall starting at the blade root and moving out towards the tip as the wind speed increases further. Stall-regulated WTs will respond much more quickly to gusts than pitch-regulated WTs (where mechanic pitch adjustments take finite amounts of time to effect), improving the power quality output by the WT above rated wind speed.

Stall Strip A stall strip is a device attached near the maximum thickness of the chord of a stall-regulated blade which is intended to promote stall.

Stand-Alone This refers to a WT operating without being attached to the electricity grid, for example in charging batteries or running in parallel with a diesel generator.

Stator The non-rotating part of an electrical generator, consisting of many windings of electrical cable.

Stiff Tower A stiff tower has a first natural frequency higher than the blade passing frequency.

Stream Tube An imaginary tube extending upstream and downstream of the WT, containing all the air that interacts with the rotor. The diameter of the stream tube is initially constant far upstream of the rotor, expands as air approaches the rotor disc and slows, then continues to expand for a short distance after the rotor disc as the air flow slows.

Suction Face The side of a WT blade upon which the air flow around the blade causes a pressure drop.

Sulphur Dioxide (SO_2) According to the United Nations (2002), SO_2 is a "heavy, pungent, colourless gas formed primarily by the combustion of fossil fuels. It is harmful to human beings and vegetation, and contributes to the acidity in precipitation".

Surface Layer The first 100 m or so of the atmosphere, in which most wind energy activity takes place.

Surface Roughness See Roughness Class.

Surface Winds The winds occurring near the surface of the Earth (in the first kilometre or so), heavily influenced by the properties of the Earth's surface and obstacles in the region (see also Geostrophic Winds).

Swept Area The area swept out by the blades as the rotor rotates - the area of the rotor disc - is also known as the rotor area. Often used as a proxy for a turbine's power production.

Switched Reluctance Generator (SRG) A SRG differs from conventional machines in that it does not have any windings or permanent magnets on the rotor. The stator typically consists of slots containing a series of coil windings, the energisation of which is electronically switched to generate a moving field. The reluctivity of the rotor results in a torque which tends to move the rotor in line with the energising coils, minimising the flux path. For an SRG, mechanical energy is converted to electrical energy by the proper synchronisation of stator phase currents with rotor position. By appropriate control of stator switching it is possible to achieve variable speed operation for the generator.

Synchronisation When using synchronous generators, it is vital that the alternating current produced is in phase with the alternating current on the network to which it is connected; the process of achieving this (part of the WT start-up programme) is known as synchronisation.

Synoptic Describes variation in the typical frequency of arrival of different weather systems, generally with a period of around four days.

T

Teeter The blades on two-bladed wind WTs are usually, in fact, one single piece stretching the whole diameter of the rotor disc. To reduce stresses on the WT as a whole when the blades pass the tower, this single piece is allowed to pivot at the centre; this is known as a teetered rotor.

Tilt The tilt angle is the angle between the horizontal and the rotor axis.

Tip The tip of the blade is the end furthest from the hub.

Tip Brake These are fitted to some WTs to avoid runaway situations when other braking mechanisms have failed. The tips of the blades are separate from the rest of the blade, and mounted on spring-loaded, threaded rods. As the rotor accelerates, centrifugal forces cause the tips to pull away from the body of the blade, and the thread on the rods causes the tip's sections to rotate, spoiling the aerodynamics of the blade and regulating the speed of the rotor, preventing overspeed.

Tip Loss Tip loss describes the loss in performance of a blade due to the fact that it is finite in extent and hence some air flow goes round the tip rather than over the chord. It is borrowed from the propeller industry.

Tip Noise The noise made by the WT blades tips moving through the air. This increases with increasing speed, so WTs near centres of population are often run more slowly

than say offshore WTs, especially at night when there is less background noise and people are sleeping. In general, tip noise is only audible at low wind speeds when there is little other wind noise around.

Tip Speed Ratio (λ) The ratio of the speed at which the blade tips are moving to the speed of the oncoming wind. A WT will typically reach peak efficiency at a particular value of λ, regardless of wind speed (see variable speed) and this is often denoted λ_{max}.

Torque The "turning force" applied to an object. Measured in Newton metres, this is calculated as the distance from the axis of rotation at which a force is applied to a rotating object, multiplied by the magnitude of that force.

Tower (Lattice, Tubular, Guyed Pole) The tower is the column supporting the nacelle and rotor above the ground. Towers are typically lattice (like an electricity pylon, consisting of a network of thin struts) or tubular (a single tubular column). For small WTs, the tower can also be a guyed pole.

Tower Shadow As wind flows around a WT tower, regions of lower wind velocity are created just upstream and downstream of the tower, particular in the case of tubular towers. As the blades pass through the tower shadow, they experience a periodic dip in loading which causes fatigue damage to blades and can excite harmonics (resonance) in the blade.

Tower Strike Occurs when extreme atmospheric conditions cause a blade to strike the tower as it passes

Trailing Edge The sharper edge of a WT blade, to the rear of the blade as it rotates.

Transformer A piece of electrical equipment used to step up or down the voltage of an electrical signal. Most WTs will have a dedicated transformer to step up their voltage output to grid voltage.

Troposphere The first 11km of the atmosphere, in which weather occurs.

Turbine Lifetime The expected total lifetime of the turbine, normally 20 years.

Turbulence The stochastic (random) motion of air characteristic of all natural winds. Though wind can be said to have an underlying steady direction and speed, on a small scale different parcels of air will move in random directions at random speeds. There is energy in turbulence that can be captured, but it also causes damage to WTs after long periods of exposure due to the constantly varying random loads a WT experiences.

Turbulence Intensity A measure of the strength of the turbulence of the wind compared to its underlying average speed. Defined as the standard deviation of the wind speed variations about the mean wind speed divided by the mean wind speed, using 10 minute or 1 hour averaging periods.

Twist The tips of a WT blade move through the air faster than the roots in the direction of rotation, but the oncoming wind speed is similar at all points along the blade. Hence, to achieve the optimal angle of attack along its length, a WT blade is twisted so that the pitch of the blade reduces from the root to the tip.

U

Upwind A WT which operates with the rotor upwind of the tower is said to be an upwind WT. Most modern WTs are upwind.

V

Value of Statistical Life (VSL) VSL is an approach that measures a society's willingness to pay to avoid additional cases of death. This can be seen in spending for improved safety in the aircraft or car industry. In the EU and the US, values of between one and 10 million US$ or € per life saved have been found in different studies. Earlier versions of the ExternE project adopted a figure of US$3 million per life saved for VSL calculations. In these calculations the age of a person saved does not matter.

Variable Speed The rotor on a variable speed WT will rotate at a speed calculated to make it as efficient as possible at the prevailing wind speed (i.e. at λ_{max} – see Tip Speed Ratio). Variable speed WTs will produce less tip noise at low wind speeds as they will be rotating more slowly, and can be up to 10% more efficient than fixed speed WTs. However, they are more complex than fixed speed WTs and require power electronic converters (PECs) to convert their output to grid frequency. A variety of partially-variable speed WTs are available, bringing most of the efficiency gains with only some added complexity and no PEC.

Velocity Deficit The amount by which the wind speed is reduced in the wake of a WT, as compared to the free stream.

Vertical Axis Wind Turbine (VAWT) An alternative design of wind turbine where the rotor rotates about a vertical axis, rather than a horizontal one. It proved difficult to scale these designs up effectively, so modern VAWTs are of limited size; also, VAWTs are less efficient than HAWTs. As the concept of yaw is irrelevant to VAWTs; they can however be rather simpler than HAWTs.

Vortex Generator Vortex generators are small mechanical devices which are attached to the suction surface of the stall-regulated blade which generate local vortices. These vortices re-energise the boundary layer and hence prevent stall. When viewed from above they are often V-shaped with the sharp end of the V pointing towards the leading edge.

W

Wake As wind passes through the rotor disc, it is slowed as energy is extracted from it, and vorticity is introduced into the air by the blades. This stream of slowed air can extend up to 10 rotor diameters behind the WT and is known as the wake. WTs placed in the wake of others will experience lower wind speeds and increased turbulence, reducing power output and increasing wear and tear.

Weak Grid An area of the electrical grid where the voltage and power quality is likely to be significantly influenced by the presence of large loads or power supplies, such as a wind farm. It may be necessary to perform grid reinforcement if a wind farm is to be connected to the grid where it is currently weak.

Weibull Distribution A probability distribution specific to a given location describing the probabilities that the wind will blow with particular strengths.

Wind Atlas An atlas mapping the wind resource across an area, for example The European Wind Atlas.

Wind Resource A reference to the quantity of energy potentially available from the wind in a particular place (as in “The wind resource of the British Isles could supply all our electricity several times over”).

Wind Rose A circular diagram giving a visual summary of the relative amounts of wind available in each of a number of direction sectors (often 12) at a given location, and the speed content of that wind.

Wind Vane An instrument for measuring the direction in which the wind is blowing, usually consisting of a vane mounted on the end of a rod, free to rotate in the horizontal plane about a pivot.

Y

Yaw Angle As the direction of the wind is constantly changing, it is normally the case that the wind does not strike the rotor disc at right angles. The angle between the rotor disc and the incident wind is known as the yaw angle (often denoted by Greek letter γ).

Yaw Control Another means of WT power control (alongside pitch- and stall-regulation), primarily used in very small WTs. The WT is deliberately misaligned from the prevailing wind direction, reducing the area of the rotor disc seen by the oncoming wind and thus the power output of the WT.

Yaw Drive This controls the direction in which the nacelle (and hence rotor) of the WT is pointing. Electrical motors are used to ensure that the WT is facing the prevailing wind direction at all times.

Yaw Error The amount by which the WT rotor is misaligned from the prevailing wind direction.

Years of Life Lost (YOLL) The YOLL approach takes into account that due to different causes people of very different age groups may be at risk. In the case of a chronic disease leading to the death of very old people, only the years of life lost due to the disease as compared to the average life expectancy are taken into account. For each year of life lost approximately 1/20st of the value of statistical life is used.

Z

Zone of Visual Influence (ZVI) In planning a new wind farm, it is important to consider the effect it will have on the local landscape. Wind farm software will analyse topographical maps of the area surrounding a planned wind farm and highlight the areas from which the new wind farm will be visible - known as the ZVI.

Technical Units

kW	kilowatt	1,000 Watts
MW	megawatt	1,000,000 Watts (1,000 kW)
GW	gigawatt	1,000,000,000 Watts (1,000 MW)

kWh	kilowatt hour	1,000 Watt hours
MWh	megawatt hour	1,000 kilowatt hours
GWh	gigawatt hour	1,000 megawatt hours