Rewarding Learning

AS LEVEL

Environmental Technology

Energy from the Wind (1)

For first teaching from September 2013

For first award in Summer 2014

FACT FILE

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Energy from the Wind (1)

Specification Content

Students should be able to:

- describe the differences between the two main types of wind turbine;
  - Vertical Axis Wind Turbine (VAWT);
  - Horizontal Axis Wind Turbine (HAWT);
- label the main components of a horizontal axis wind turbine;
- use the formula π × r2 to calculate the rotor swept area for different rotor diameters;
- use the equation ½ mv2 to calculate the energy available to a wind turbine at different wind speeds;

Course Content

Wind energy has been used for thousands of years for a variety of applications such as;

- Milling grain;
- Providing mechanical power; and
- Pumping water.

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In the modern world it is the use of wind energy to generate electricity which has made it a major source of renewable and pollution free energy.

There are two main types of wind turbine which are distinguished by the axis in which the rotor or moving part of the turbine rotates. These are;

- **Vertical Axis Wind Turbines (VAWT)** in which the rotor blades rotate about a vertical axis. These can harness the wind when it blows from any direction without having to adjust the position of the rotor to face the incoming wind. This makes them suitable for areas where the wind direction is not consistent. They are generally suited for low wind speeds and rotation at low levels of revolutions per minute (rpm) making them more suitable for small wind projects or residential applications. They also produce low levels of vibration and noise when in operation.

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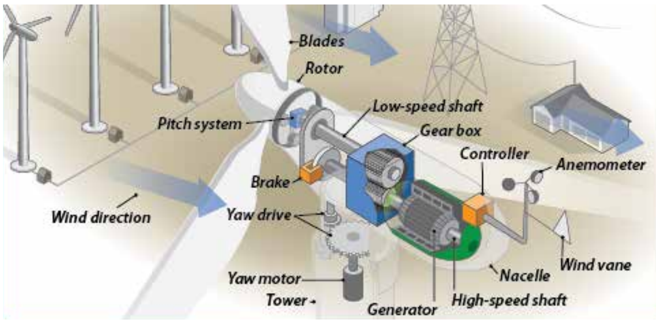
- **Horizontal Axis Wind Turbines (HAWT)** means the rotating axis of the wind turbine is horizontal, or parallel with the ground. These are the type which you are most likely to see in different areas of the country. The major advantage of horizontal axis wind turbines is that this technology is able to produce more electricity from any given amount of wind. The disadvantage of horizontal axis however is that it is generally heavier and it does not produce electricity well in turbulent winds. These require larger wind speeds to operate and produce larger amounts of vibration and noise than the vertical axis type.

The main components of a horizontal axis wind turbine



Anemometer – This is used to measure the wind speed.

Blades – These Lift and rotate when wind is blown over them, causing the rotor to spin. Most turbines have either two or three blades.

Brake - Stops the rotor mechanically, electrically, or hydraulically, in emergencies.

Controller – This is used to start the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. It is not advisable to operate turbines above certain speeds e.g. 55 mph because they may be damaged by the high winds.

Gearbox – This connects the low-speed shaft to the high-speed shaft and is used to increase the rotational speed from approximately 30-60 rotations per minute (rpm), to about 1,000-1,800 rpm which is the rotational speed required by most generators to produce electricity.
Generator – this converts the rotational or kinetic energy of the shaft to electricity.
Nacelle – this is a structure which is located at the top of the wind generator tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake.
Pitch system – this is used to adjust the angle of the blades with respect to the wind direction) so controlling the rotor speed, in order to prevent the rotor from turning in winds that are too high or too low to produce electricity.
Rotor – The blades and hub form the rotor.
Tower – This is made from tubular steel, concrete, or a steel lattice. It supports the overall structure of the turbine. Due to the fact that wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.
Yaw drive – This is used to adjust the position (or yaw) of the rotor blades to keep them facing the wind when the direction changes.
Yaw motor – This is used to power the yaw drive.

Wind vane – This measures wind direction and communicates with the yaw drive to ensure the turbine is positioned properly with respect to the wind direction

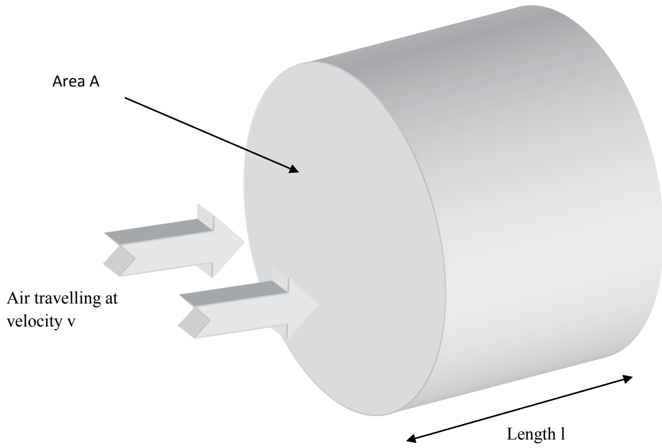
Wind energy calculations

The power which any wind generator is capable of producing is dependent on a number of factors such as;

- The size of the rotor blades;
- The speed of the wind;
- The efficiency of the wind turbine system; and
- The location and design of the system itself – number of blades etc.

Imagine the area swept out by the blades as they rotate in the wind. If the blades have a diameter of **d** metres then the area **A** swept out by the blades as they rotate is given by the equation;

$A = \pi r^2$ where r is the radius of the blades i.e. d/2 and π equals 3.142.



The energy available from the wind is due to its kinetic energy which is given by the equation;

Kinetic energy = ½ x mass of the air x velocity of the air squared = ½ mv^2

Mass of the air = density of the air x volume

= density of the air x area x length

= ρ x A x l where ρ is the density of the air.

To calculate l consider the air moving at velocity v

V=l/t where t is the time for the air travelling at velocity v to move a distance l, so l = v x t.

This gives us the mass of air as ρ x A x v x t.

Therefore the kinetic energy of the air is given by

Kinetic energy = ½ ρ x A x v x t x v^2

= ½ ρ x A x t x v^3

So, the theoretical power available from the wind generator which is energy divided by time will be given by the equation;

$$\textbf{Power} = \tfrac{1}{2}\rho \times A \times v^3$$

If density is measured in kg/m^3, area in m^2 and velocity in m/s, then the power will be in Watts.

Example:

If the density of the air is $1kg/m^3$ and the wind speed is 10m/s and the radius of the blades is 10m then;

Area swept out = π xr^2 = π x 10^2 = 314.2 m^2

Power = ½ x 1 x 314.2 x 10^3 = 157100 Watts or 157.1 Kilowatts

This would be enough to power 1571 100Watt light bulbs.

It must be stressed that the power contained in the wind is different to that which can be extracted by a wind turbine. Losses are caused by inefficiencies in the energy conversion process and not all of the available energy can be transferred to the wind turbine for a variety of reasons e.g. some of the air is "pushed aside" by the rotor blades and so is not used in the energy conversion process.

Activity

Investigate the power requirements of the most commonly used electrical devices in your home e.g. light bulbs, cooker, television, computer, etc. Calculate the diameter of a typical rotor blade for a wind generator system which could power these devices, if all are used at the same time, for a range of wind speeds from 1 m/s up to 6m/s in increments of 1 m/s.

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