DLPSTAFFS

Go green

Wind Energy Measurements

There are four measurements associated with wind energy, the measurements of electrical signals including voltage, current or collectively electrical power, wind turbine rotational speed and the wind speed.

Electrical measurements:

In order to determine electrical energy out put, it is necessary to be able to measure it either directly as energy in kWh, or indirectly by measuring the voltage, current of the generated output of the wind turbine.

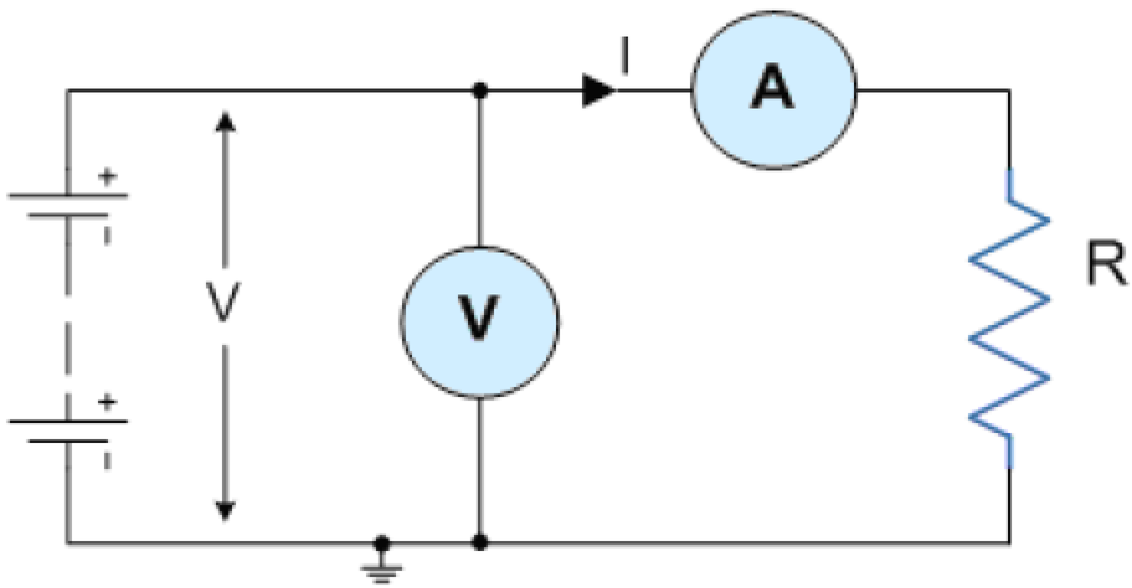
Quantity	Symbol	Unit of measurement	Unit abb.
Current	I	Amp	A
Voltage	V	Volt	V
Resistance	R	Ohm	Ω
Power/Energy	E	Watt	w

Electrical measurements

Ohms law:

Ohm's law states that the current (I) through a conductor between two points is proportional to the potential difference(V) and inversely proportional to the resistance(R).

$$V = I \times R \qquad \text{----- (15)}$$



Ohms Law

Electrical Power:

Electrical power(E) is the amount of energy produced.

The unit of measurement of Power being the **Watt** (**W**) with prefixes used to denote **milliwatts** (mW = 10^{-3} W) or **kilowatts** (kW = 10^{3} W).

By using Ohm's law and substituting for V (volts),I (amps) and R (Ω) the formula for electrical power, E (watts) can be found as:

E = V x I ---- (16a)

E = V^2 / R ---- (16b)

E = I^2 / R ---- (16c)

Alternating Current Power:

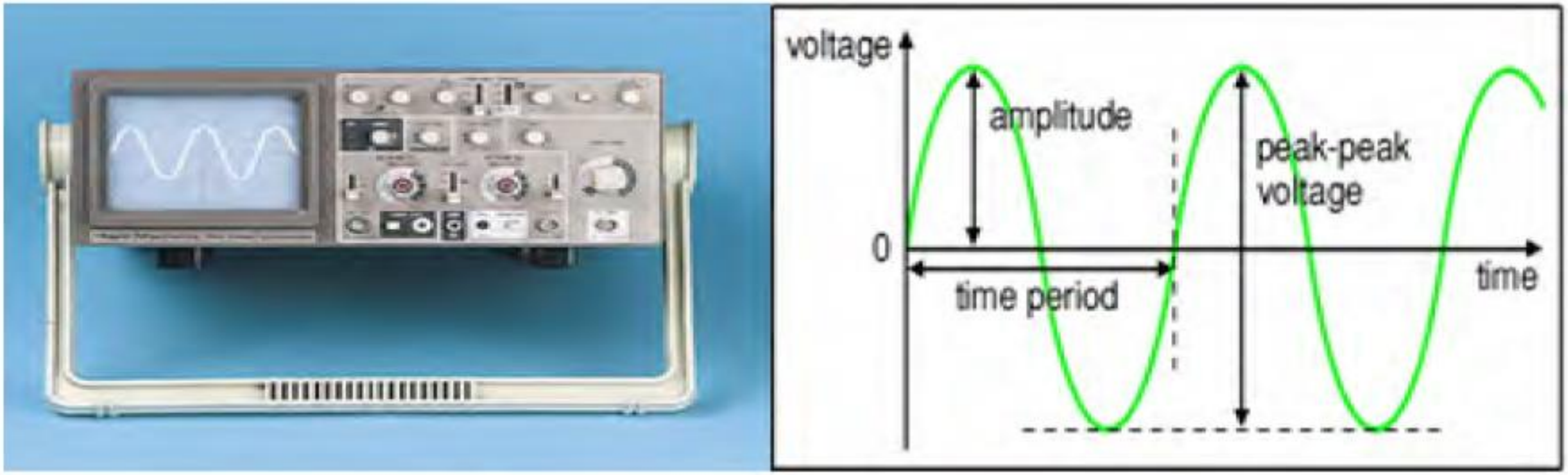
As in the case with DC power, the instantaneous electric power in an AC circuit is given by

$$E = VI, \qquad ----- (17)$$

But these quantities are continuously varying. Almost always the desired power in an AC circuit is the average power, which is given by

$$E_{avg} = VI \cos\phi \qquad -----(18)$$

Where ϕ is the phase angle between the current and the voltage and where V and I are understood to be the effective or rms values of the voltage and current, see below figure. The term $\cos\phi$ is called the “power factor” for the circuit, a power factor of one or “unity power factor” is the goal of any electric utility company since if the power factor is less than one ,they have to supply more current to the user for a given amount of power use. In so doing, they incur more line losses. They also must have larger capacity equipment in place than would be otherwise necessary.



Resistive AC circuit

The difference between the maximum and minimum values is called peak-to-peak voltage(V_{pp})and is twice the peak voltage (V_p).The RMS voltage.(V_{rms})is related to the peak voltage as:

$$V_{rms} = 0.707\ x\ V_p \qquad \text{------ (19)}$$

Circuit currents and voltage in AC circuits are generally stated as root-mean-square or rms values rather than by quoting the maximum values. The root-mean-square for a current is define d by

$$I_{rms} = \sqrt{I_{ave}^2} \qquad \text{------ (20)}$$

That is ,you take square of the current and average it, then take the square root. When this process is carried out for a sinusoidal current

$$[I_m^2 * \sin^2(\omega t)]_{ave} = \frac{I_m^2}{2}$$

Hence

$$I_{rms} = \sqrt{I_{ave}^2} = \frac{I_m}{\sqrt{2}} \qquad \text{---- (21)}$$

Since the AC voltage is also sinusoidal, the form of the rms voltage is the same. These rms values are just the effective value need in the expression for average power:

$$Eav = (V_m * I_m)/2 * \cos(\phi) \qquad \text{------(22)}$$

Since the voltage and current are both sinusoidal, the power expression can be expressed in terms of the squares of sine or cosine functions, and the average of a sine or cosine squared over a whole period is =1/2.

Electrical Measurements

Energy related measurements concerned with electricity production and consumption are usually derived from three elements namely: the electrical current, voltage and resistance of the load. These three variables are directly linked with the energy or power consumption of the load and hence it is common to see a single meter combining these to give a direct reading of the energy consumption.

Multimeters are very useful test instruments. By operating a multi-position switch on the meter they can be quickly and easily set to be **a voltmeter**, an **ammeter** or an **ohmmeter**. Two devices can be used to measure the electrical measurements: analog and digital multimeters as shown in below figure.

Digital and Analog Multimeters

As far as power is concerned, the most common unit of consumption measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Some electricity companies use the SI mega joule instead. Modern electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical power (watts) which is then integrated against time to give energy used (joules, kilowatt-hours etc). The meters fall into two basic categories, electromechanical and electronic, as shown in below figure.

The **mechanical electricity meter** has every other dial rotating counter-clockwise.

The most common type of electricity meter is the Thomson or electromechanical induction watt-hour meter, invented by Elihu Thomson in 1888. It work by counting the revolutions of an aluminium disc which is made to rotate a speed proportional to the power. The metallic disc is acted upon by two coils. One coil is connected in such a away that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current.

A modern **digital electronic wattmeter/energy meter** samples the voltage and current thousands of times a second . The average of the instantaneous voltage multiplied by the current is the true power. The true power divided by the apparent volt-amperes (VA) is the power factor. A computer circuit uses the sampled values to calculate RMS voltage, RMS current, VA, power (watts), power factor and kilowatt-hours. The simple models display that information on LCD. More sophisticated models retain the information over an extended period of time, and can transmit it to field equipment or a central location.

Measurement of power

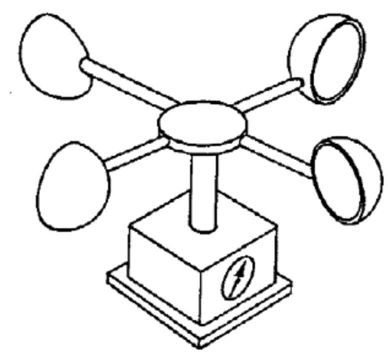
Velocity and flow measured by Anemometers:

Wind speed is the most important factor directly proportional to the power output of a wind turbine.

Various types of anemometer are used to measure the velocity , usually of air.

The 'cup type' air speed measurement:

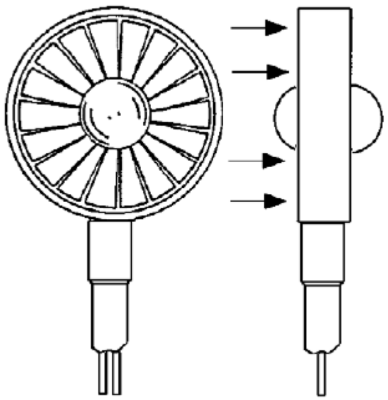
Below figure is used for free air and has hemispherical cups on arms attached to a rotating shaft. the shape of the cups gives a greater drag on one side than the other and result in a speed of rotation approximately proportional to the air speed. Velocity is found by measuring revolutions over a fixed time.



Cup Type Anemometer

The ‘vane anemometer’:

Below figure has an axial impeller attached to a handle with extensions and an electrical pick-up which measures the revolutions. A meter with several ranges indicates the velocity.



Vane Anemometer

The ‘hot- wire’ anemometer’:

Below figure is a probe terminating in an extremely small heated wire element when subjected to a fluid stream it cools to an extent, which depends on the velocity of the fluid passing. The resulting change in resistance of the element is measured by a bridge circuit and is related to velocity by calibration

Measurement of speed of rotation:

The following methods are used to measure the speed of rotation of an object:-

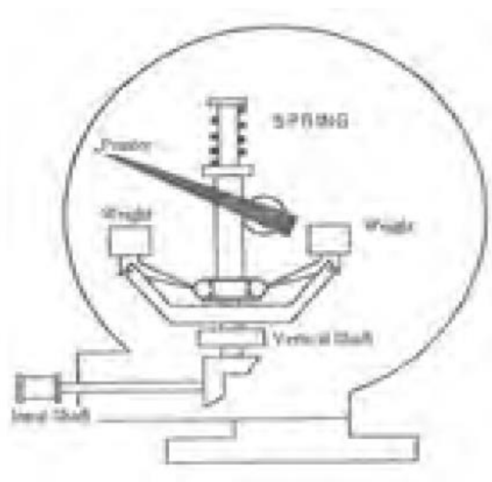
- Mechanical Tachometer
- Digital Tachometer
- Stroboscopes
- Magnetic field angular position sensors
- Wheel encoder

The choice of technique used for measurement is governed by the application range considered, degree of accuracy required, type of installation and original cost. In this section each type will be discussed and an overview of the importance of time measurement will also be discussed.

Mechanical tachometer:

This type of tachometer is a linkage of shafts, gears and rotating weights. when the input shaft which is seen horizontal rotates the vertical shaft it also rotates the weights attached to it which are hinged and free to move inward and outwards. The movement of these flyweights rotates a pointer which is calibrated to give the speed in desired units such as RPM.

Two main drawbacks of this are that the mechanical weights have inertia and hence not very accurate and secondly it does not give an Indication of the direction of rotation.



Electrical Tachometers:

This type of tachometer could be as simple as DC or AC generator that can determine the speed of shaft rotation by the amount of voltage the generator produces or the frequency of the output signal. The magnitude of the generator or voltage and the frequency of the generated voltage will increase proportionally with speed. Frequency can also be measured by a photocell tachometer. The number of pulses produced by the photocell will increase as the speed of the rotation increases.

The rotating field and the toothed rotor tachometer produce a waveform and the photocell uses a rotating disc that has a number of windows in it. A light source is positioned so that it will shine light through each window in the disc to a photocell detector a the disc spins. The disc connected to the tachometer shaft, so when it turns the windows line up with the photocell and the photocell produces a pulse when it is struck by light. In each of these types of tachometer a pulse stream is produced and it is proportional to the speed of the tachometer shafts.

Digital tachometer

Stroboscope:

Also known as the “strobe” is an instrument used to make a cyclically moving object appear to be slow-moving or stationary . The principle is used for the study of rotating, reciprocating, oscillating or vibrating objects. Machine parts and vibrating strings are common examples.

In electronic versions the perforated disc is replaced by a lamp capable f emitting brief an d rapid flashes of light. The frequency of the flash is adjusted so that it is an equal to or unit fraction below or above the objects cycle speed at which point the objects is seen to be either stationary or moving backward or forward, depending on the flash frequency.

Stroboscope

In order to make a measurement a mark is mad e on the object when it is stationary and the object is spun up to speed. The oscillator is set to a low frequency to start with and the LED is shone at the object where the mark is. At first the mark will appear at points around the object.

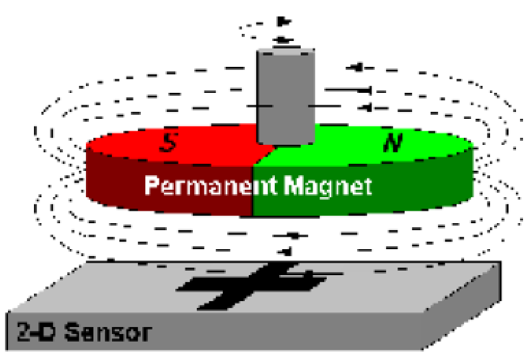
When it is stationary the LED is flashing at the same frequency as the object is rotating. Since the frequency is known the rotational speed is also known and can be stated in RPM using the formula

$$RPM = 60 \times f_{strobe}$$

Magnetic field Angular position sensors:

These are similar shaft encoders, with one exception. They are capable of measuring the angle direction of a magnetic field form a magnet with $<0.07^0$ resolution. The advantages of measuring field direction versus field strength include: insensitivity to the temperature coefficient of magnet, less sensitivity to shock and vibration, and the ability to withstand large variations in the gap between the sensor and magnet. The sensors may be operated below 3 volts with a bandwidth response of 0-5 MHz. Output is a typical Wheatstone bridge permitting balanced output signals for noise immunity.

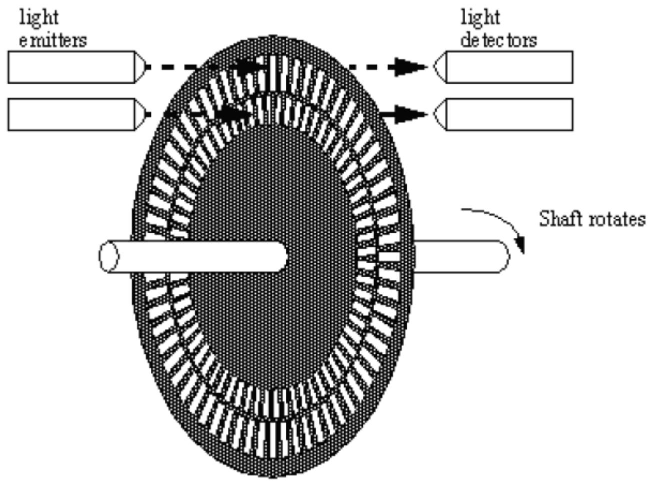
The main application of this sensor is to determine the angular position of a rotary axis. In this case a permanent magnet is fixed on the engine axis just above the sensor. This magnet generates a directional magnetic field parallel to the surface of the sensor shown below. This field works as a contactless interface between the orientation of the axis and the sensor.



The permanent magnet speed sensor

Wheel encoder:

Below figure shows an example of a typical encoder wheel. The resolution of the encoder wheel is determine by the number of cycles or complete phases.



Wheel encoder

The encoder is a sensor attached to a rotating object(such as a wheel or motor) to measure rotation .A typical encoder uses optical sensor(s),a moving mechanical component ,and a special reflector to provide a series of electrical pulses. These pulses can be used as part of a feedback a control system to determine translation distance , rotational velocity of a rotating component.

For instance, to measure the time it takes motor to rotate exactly 360 degrees or more or less, an encoder would be ideal. The sensor would be fixed on the shaft (the encoder wheel) would rotate with the shaft. The output of an encoder would be a square wave, so if you hook up this signal to a digital count or microcontroller you can then count the pulses. Knowing the distance/angle between each pulse, and the time from start to finish, you can easily determine position or angle or velocity of the motor.

The importance of speed in Turbine's measurements:

It was discussed earlier that the power output of a wind turbine is proportional the cube of the speed. The speed is the most important parameter in evaluating the power from a turbine. It is often understated by manufacturers or misunderstood by buyers that the power rating of a wind turbine is only true at a given speed, know as the rated speed, which is neither too loo nor too high, but somewhere where it is trusted that the wind turbine will be able to withstand the forces of rotation. These speeds are distinguished into four different regimes(below shown figure):

a) Start-up speed –

This is the speed at which the rotor and blade assembly begins to rotate.

b) Cut-in Speed –

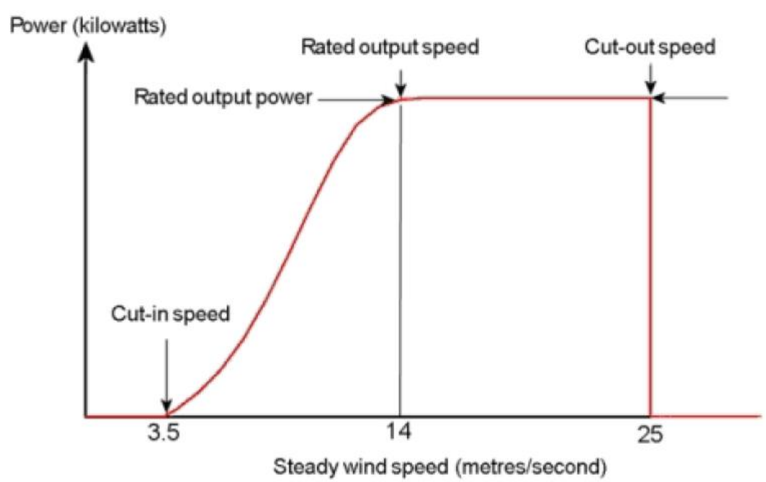
Cut-in speed is the minimum wind speed at which the wind turbine will generate usable power. This wind speed is typically between 7 and 10 mph for most turbines.

c) Rated Speed –

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. For example, a "10 kilowatt" wind turbine may not generate 10 kilowatts until wind speed reach 25 mph. Rated speed for most machines is in the range of 25 to 35 mph. At wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called "power curves", showing how their wind turbine output varies with wind speed.

d) Cut-out Speed-

At very high wind speeds, typically between 45 and 80mph,most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed, Or sometimes the furling speed. Having a cut-out speed is a safety feature which protects the wind turbine from damage. Shut down may occur in one of several ways. In some machines an automatic brake is activated by a wind speed sensor. Some machines twist or “pitch” the blades to spill the wind. Still others use “spoilers,” drag flaps mounted on the blades or the hub which are automatically activated by high rotor rpm’s, or mechanically activated by a spring loaded device which turn the machine sideways to the wind stream. Normally wind turbine operation usually resumes when the wind drops back to a safe level.



Wind speeds for a wind turbine