Measurements Matter in Wind Energy Production – DAQ systems for Wind Farms

Locating and exploiting new and ever greater sources of oil, gas and coal is increasingly difficult, as highlighted by the current problems in the Gulf of Mexico; the costs of extracting such fuels will inevitably continue to rise pushing prices to the consumer up.

Importing energy can also make a country vulnerable – for example a dispute in 2009 between Russia and the Ukraine led to gas pipelines being turned off resulting in supply outages across Europe.

Pollution and rising CO_2 levels in the atmosphere, which many scientists believe to be a major contributing factor to global warming, will only get worse as fast paced development in countries like China lead to more and more fossil fuel based power generation.

Nuclear energy offers a possible alternative but there are pros and cons involved which I won't go into in here.

Harvesting the natural, renewable energy from the world around us, however, will allow us to reduce our reliance on fossil fuels, lower our collective carbon footprint and become more energy self sufficient.

The EU has set a binding target that 20% of its energy supply be renewable by 2020 and to meet this target a third of all electricity generation must come from renewable sources by that time.

However, selecting suitable sites, choosing the most appropriate technology and systems, monitoring output and forecasting energy generation all require accurate measurements of meteorological parameters to be made.

The Hunt For Suitable Sites – Wind Prospecting

Wind generated electricity is the fastest growing renewable energy sector and Europe remains at the forefront of the market. By 2020 it is predicted that between 12 and 14% of the EU's electricity demand will be fulfilled by wind energy – this will save an amount of CO_2 equivalent to taking 165 million cars off the roads. Measurements matter in wind energy as we seek new locations and improve efficiencies.

The starting point for expanding wind power capacity is finding suitable new sites for turbine installations. There are published maps giving estimated wind resource for many areas and 'wind prospecting', as this process is sometimes called, often starts with such maps. However, wind is notoriously fickle and whilst map accuracy is improving all the time site specific measurements remain a necessity for large and utility scale wind farm projects to ascertain the commercial viability of a site.

For domestic and even some small commercial projects however the cost of pre-installation assessment is prohibitive and so turbines are installed with only a limited understanding of the likely pay-back period using general wind maps and data from nearby airports or other calibrated weather stations.

Successful wind farms rely on pre-installation site measurements to prove the sites viability for profitable wind power generation.

Wind Resource Assessment

There are three technologies in use for such resource assessments – Lidar, Sodar and cup anemometry. Lidar and Sodar both work on a similar principal with one using pulses of light and the other of sound to measure wind speed and direction by monitoring the reflected signals. The advantage of these devices is that they give measurements at any height across a set range. However, these devices typically require generators where mains power is not available (i.e. most sites) and there are obvious issues with this - for example regular site visits to keep the generator fuelled and a risk of data gaps caused by mechanical breakdown. However, for many people it is the incongruous use of a diesel powered generator as part of green energy study which makes cup anemometry the preferred route.

Conditions at prospective sites are typically far from ideal – access is often difficult, and usually there is no mains electricity or fixed line communication systems, and sometimes no mobile network coverage either. The other thing about such sites is that, strangely, they tend to be very exposed and windy places making working conditions difficult, especially in winter. This means that a monitoring system has to be simple to install, be pre-tested off-site, offer outstanding reliability, include a viable telecommunication platform and operate autonomously 24/7/365 from a sustainable power source.

Solar Powered Data Acquisition.

A typical mast based set-up involves several cup anemometers and wind vanes mounted at various heights on a meteorological mast of up 80 – 100m tall. Sometimes two sensors will be positioned at each height to provide redundancy in case the primary sensor fails. Other parameters such as air temperature, relative humidity, vertical wind speed, barometric pressure and solar radiation can also be measured as these elements can be used in wind modelling. For large sites several identical towers (same sensors, same mounting heights) will be erected so that a full site profile can be built up using correlated data from all the masts. The use of multiple systems also serves to provide redundancy in case of data gaps in any single masts dataset. A pre-programmed data logger, back-up battery and communications modem would be housed in an enclosure at the base of the tower to control the system and collect and process the data. The enclosure components will normally have been pre-wired to external connectors making on-site sensor connection as easy as possible – ideal for glove wearing engineers battling against icy cold winds. The whole system would be powered by a solar panel making it suitable in virtually any situation/location.

Data loggers such as Campbell Scientific's CR1000 control the monitoring station and process and store the data on-board for later remote collection.

Sensors would normally be sampled every two seconds with 10 minute averages being recorded along with standard deviation and maximum and minimum data. A data logger such as the Campbell Scientific CR1000 would make these measurements and process the data, converting the sensors output into engineering units for final storage on-board for later retrieval. All data is date and time stamped.

Long Term Monitoring

Sites will be continuously monitored over 12 or 24 months in order to provide a detailed profile of the wind speed frequency distribution throughout the year. However, even 24 months of site specific data may not be representative of longer term wind patterns and so site data is often correlated with long term reference data taken from nearby calibrated weather stations such as those found at airports. Measurements really do matter here as just a few percentage points of error can mean the difference between profit and loss.

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Data recorded at the mast cannot be assumed to be representative of the whole site especially for large projects or where there is a lack of homogeneity in the terrain and therefore complex modelling may be undertaken to better assess the whole site.

Once long term wind speeds have been calculated for the hub height of the proposed turbine, the gross electrical energy production can be calculated by using the manufactures power curve. There are six main factors which then need to be factored into the equation to derive a net production figure which will be significantly lower than the theoretical gross. These factors are:

- Wake loss
- Availability of the turbine
- Electrical efficiencies
- Reduction in the blade aerodynamics due to ice, dirt or insects
- Shut down due to environmental factors
- Curtailments

Once a turbine has been installed measurements continue to be taken on-site and used to compare turbine output to live wind data – this is to both verify manufacturers output claims but also to identify any problems. Ongoing data is also fed back into wind models for the site which, along with weather forecasts and live verification data, is used to forecast electricity output for the coming 24-72 hours.

Ice Storms – Sensor based warning system

The accretion of ice on turbine blades reduces output as the blades become less aerodynamic and slow down. Additionally the extra weight can cause damage to the gearing and there is a potential risk of injury from ice shearing off the blades at speed. Ice accretion is commonly a feature of a freezing rain event, or ice storms as they are sometimes called. Freezing rain occurs when rain, is 'supercooled' to below freezing as it passes through cold air in the atmosphere, yet remains liquid as it falls. If the turbine blades are at or below 0°C the rain freezes instantly on contact to coat the blades with a 'glaze' of ice which can quickly build-up. Ice can also be caused by low temperatures and high humidity – freezing fog conditions for instance.

As turbine blades are designed to be aero-dynamically efficient even a small amount of ice quickly causes imbalances to develop which dramatically slows the rotation. Turbines are normally turned off during icing to prevent damage. However, if ice is still present on a blade when the turbine is restarted it could shear off at speed presenting the risk of damage or injury in a sizeable area around the turbine.

So the early detection of icing can prevent damage and reduce the risk of injury. Specialist instruments such freezing rain or ice detection sensors can be used in conjunction with temperature and relative humidity sensors to form an ice warning system whereby a data logger and modem might be used to, for example, send a warning via SMS text or even to trigger the shut down and re-start of the turbine based upon pre-set conditions being met.

Ice detection sensors and freezing rain sensors can be used to warn operators of ice glazing occurring allowing early shut down of turbines.

Conclusion

Measurements matter in wind energy – for prospecting and validating new sites, for modelling wind patterns and forecasting output, for monitoring turbine performance and for ensuring the safe operation of turbines during ice events. The data acquisition system chosen needs to be power efficient and reliable; it must be robust enough to work in challenging environments and flexible enough to cope with multiple makes and types of sensors and provide a choice of communication options. Campbell loggers offer all the above and are widely used by specialist wind consultants around the world – to find out more please get in touch.