Measuring wind conditions is of central importance to wind power engineering, and new developments in remote sensing are transforming how this is achieved. Portable lidar devices, which remotely detect the wind conditions using lasers, enable direct measurements to be made where once only model approximations were possible. This is revolutionising our ability to predict the productivity of proposed wind farms and enabling us to operate existing wind farms more effectively. Lidars are rapidly becoming essential tools for characterising and exploiting the wind resource. The recent launch of the Galion – an innovative lidar for wind power applications – shows the versatility and increasing importance of these techniques.

By Peter Clive, SgurrEnergy Ltd, UK

Next Generation Lidar

All-Sky Scanning Capability Maps the Wind Using Laser-Based Technology

In recent years lidar has established itself as an innovative method of measuring wind parameters, often in locations where measurements would otherwise not be possible. At the recent BWEA 30 event in London a new lidar for wind power applications, the Galion, was launched. This promises to take the adoption of lidar by the wind power industry a step further.

New Application of an Established Technology

Lidar (LIght Detection And Ranging) is a mature remote sensing technology that in recent years has been used successfully in wind power applications. Lidar is a well-established and trusted technique in other fields: it has been used for decades analysing the composition of the atmosphere and the oceans, monitoring vortex shedding and turbulence at airports to clear aircraft for landing, mapping the surface of the land from air- and space-borne platforms, and providing target information in military applications. In May 2008 a lidar was even deployed to Mars on board NASA's Phoenix Lander. The development of fibre lasers over the last ten years has enabled this highly successful technology to meet the demands of the wind power industry. This has led to the development of products that are increasingly compact and highly deployable to the remote and poorly accessible locations typical of many wind farm developments. Once there, they operate with a high degree of autonomy, acquiring valuable and accurate wind data.

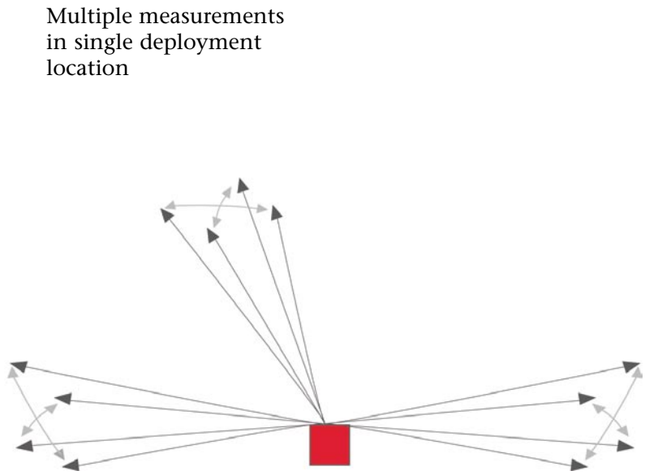

Figure 1. Multiple measurements from a single deployment

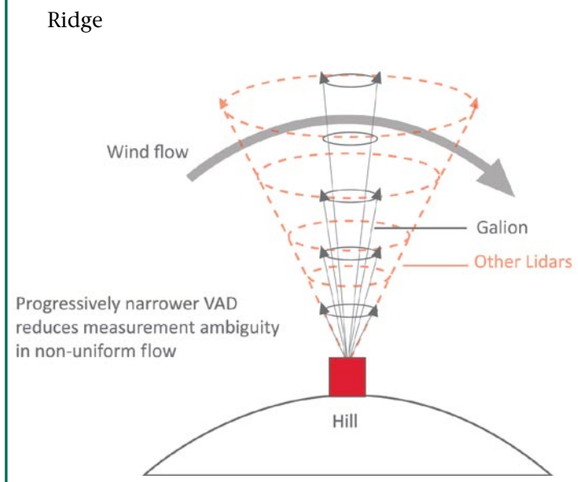

Figure 2. Galion captures accurate data in areas of complex terrain

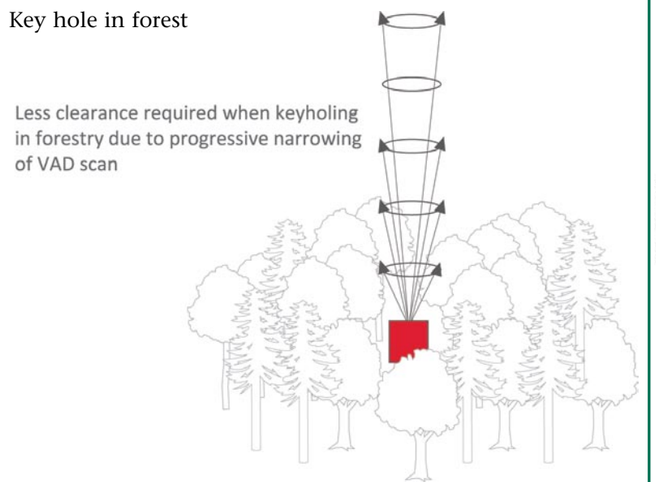

Figure 3. Galion requires less clearing in areas of forestry

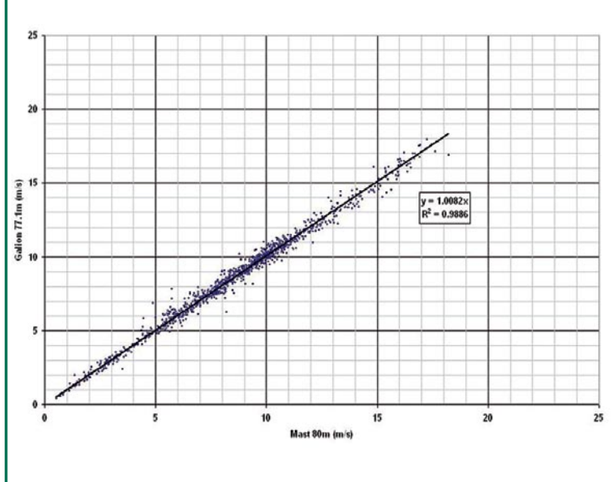

Figure 4. Comparison of Galion with mast-mounted cup anemometry

Remotely Sensing the Wind

Lidar works in much the same way as radar. Electromagnetic emissions from the device are scattered by objects in their path, and the device then detects the back-scattered emissions. Analysis of these indicates some properties of the objects that the emissions encountered. In the case of lidar the wavelength of the emissions is much smaller than radar, typically set to about 1.5 micrometres. This means that, whereas radar emissions are scattered by objects the size of a car, lidar emissions are scattered by molecules and microscopic airborne particulates (or 'aerosols'), which move with the wind. The motion of these aerosols relative to the device imposes a Doppler shift on the back-scattered emissions – a change in wavelength which indicates the wind speed.

Introducing the Galion Lidar

The engineering consultancy SgurrEnergy specialises in renewable energy projects and was an early adopter of lidar technology for wind power applications. With extensive wind power expertise, the company is uniquely well placed to meet the demands of the wind power industry, by providing a full package of wind monitoring, analysis, and operations and maintenance services. Because of this it was ideally placed to develop the next generation of lidar technology for wind power applications and formed a joint venture vehicle with a partner to pursue this.

Experience with existing lidar products led to the creation of a 'wish list' of features around which the specifications for the new product were built. The joint venture partner was able to provide the best technology for this purpose based on proven technology used for atmospheric science research. With the creation of the Galion, SgurrEnergy is now able to bring the benefits of this technology to the wind industry by providing accurate and timely measurements in difficult and challenging environments.

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The name Galion has been adapted from the Scottish Gaelic word Gaillionn, meaning windstorm. This is in keeping with our Scottish roots: SgurrEnergy's name also comes from the Scottish Gaelic meaning peak or pinnacle.

Pulsed Laser Technology

A remote sensing device needs to resolve both the quantity it is measuring (in this instance wind velocity) and the point in space where it is measuring it. The Galion measures wind velocity using a coherent heterodyne system, which measures the Doppler shift in the frequency of the back-scattered signal in a way similar to an FM radio. This allows wind speeds to be very accurately measured. It was clear at an early stage in the development of the Galion that the most effective way to achieve the second of the requirements above, distance resolution, would have to entail the use of pulsed lidar technology. This maintains a constant distance resolution over the entire range of the device, and allows measurements at all distances within that range to be acquired, in effect, instantaneously. So, for example, one can acquire instantaneous wind shear profiles using pulsed technology.

Unambiguous Distance Resolution

Perhaps more significantly, the distance to the point in space where the laser pulse is acquiring wind velocity data is unambiguously determined by the time-of-flight of the pulse – the

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duration of the interval between its emission and the detection of the back-scattered signal. This contrasts with continuous wave lidars, for which this technique is not available, whose distance resolution deteriorates the more distant the measurement, thus limiting their range. The range of the Galion is 2km, an order of magnitude greater than other devices, giving it an unrivalled combination of range and resolution.

All-Sky Scanning

One of the most significant features of the Galion Lidar is its steerable beam. This allows total freedom to select scan geometries that are most suitable for any given application. Conventional lidars for wind power applications are restricted to a single scan geometry that measures wind parameters in the 200m immediately above them. The freedom to choose other scan geometries allows the Galion to acquire measurements anywhere within its 2km range. So, for example, multiple proposed wind turbine locations can be surveyed from a single lidar deployment site, as shown in Figure 1. In addition, scan geometries are possible that are particularly suitable for the non-uniform wind flows in the complex and forested terrain typical of many upland wind farm developments, as seen in Figures 2 and 3.

User Friendly

The practical considerations arising from conducting a lidar measurement campaign are fully accommodated by the design of the Galion. It benefits from a unique self-levelling feature, which is particularly useful for rapid deployment. It is light, compact and portable, and can be deployed easily in remote locations by two people without the need for specialist equipment or extensive training. The predecessor atmospheric science devices have an unrivalled record of reliability in a wide variety of demanding environments. Data is stored on the system's onboard computer: memory imposes no restriction on its operation, as hundreds of gigabytes are available. All the data can be accessed remotely via a secure internet connection by GSM or satellite, and the operator has access to real-time and historical data.

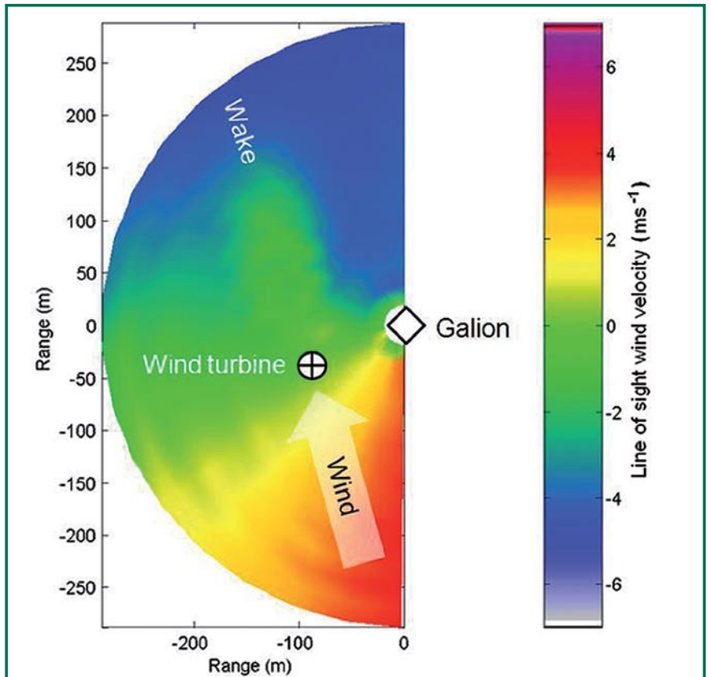

Figure 5. The use of a Galion in proximity to a wind turbine

Figure 6. Galion being set up by SgurrEnergy Product Development Manager Graham McKinlay

Figure 7. Galion deployed on a wind farm in Scotland

Analysing the Data

Preliminary results obtained using the Galion have been very encouraging. A comparison with measurements made using mast-mounted instruments is shown in Figure 4. A Galion was situated about 110m from the foot of an 80m tall mast and a conventional scan geometry was employed to allow comparison with other remote sensing devices. The Galion agreed with the mast measurements within the range expected given the real differences that exist between conditions at sites 110m apart, and performed significantly better than other co-located remote sensing equipment.

Convergence between Modelling and Measurements

One of the most significant sources of uncertainty when trying to predict the productivity of a proposed wind farm is associated with computer modelling. Observed wind data is input into the model, which then approximates the wind conditions at each wind turbine location in order to predict energy production. This approximation incurs an associated uncertainty. Direct measurement is always preferable to model approximation, and lidar provides the option to acquire direct measurements at many more locations than was previously possible. This allows model predictions to be compared to direct measurement at proposed wind turbine locations, allowing model validation and refinement and a consequent reduction in prediction uncertainty.

Lidar provides the option to acquire direct measurements at many more locations than was previously possible

Lidar and Operational Assets

The performance of operational wind turbines can only ever be fully understood if the wind conditions to which those assets are responding are properly characterised. The Galion allows measurement of parameters such as turbulence, wind shear and wind veer, which impact wind turbine performance. Once the prevailing conditions are fully understood the performance of the wind turbine can be optimised and the operation and maintenance strategy configured to best effect. The use of a Galion in proximity to a wind turbine is shown in Figure 5.

Availability

Independent testing is being carried out at DTU Risø in Denmark. The results of the 3-month test, whose completion is expected in March 2009, will be published and in addition made available at www.sgurrenergy.com. The Galion is an example of pioneering technology that will bring significant widespread benefits to the wind power industry. Figures 6 and 7 show examples of the Galion being set up and in use. Galion Lidar is exclusively available from SgurrEnergy. ■

Biography of the Author

Peter Clive is a Technical Development Consultant for SgurrEnergy, which has given him many opportunities to participate in the rapidly developing wind power industry. His interests include the use of remote sensing instruments such as lidar, and the development of techniques for extracting useful turbine performance information from operational SCADA data. Peter's background is in physics, and he obtained his doctorate in nuclear physics from Glasgow University in 2002.

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