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A Long Term Noise Measurement System for Wind Farms

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Abstract

Wind energy generation has been an area of rapid growth over the past decade. As a source of renewable energy wind turbines offer a clean and stable alternative to fossil fuels. Ireland's geographical location and prevailing weather conditions mean the country has enormous potential to be a prominent producer of wind energy. Significant investment in wind farm development is planned over the next ten years. Irish authorities are beginning to develop more advanced and comprehensive legislation to regulate both the planning phase and the ongoing assessment of these developments. One of the key concerns and barriers to expansion of the farms is the perceived impact of turbine noise on local residents. New regulations and methodologies are being developed to allow turbine operators, regulators and acoustic professionals to assess and manage noise emissions from wind farm developments. The nature of turbine operations, associated noise emissions and the timeframes for assessment will present a unique set of challenges to those responsible for noise limit enforcement and monitoring.

The authors have developed a noise measurement system for long term, automated monitoring. The noise monitoring unit is designed for long term, remote monitoring of environmental noise. The units are specifically designed to provide the type of functionality which is needed for addressing the issues unique to wind turbine noise measurement. The noise monitors can be deployed in situ and operate autonomously for extended periods of time. Results are stored locally and can also be monitored remotely.

Our web based visualization and analysis tools allow the consolidation of wind speed, weather and noise data. Early testing has shown that the system is particularly well suited to meeting the acoustic and environmental challenges of long term measurement at wind turbine developments. The system presents numerous benefits for operators, regulators and concerned residents alike. Our planned application of the technology will aid the effective implementation of new legislation and noise assessment methods.

Introduction

As an island next to a large ocean, Ireland is exposed to some of the strongest winds in Europe, and is thus well positioned for the development and deployment of wind energy technology. Wind turbines are one of the cleanest forms of energy producers available, producing no emissions, no pollutants no harmful gases, no effluent and no radioactivity. Concerns exist that wind farms can negatively affect local scenery (Hurtado et al 2004), wildlife (Kuvlesky et al, Smallwood 2007), property values, tourism and indeed cause noise nuisance (Pedersen 2004). However, each of these factors can be largely negated in the planning and development stages. By having policies and systems in place to manage these issues, the benefits and the acceptance of wind farm installations can be more easily realised.

The first wind farm in Ireland opened in 1992 in an area on the Atlantic seaboard. Since then, production of energy from wind farms (both onshore and offshore) has increased steadily. The sustainable energy authority of Ireland, the SEAI, envisages that wind power will make the most significant contribution to the nations targets for green energy production "due to its environmental benefits, technological maturity and increasing competitiveness".

At present, Ireland has 1,379 MW of installed onshore wind capacity. The total installed electricity capacity is in Ireland is over 6,000 MW, meaning wind power accounts for approximately 20% of production capacity. In addition there are another 1000 MW of wind farms under development with a further 15,000 MW of capacity planned (O'Doherty 2010). The management of the impact that these developments will have on local communities and habitats is crucial to the success of Ireland's goals to find more environmentally friendly forms of energy. This can be done through careful and effective planning of wind turbine developments and ongoing management of key issues. Acceptance of wind farms by the general public, particularly those in the vicinity of developments, is dependent on overcoming a number of barriers. Among the most prominent and publicised of these issues is noise.

Wind farms are relatively quiet when compared to many other industrial power generation sites. The acoustic emissions produced at wind turbines however, can result in resistance to planned and existing installations, due in part to the characteristics of the noise. There are four main types of noise that are generated during wind turbine operation. Tonal noise, primarily from mechanical parts, which can cause annoyance even at low levels. Low frequency noise, which propagates over long distances, impulsive noise from wind turbines and a broadband noise component often characterised as "swish" noise. When developing planning procedures and managing existing developments, the consideration of public perception of this noise as being intrusive or annoying is as important as accurate measurement of the noise levels. This understanding can be gained through

extended collection of data, accurate monitoring, careful analysis and engagement of the public and relevant stakeholders.

Effectively measuring noise at wind farms for this purpose presents a unique set of challenges. The requirement to monitor in several different wind/weather scenarios, across various times of the day and through changing seasons makes attended, short-term monitoring undesirable and somewhat impractical. Coupled with the fact that measurements should be compared to a background level, measured during turbine inactivity, or ideally, before installation, the case for autonomous monitoring becomes more apparent.

Irish guidelines for wind farm planning (DoE 2006) specify that the noise impact of the turbine installation should be controlled, relative to the existing background levels, during both the development and operational stages. Noise levels during turbine operation are not to exceed the background level by more than 5dB LA90, 10min. Certain circumstances may warrant more relaxed limits in the case of extremely low background levels. Noise impact is measured by reference to the existing situation at noise sensitive locations e.g. dwellings, or locations of particular scenic quality. These criteria outline a need for a system capable of monitoring the noise emissions of turbine installations in the long term, both for the purposes of regulation and increasing public acceptance by communicating relevant environmental data to neighbours and concerned parties.

Technology

Our noise monitoring unit is designed for long term, remote monitoring of environmental noise (McDonald 2010). The noise monitors can be deployed in situ and operate autonomously for extended periods of time. Equipped with a class 1 microphone the units are constantly monitoring noise levels and logging statistical data as required. Figure 1 shows a Sonitus Systems noise monitor. The Leq and L90, both A and C-weighted, are logged to the internal memory every ten minutes. A range of other optional statistics are also computed and recorded.

Figure 1: Noise Monitoring Unit and Microphone

The technology was developed using the concept of delay tolerant networking, or DTN (Fall 2003, Farrell 2006). Designed for extended operation in harsh environments, the system is capable of operating without user input for many months at a time. DTNs consist of sensor units which are designed to measure independently but aggregate all data to leverage the benefits of a widely deployed network (Farrell et al 2006). This amalgamated data can then be further analysed, or used to provide information on a wide geographical area.

We have incorporated sound level meter technology into the measurement front end of our sensor platform. The noise monitors are deployed at numerous locations and return data to a central repository using a GSM link. Information is then presented to the end user via a powerful web based analysis tool. Each unit syncs data according to a pre-defined schedule, however, if a data link is unavailable due to adverse weather or network failure the unit will log all noise readings for upload at a later time. The figure below illustrates this concept.

Figure 2: Widely deployed network with centrally stored data

Data is made available to the end user through a web based visualisation and analysis tool.

Application Case Study

Wind farm developers and promoters of the technology now recognise that noise impact assessments are a necessary part of any turbine installation. A full understanding of the effect a development has on the surrounding environment is necessary to meet regulatory requirements and to ease local concerns.

A number of units were deployed at a green-field site which is the location of a planned wind farm development. The aim of this initial monitoring stage was to assess the existing background noise levels prior to the commencement of building works. Noise level data was collected at noise sensitive locations for two weeks. This data was supplemented with a detailed set of weather readings describing the prevailing conditions during the measurement period.

The data was transmitted to a central server and was accessible at all times from remote locations. Readings were synchronised once per day and could be viewed as raw tabulated data or graphed using web based plotting tools. The data was not made available publically but will be used as part of an environmental impact survey (EIS) and also for ongoing comparisons to aid noise impact management.

Results

A sample of the results from the measurement period are displayed below. As can be seen from figures 3 – 7, this site shows little influence from factors other than weather. The background levels remain consistently low for much of the sample period. The periods of higher noise levels correspond directly to intervals f sustained high wind speeds. This suggests that the dominant source of noise at this location is wind noise itself. This is shown most clearly in figure 7, where noise levels at higher wind speeds (> $8ms^{-1}$) are consistently above the baseline level. This would indicate that a wind farm installation should have minimal impact. Guideline regulations propose a limit level of 45dBA or no more than 5dB above prevailing background levels. Despite the fact that noise emissions are greatest at high wind speeds, the existing conditions indicate that a turbine development is unlikely to cause an increase in noise sufficient to have a significant effect at these higher background levels (55-60dBA). In fact, at high wind speeds, the noise of the sound of the turbine is likely to be masked by the sound of the wind itself. At lower wind speeds, where background levels are beneath 45dBA, the influence of the turbine should be minimal.

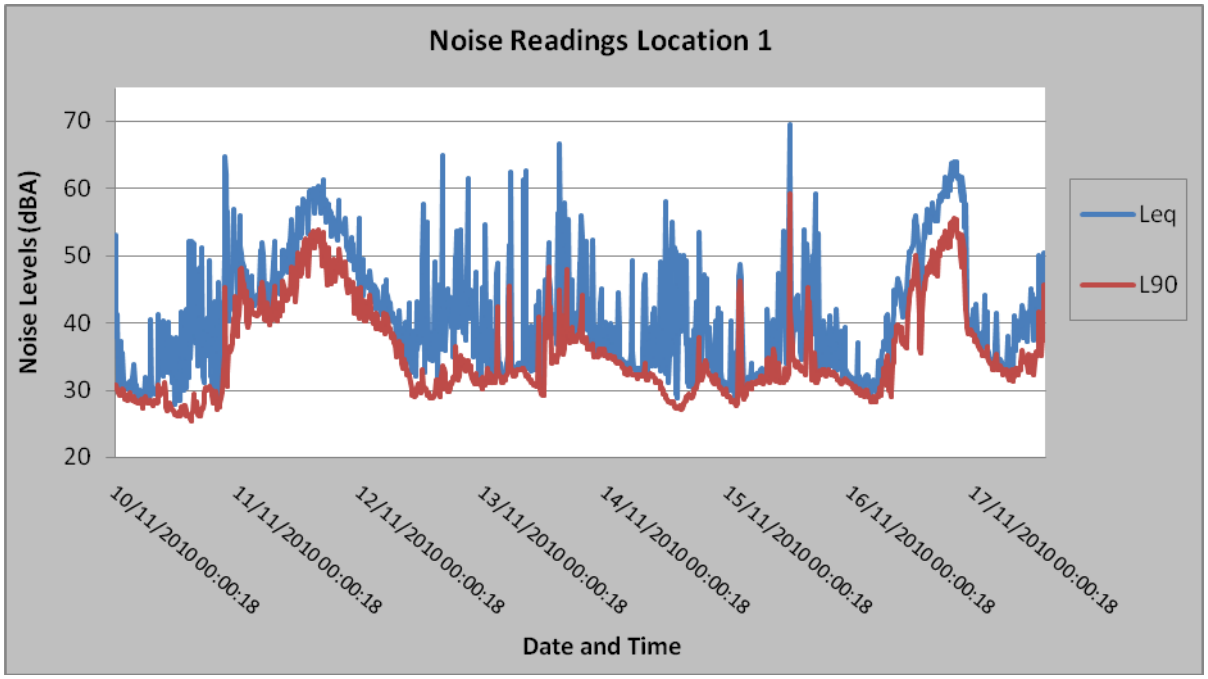

Figure 3: Sample of Noise Levels at Site Location 1

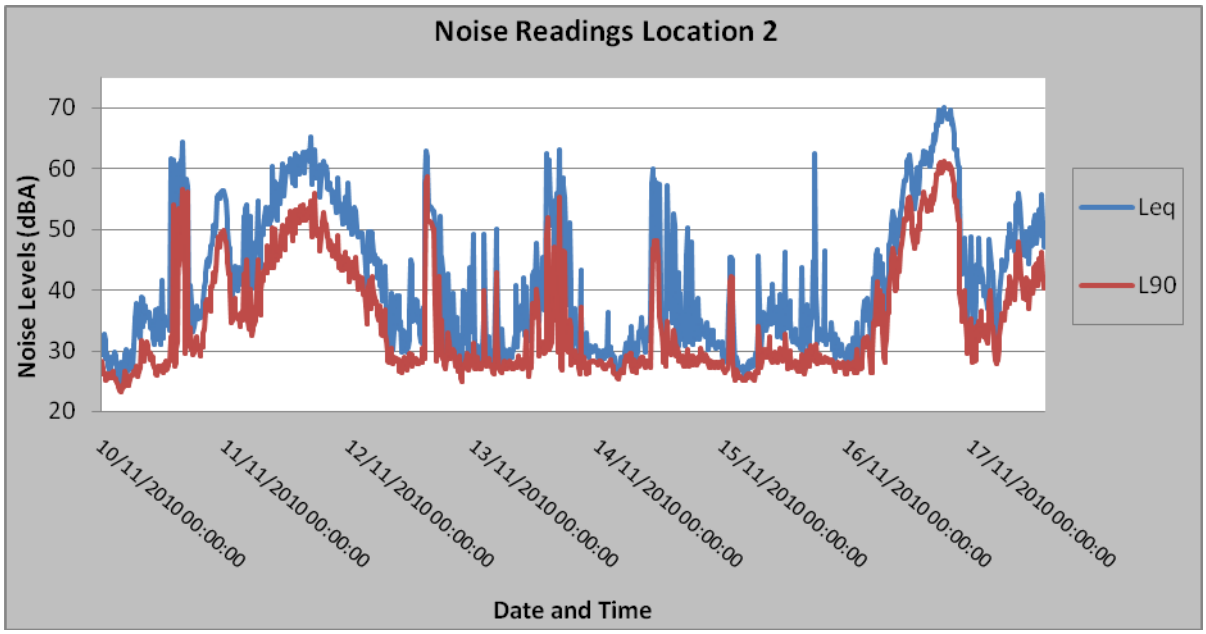

Figure 4: Sample of Noise Levels at Site Location 2

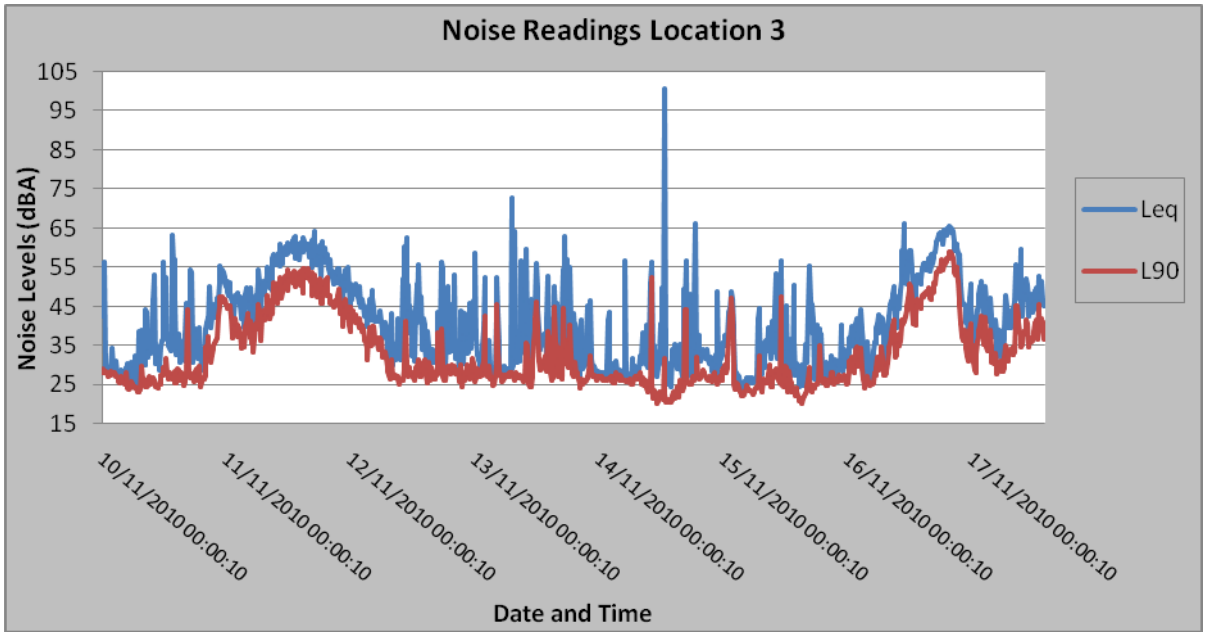

Figure 5: Sample of Noise Levels at Site Location 3

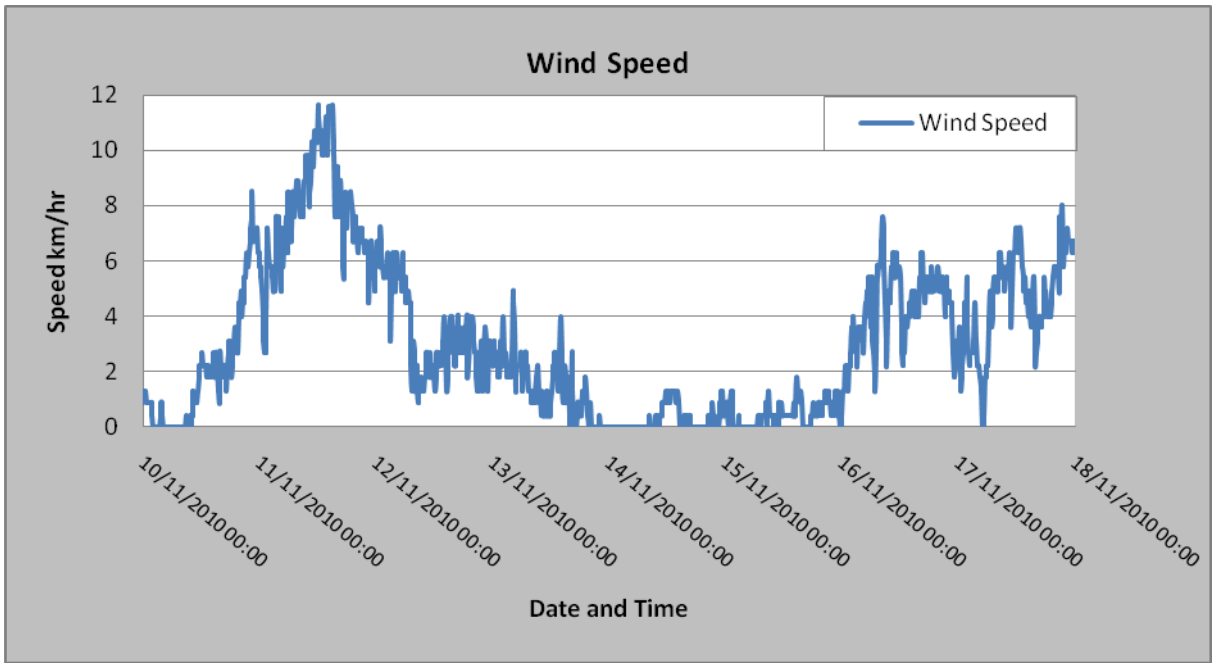

Figure 6: Wind speeds for entire site (no direction shown)

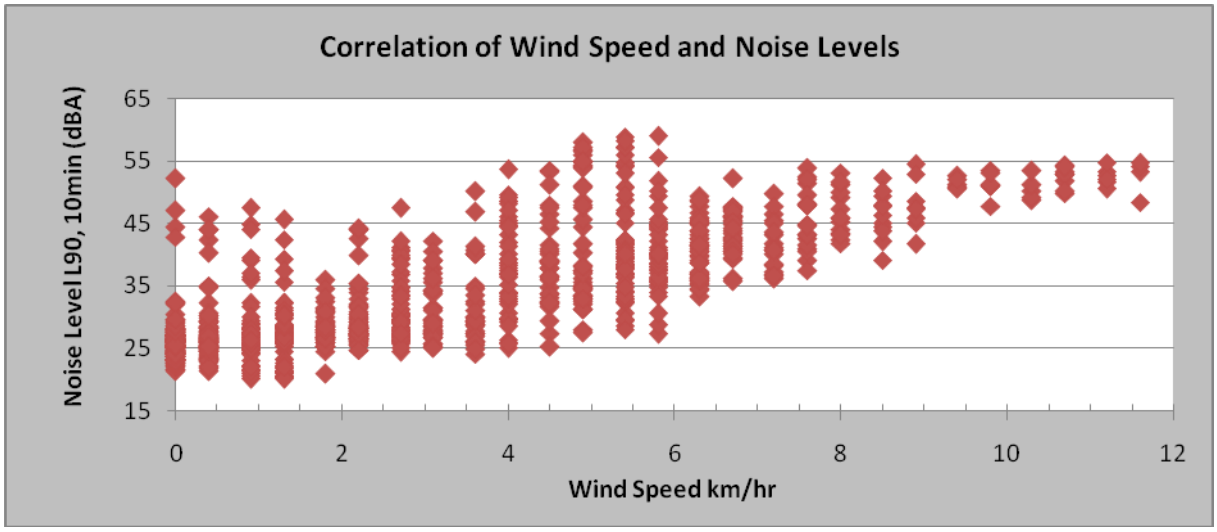

Figure 7: Scatter plot of noise levels at various wind speeds

System Benefits

The results analysis presented above forms part of any standard procedure for wind turbine site assessment and EIS preparation. While the tailored nature of the equipment and accessibility of the data is of great benefit in this regard, the real value of the technology is realised during the ongoing assessment of wind farm noise impact. By constantly monitoring noise emissions and making the readings available via the web the systems can impart two significant benefits. The first is an emission control system, alerting operators to any limit exceedance, helping to develop control procedures and increasing the understanding of the local wind/noise relationship.

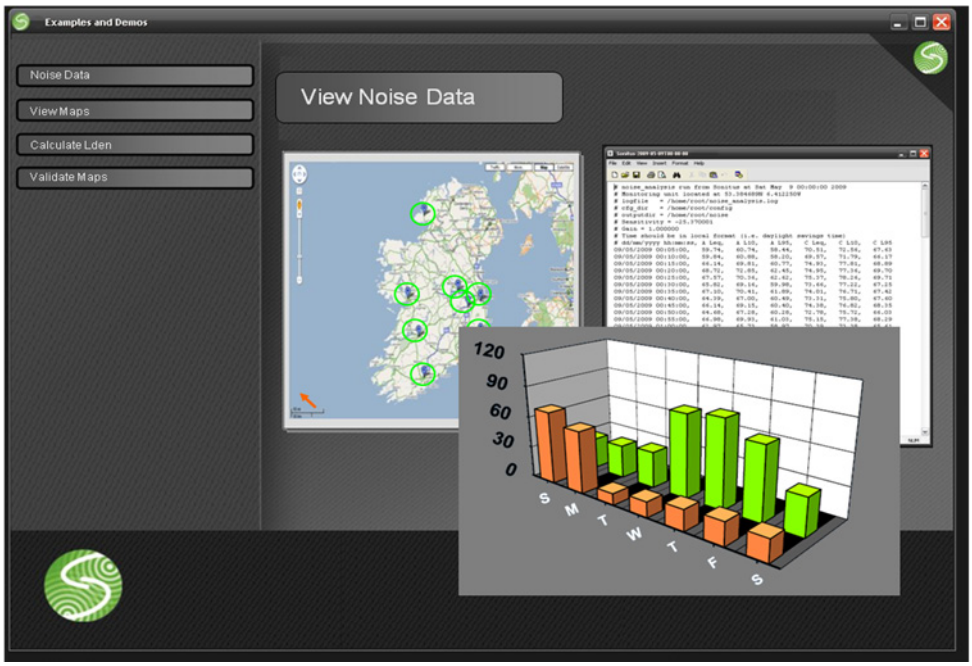

Figure 8: Web based interface for displaying remote noise readings

The second benefit is to address and assuage public concerns by providing relevant information to educate and reassure wind farm neighbours. By involving local residents, stakeholders and concerned groups, the problems of opposition can be largely diffused. Figure 8 shows an example of the system's web interface which displays location based noise level readings and offers an explanation of the data. A public forum which displays compliant noise levels can have a significant influence on the attitudes of affected parties. It is in this way that the noise management system also becomes a complaint management system by allowing the public to understand and view noise emission data and by involving them in the environmental assessment procedure.

Conclusions

Wind generated power will continue to expand as a source of clean renewable energy. With increasing investment and rising fossil fuel prices wind farm development presents a viable alternative means of producing electricity. However, there remain some barriers to acceptance, mainly in the area of environmental impacts. Not least among these concerns is noise. Noise emissions and noise annoyance are a source of concern for neighbouring households. The evolving legislation aims to minimise these influences, but a system of monitoring and control is needed which can meet the requirements of all parties. We have developed a long term monitoring system, based on ruggedized sensor technology which is ideal for this application. By monitoring noise levels during the planning, development and operational stages of wind turbine installation we can offer a full life cycle solution to ensure compliance with regulations and promote acceptance and support. Our web based display tools can be used by acoustic consultants to analyse noise level data and also to engage and reassure interested stakeholders. This holistic solution offers a simple and reliable method of wind farm noise management.

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