Wind Industry Addressing Noise from All Angles

As the wind industry continues to expand, siting for new wind farms becomes more complex as many ideal locations have already been developed. Because of the close proximity of proposed wind farm to residential developments, investors and developers are having to examine noise production from wind turbines more than ever before. Thankfully, the wind industry is responding to many of these concerns with new technologies and methods for reducing turbine noise, whether it's mechanical, aerodynamic, or vibrational.

Wind Turbine Modifications to Address Mechanical Noise concerns

Mechanical noise can also be a significant problem for wind farms. This type of wind farm noise is associated with the machinery housed inside the nacelle of the turbine, and is the type of noise that is most often a nuisance factor for residents living near a wind farm.

Mechanical noise occurs for many reasons. One is shaft noise, which can result from unbalanced or bent shafts, or from non-concentric alignment of the shaft. Gear noise is also common because of the uneven wear that results from high common multiples. In extreme cases, this can result in gear box failure. The noise from bearings and generators are also typical problems.

By way of example, the Pinnacle Wind Farm at NewPage in Keyser, West Virginia, USA started to receive complaints from residents of noise problems. Edison Mission Group, developer of the wind farm, worked with a California-based EMG firm by conducting tests to determine the source and nature of the noise.

Their analysis revealed that by installing an acoustic louver on the cooling machinery housed in the nacelles would significantly reduce the noise. The upgrade for the remaining 22 turbines will cost the company an additional $500,000, though it did not take more than a couple of months to complete.[i]

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Passive Control Methods for Control of Aerodynamic Noise at Wind Farms

Aerodynamic noise that is that which is created by the blade passing through the turbulent, sometimes gusty flow of air. This in turn causes turbulence which creates sound. Aerodynamic noise gets even louder as each blade passes by the tower. This type of noise is what is commonly heard as swishing or swooshing.

One of the most common ways to deal with aerodynamic noise is via passive control whereby adjustments are made to the trailing edge of the blades. Engineers and wind turbine designers are using complex computer modeling software to experiment with many variations on blade design in order to reduce both noise and drag. They face several challenges however, not least of which is the fact that when you modify the blade to solve one problem, you may introduce a new sound-producing source. Nevertheless, there are several promising technologies that are being examined, primarily in Europe.

GE prototype turbine with trailing edge serrations

Some researchers are working on a passive control method that involves adding saw-tooth extensions to the trailing edge of the blade, known as trailing edge serrations. These serrations are at an angle to the stream wise flow direction, which reduces the efficiency of the edge sound source. This method is theoretically supposed to work as a means of scattering the noise.

This sawtooth method is being tested by a number of different companies, including Siemens. Their design changes the frequency spectrum of the noise, which thereby reduces the high frequency noise to make them less audible at longer distances. GE is also playing with serration optimization along with new tip

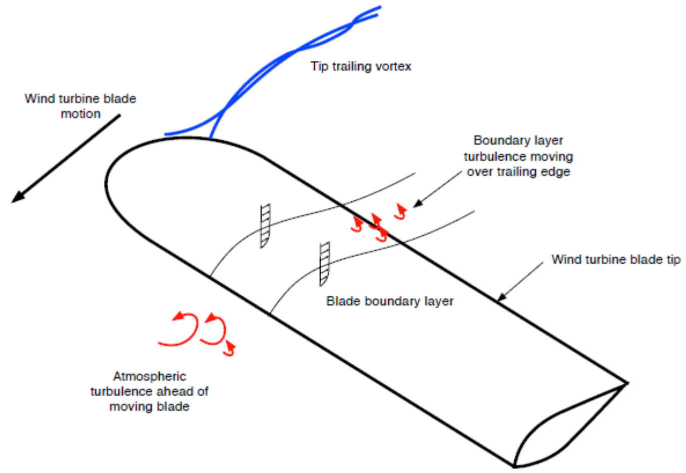

Figure 1: The flow over a wind turbine blade tip.

designs which together are supposed to increase their turbine energy output by 10%.[ii]

Though in theory serrations should be highly effective for reducing noise, researchers are finding that the production of additional turbulence noise by the serrations may be canceling out any benefit.[iii]

Another method being tested is the introduction of pores into the trailing edge inserts of a blade. But because of the likelihood of debris collecting in the pores and the resulting, costly cleaning this would require, this concept may not go very far.

Yet another technique being explored is low-noise airfoils whereby the shape of the blade is adjusted to decrease noise production. These design tweaks seek to minimize boundary layer thickness and maximize skin friction coefficient at the trailing edge as these are predicted to lead to low trailing edge noise. However, there have been many challenges with these new designs. Some were found to be louder than original models, especially at higher frequencies, though many of these challenges were related to manufacturing limitations in the prototype phase.

Trailing edge brushes are also being applied to some blade designs. These closely spaced, brushlike fibers are attached to the blades on the trailing edge as a means of replacing the sudden impedance mismatch at the hard trailing edge with a more gradual change in impedance over the brush extension. Gamesa has been working with this technology with a 0.5 decibel noise reduction reported for one of the models. Other tests have shown similar, unremarkable improvements, though more research is currently being conducted into these options.[iv]

Most manufacturers are working with software programs for developing new blade designs. Mitsubishi, for instance, is currently testing a prototype in Oregon that increases power and output but is supposed to be quieter as well. They developed their new designs based on a noise reduction prediction method, which evaluates noise quickly and accurately during the design phase. They claim that their prediction method can exploit current computational capacities to aid in efficient blade development.[v]

Active Noise Control Methods and Software Solutions for Wind Turbine Noise Reduction

In-phase noise production is often common on wind farms with multiple turbines. In these installations, turbines tend to rotate in the same direction at close to the same speed and angular velocity. As a result, the group of turbines produces sound at nearly the same time and in the same manner, which can generate zones of high amplitude modulation of trailing edge noise.

A concept known as active phase desynchronisation is being tested as an active means of controlling noise from wind farms with this in-phase noise production problem. This is accomplished by monitoring the phase of each turbine and blade, making adjustments to the pitch or brake of various rotor blades in order to reduce noise reinforcement. Though more research is required, this method seems to have potential to overcome the noise reinforcement problem.[vi]

Gamesa (and developer Iberdrola Renewables) has recently started using wind power software to make adjustments to blade positioning in order to reduce turbine noise. These tests are being conducted for application at their 2 year old Hardscrabble wind project in Herkimer County (USA). Sound limits of 50 decibels at a distance of 100 feet were being exceeded (they were spiking at 60 decibels) at the towns of Fairfield and Norway. [vii]

The software is based on alternative power curves which result in reduced noise. By using power curves, which are calculated based on wind speed, wind direction, and a time schedule, the software is able to make adjustments to the blades to minimize noise. The software is also able to slow the turbines as needed to limit noise output when required. The system runs automatically once it is configured.

GE is also implementing a software solution for noise reduction. Their sound power management (SPM) works to optimize control settings for the turbine based on real-time wind conditions. It can be configured for daytime and nighttime modes, based on turbine placement and mode switching. Wind farm managers are able to customize the sound power curve to precise requirements over the entire wind speed range using this software.[viii]

Another active noise control technology being pioneered is that from the Universitat Politecnica De Catalunya, Barcelona where they are testing a technique that introduces an electronically generated destructive interference with an additional (secondary) acoustic field as a way of reducing unwanted noise. Though this technology is being tested for windows and aircraft noise, they are also researching whether it would apply to wind turbines. Using a microphone and a loudspeaker, the researchers are determining whether two transducers could reduce noise, and if so what the best location on the turbine would be.[ix]

Vibration Noise Reduction in Wind Farms

Another unique noise challenge faced by wind farms is the problem of vibration. Due to structure-borne problems within a wind turbine, vibration energy can be transmitted throughout the entire system. This can cause every exterior surface to radiate sound energy, the effectiveness of which is known as radiation efficiency.

Xi Engineering Consultants is a specialist in vibration issues and recently examined some megawatt-scale wind turbines for a manufacturer of turbines. They discovered that the tower wall was resonating because of vibrations traveling to it from the gearbox. Using COMSOL Multiphysics modeling system, they were able to examine many variables and potential solutions to determine which would be most effective and financially feasible.

Several solutions were discarded as either impractical or impossible given engineering constraints. But after looking at several options, their solution was to coat the inside of the tower with a special material that reduces the amplitude of vibration. The modeling software allowed them to even determine the correct amount of the coating product to ensure it was both cost effective and sufficient to achieve the noise reduction goal.[x]

Much More Noise Reduction Technology Development to Come

Scientists will likely continue to tweak blade design, turbine position, and software management tools for many years in order to achieve more accurate and efficient blade designs. No doubt as wind power proliferation increases and greater public demand for silent operations are required, these technologies will vastly decrease noise pollution.

Images via The University of Adelaide School of Mechanical Engineering – Colin Kestell and The University of Adelaide School of Mechanical Engineering – Con Doolan

Maryruth Belsey Priebe

A student of all things green, Maryruth has a special interest in cleantech and green buildings. In recent years, Maryruth has worked as the senior editor of The Green Economy magazine, is a regular blogger for several green business ventures, and has contributed to the editorial content of not one, but two eco-living websites: www.ecolife.com and www.GreenYour.com. You can learn more about Maryruth's work by visiting her site, www.jadecreative.com.

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