CASE STUDY

United States of America

Industrial Products

PULSE

National Renewable Energy Laboratory
Testing Wind Turbine Power Generators using PULSE

The National Renewable Energy Laboratory (NREL) is operated for the U.S. Department of Energy by the Midwest Research Institute, Battelle, and Bechtel. Within NREL is the National Wind Technology Center that carries out advanced research on all aspects of wind turbine power generation and provides support to the American wind turbine industry.

Wind turbine noise is an important environmental issue, not only in the U.S. but throughout the world. The National Wind Technology Center uses a PULSE™ system to measure the noise produced by wind turbines and their component parts. The test data is used in the design and development of wind turbine generator systems and to ensure that the noise produced by a design is within the specified levels.

History

The National Renewable Energy Laboratory, founded 25 years ago, is operated for the U.S. Government's Department of Energy by the Midwest Research Institute, Battelle, and Bechtel. Within NREL, the National Wind Technology Center carries out state-of-the-art research into all aspects of wind turbine generators and their components. It provides extensive support to the wind turbine industry, not only in the U.S. but throughout the world.

The National Wind Technology Center, established ten years ago, is located at Golden, some 20 miles (32 km) northwest of Denver, Colorado and in the midst of spectacular scenery. The flat countryside, flanked by a range of mountains to the west that reach up to more than 12 000 feet (3650 m), provides near perfect conditions for testing wind turbine generators with constant wind-speeds that vary from hurricane force down to still-air conditions.

Research & Development

The laboratories at Golden extend to some 6000 square feet (557 m^2). The research carried out covers many areas and includes the latest aerodynamic research into the performance of turbine blades, the design of major components used in the construction of wind turbines, their efficient siting, and a range of environmental issues that especially focus on wind turbine noise. Investigations extend to the affects of wind turbines on wild-life and the problems of bird-strikes.

The current total power produced by wind turbines throughout the U.S. is about 4400 megawatts. The wind turbine industry is expanding rapidly, not only in America but throughout the world and a number of large companies dominate the market and operate internationally.

Although funded by the U.S. Government, in addition to providing support to the industry, the National Wind Technology Center also operates as a consultant organisation and carries out specific research and testing for many companies that manufacture components and complete wind turbine power generation systems.

Engineering Expertise

Fig. 1
Arlinda A. Huskey has worked at the National Wind Technology Center for eight years. She has extensive wind turbine experience and sat on the committee that established the latest IEC Standard

The National Wind Technology Center has about one hundred employees and it has assembled a group of engineers with extensive experience and expertise in the design of wind turbines.

Arlinda A. Huskey has worked at Golden for eight years. Arlinda has a B.Sc. in Mechanical Engineering from Arizona State University and is currently studying for her Masters', also in Mechanical Engineering at The University of Colorado.

Jeroen J.D. van Dam is a Dutchman. He has a Master's degree in aerospace engineering from Delft University in The Netherlands. Before joining the National Wind Technology Center two years ago, Jeroen worked at The Netherlands Energy Research Foundation for five years.

Fig. 2
Jeroen J.D. van Dam has a Master's degree in aerospace engineering. He also sat on the IEC Standard committee

Design Compromise

Arlinda explains, "There are many variable factors in the design of a modern wind turbine. Some configurations provide optimum power while others give the highest efficiency or produce the lowest noise. There are two major schools of thought. One favours the use of a two-blade turbine that runs downwind while the other prefer a three-blade design that faces into the wind".

In general, three blade turbines are considered to be quieter than those with two blades since they normally rotate slower.

Turbine Noise

Fig. 3
This 600 kW wind turbine at NREL's facility is used to investigate the noise produced by typical downwind two-blade designs

Arlinda says, "The noise produced by wind turbines is a major factor in Europe, and it's becoming an increasingly important issue a not only in the U.S. but throughout the world. Much of our investigative work is in this area and it occupies about 50% of my time."

Jeroen continues, "We carry out a lot of research on components with a view to decrease the cost of energy of wind turbines and to reduce their environmental impact. Most blades are currently made of glass fibre but there is currently a transition to carbon fibre with the advantages of a much higher strength to weight ratio and lower total weight. We experiment with both fixed and variable pitch blades and with turbines of different sizes. The critical factor is the power curve of the design – the power output compared to the wind speed."

Jeroen adds, "Some wind turbines are very large. The blades rotate at about 30 rpm and the blade tips can reach a speed of 60 meters per second. The slower the blade, the less noise but this affects the power output so, as Arlinda mentioned, there are many factors that must be considered.

PULSE

Fig. 4
A three-blade100 kW turbine generator at NREL's facility. This configuration runs into wind and tends to be quieter than designs using two blades

The National Wind Technology Center recently purchased a 6/1-channel Portable PULSE system for general NVH analysis and investigations into turbine noise with respect to noise legislation. Before the acquisition of PULSE, noise data was stored on a DAT recorder and post-processing analysis was subsequently carried out in the laboratory.

With PULSE, analyses can be made in real time on a laptop PC and the complete portability of the system enables it to be easily transported to other sites around the world. The DAT recorder is no longer necessary and post-processing of the data can be performed anywhere, and at any time.

If, in the future, the National Wind Technology Center's testing demands grow, then PULSE can be easily expanded to provide more functionality, and this was another key reason for selecting it.

Testing

Fig. 5
The National Wind technology Center at Golden has been established for 10 years. The site provides near-perfect testing conditions – and there are not many neighbours!

To determine the noise characteristic of a turbine, it is necessary to place the microphones at a number of different positions and to also measure the main operating parameters.

Four microphones are normally used, and are positioned around the turbine. The positions of the microphones are determined by the tower height and blade diameter. The data from the microphones can be analysed in real-time and is also stored in PULSE for post-processing analysis.

Other factors such as the wind direction, wind speed and the turbine power output are also measured and stored in PULSE. The noise response is typically measured over a frequency range from 20 Hz to 10 kHz.

Arlinda explains, "Because a noise test depends on the wind blowing from the right direction and at a correct speed, a typical test could last from just a few hours up to more than a week."

The microphones are calibrated using a Brüel & Kjær Calibrator Type 4231 before each testing session, or at intervals of every two hours, whichever is less.

Jeroen adds, "The noise measurements must be taken with both the turbine running and when parked so that the background noise can be measured. We must make sure that there is no 'external' noise present during the measurement process. This includes trains, planes, dogs barking, etc. We once had a problem with a field full of goats close to a turbine! It's therefore vital that we can listen to the noise recorded by the system as the measurements are made".

IEC Measurement Standard

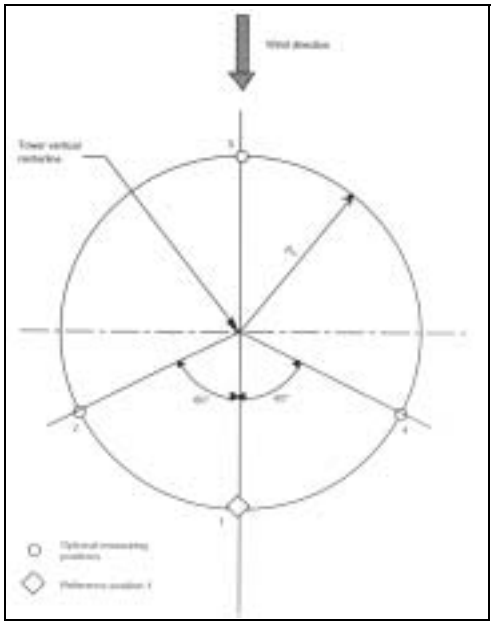

Fig. 6
Standard pattern for microphone measurements positions (plan view) in the draft IEC Standard 61400 – 11

Many countries around the world have enacted legislation that sets the levels of noise allowed for wind turbine generators. Typical values are an SPL of 40 dB (A) during the day and 35 dB (A) at night.

A new IEC Standard 61400 – 11 edition 2 is in its final draft stage, and when ratified, will specify the techniques for the acoustic noise measurement of wind turbine generator systems. The second edition draft specifies one microphone with three others as optional. The first edition specifies four microphones. In both editions, the reference microphone position is always required. One microphone is placed immediately downwind of the turbine, two are placed at 60 degrees from the turbine centre line and downwind of it, and a fourth is placed on the center-line at the back (upwind) of the turbine.

The draft IEC standard specifies all parameters relevant to the measurement of turbine noise including:

- Instrumentation – acoustic and non-acoustic instruments, traceable calibration
- Measurements and measurement procedures – measurement positions, acoustic and non-acoustic measurements
- Data reduction procedures
  - Wind speed
  - Correction for background noise
  - Apparent sound power (A-weighted)
  - 1/3-octave (CPB) levels
  - Tonality (using FFT analysis)
  - Directivity (optional) – how much the noise varies with the wind direction
- Information to be reported – characterisation of the wind turbine, physical environment, instrumentation, acoustic and non-acoustic data, uncertainty

Arlinda and Jeroen were members of the IEC committee that drafted the new standard. Arlinda represented the U.S.A. and Jeroen represented The Netherlands.

Data and Reporting

Test data is held on the laptop PC's hard disk and archived on CD-ROM. Reports are made using the PULSE export facility to the Microsoft® Office suite and then created in Word and Excel. It's easy, quick and effective.Data from a previous test can be easily accessed and compared.

Key Facts

- The National Renewable Energy Laboratory is operated for the U.S. Department of Energy by the Midwest Research Institute, Battelle, and Bechtel
- Within NREL, the National Wind Technology Center carries out advanced research on all aspects of wind turbine power generation
- The current total power produced by wind turbines throughout the U.S. is about 4400 megawatts
- The National Wind Technology Center supports the U.S. wind turbine industry, and also operates as a consultancy
- "The noise produced by wind turbines is a major factor in Europe, and it's becoming an increasingly important issue not only in the U.S. but throughout the world"
- The National Wind Technology Center recently purchased a 6/1-channel PULSE system for general NVH analysis and investigations into turbine noise with respect to noise legislation
- PULSE enables analyses to be made in real time on a laptop PC – the portability of the system enables it to be easily transported to sites around the world
- If testing demands grow, PULSE can be easily expanded to provide more functionality
- Microphones are calibrated using a Brüel & Kjær Calibrator Type 4231
- IEC Standard 61400 – 11 specifies the techniques for the acoustic noise measurement of wind turbine generator systems
- Reports are made using the PULSE export facility to the Microsoft® Office suite

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