



Tecplot 360 Case Study

Predicting broadband noise in wind turbines

Innovative Technology Applications Company, LLC using numerical simulation to examine the flow around wind turbines and accurately identify the acoustic field sources that are associated with the unsteady fluid behavior.

In 2010, global wind power installations increased by 22%,¹ according to the most recent information available from the Global Wind Energy Council (GWEC), an international representative forum for the wind energy sector. This added capacity represents investments worth \$65 billion, according to that same report. In addition, a number of factors are combining to virtually guarantee interest in more “environmentally friendly” methods of power generation that will continue to grow in the coming years, such as rising oil prices, political turmoil in the Middle East, and the recent Fukushima nuclear accident.

One of the challenges for this burgeoning industry is finding ways of reducing the noise created by large wind turbines, especially as more and more are being built near densely populated areas.

“The objective is to avoid a negative impact wherever possible, but physically testing these machines is not economically feasible,” says Christopher C. Nelson, Ph.D., the chief scientist at Innovative Technology Applications Company, LLC (ITAC). “A lot of times, you build the machine, operate it, and then realize that there’s a bad whine. It may be far from a populated area today, but it will save time and money in the future if we start building quieter wind turbines before they become an issue.”

As part of a program for the US Department of Energy led by the Illinois Institute of Technology, ITAC is helping develop ways of predicting the broadband noise that might be generated by a wind turbine. Their work is focused on using numerical simulation to examine flow around wind turbines and then accurately identify the acoustic field sources associated with the unsteady fluid behavior.

“We’re trying to characterize the noise sources, that’s the simplest way of putting it,” says Nelson. “Once you can do that, you can come up with less noisy solutions or solutions at a frequency that doesn’t annoy people as much.”



tecplot.360

Using Tecplot 360 to visualize and validate results



Innovative Technology Applications Company, LLC is using numerical simulation to examine the flow around wind turbines and accurately identify the acoustic field sources that are associated with the unsteady fluid behavior.

The image above is taken from a Tecplot 360 animation showing the vorticity magnitude where air is spinning behind the moving blade of a wind turbine.

¹ “Global wind capacity increases by 22% in 2010 - Asia leads growth,” Global Wind Energy Council, 2 February 2012.



Methodology: Synthetic Array Technique

Nelson and his group employ a methodology called the “synthetic array technique,” which uses numerical methods to perform an analysis identical to that used for experimental data from microphone phased arrays.²

The methodology involves a three-step process using different numerical tools and a dataset obtained from wind tunnel testing:

1. Navier-Stokes equations are solved with the OVERFLOW solver to obtain an unsteady flow field in the vicinity of the turbine.
2. This data is fed into the PSU-WOPWOP solver,³ to predict the farfield acoustics and then, in turn, to record sound levels at virtual microphone locations
3. That information is fed into the Beamform Interactive software package which analyzes the data using a variety of beamforming methods.

The objective is to do a good job defining the acoustic sources close to the rotor and the immediate wake and then to use the resulting data to predict the acoustics farther away.

“One of the issues we’re facing is that capturing the acoustics at long distance would require billions of points,” says Nelson. “For example, we’re already at 220 million cells close range. We have to focus on defining the close range very, very precisely and use that information to predict farther out.”

Nelson’s team begins by running a CFD simulation around the wind turbine, with the unsteady wake and rotors turning. The acoustic data surfaces are then defined around the blade, the flow is recorded, and the information is saved off at every step. Then the PSU-WOPWOP tool takes the CFD data and makes predictions about the acoustics, such as unsteady acoustic pressure and unrelated quantities at locations near and far.

“The third piece is, we feed that info into the Beamform Interactive data processing software, which is normally used with experimental data from phased microphone arrays and allows you to get a handle on where the noise sources are located,” says Nelson. “It’s pretty cool.”

Tecplot 360: Visualizing and validating the results

The final step is visualizing everything in a post-processor, which is where Tecplot 360 comes in. Nelson and his group selected Tecplot 360 because of its flexibility and ease-of-use. One of the outputs was a 3D animation within the adaptive mesh environment, which allowed the researchers to see and validate the results.

“Tecplot 360 was the linchpin. It allowed us to fuse everything together and take a look at it,” says Nelson. “It did amazing work reading in the OVERFLOW solutions where you had the grid and the solution file at each step. Not only is the grid moving, you have new points being read into it.”

“Many packages can read in the results from a solver,” he adds. “But Tecplot 360 was able to read in a sequence of files where each grid didn’t have the same number of points, and process it all. That’s something the others can’t do.”

Nelson also finds many of the 2D plots generated in Tecplot 360 to be very useful, but the 3D animation was the critical piece.

“When you’re doing these big complex runs, you can’t do it without the 3D visualization,” says Nelson. “That’s why experimentalists have struggled with this problem for years. They can’t see what’s going on because they can’t visualize it. It’s just that the human eye needs an overview. We still can’t do it with tools. Our ability to integrate information from our eyes to our brains is amazing.”

There are many other applications for this kind of process, according to Nelson, who cites similar work that ITAC has already carried out on blunt trailing edge airfoils.

“I think these are beautiful machines. To me, a wind farm seems like one big dynamic sculpture,” he adds. “It would be nice if most people looked at them that way as well. Eliminating potential objections to noise just might help us get there.”

² A similar technique was successfully implemented in a previous joint effort by ITAC, Dr. Dougherty, and Profs. Brentner and Morris studying the acoustics of an airfoil with a blunt trailing edge.

³ A general purpose Ffowcs Williams–Hawkings (FW-H) solver developed at The Pennsylvania State University by Dr. Brentner and his research team. The code was originally developed to compute the noise of rotorcraft in maneuvering flight, but was developed using an object-oriented design in the Fortran 95 language in a very general manner.