ILLINOIS WINDWORKING GROUP

Advancing Wind Power in Illinois Conference 2011

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Emerging Technologies

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Emerging technologies for wind turbine design and health monitoring

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Viryd: Martin Price and Matthew Arnold
Optinav: Robert Dougherty
ITAC: Alan Cain

Emerging technologies for wind turbine design and health monitoring

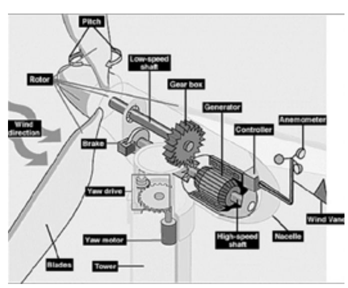
- New blade designs
- New computational tools in aeroacoustics
- Advanced acoustic source localization and wind turbine health monitoring methods

Motivation for wind turbine noise studies and solutions

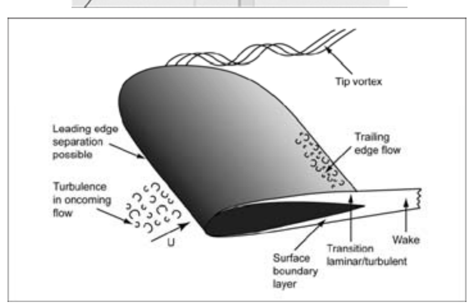
- The noise produced by a machine is a measure of its inefficiency.
- Excessive noise made by a machine represents wasted energy.
- Acoustics and Vibration are coupled in both directions. Aerodynamic noise due to blade motion can couple with the structural modes of the blades and produce vibrations. Drive train vibrations can be radiated and acoustic waves
- Excessive vibrations can lead to fatigue failure of components.
- Site permit considerations.
- Quality of life issue for local residents (annoyance, sleep deprivation)
- Other issues with wind turbines (birds and bats)

Wind Turbine Noise

- Mechanical sources include sound from
  - Gearbox
  - Generator
  - Yaw drives
  - Cooling fans
  - Hydraulics



- Aerodynamic noise
  - low-frequency sound
  - Inflow turbulence
  - airfoil self- noise



Noise mitigation by improved blade design

(GE Research conducted by Petitjean, Drobietz and Kinzie)

Blunt tip

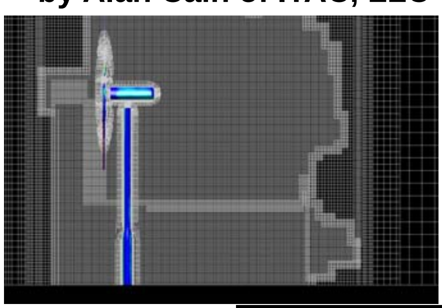
Slender tip

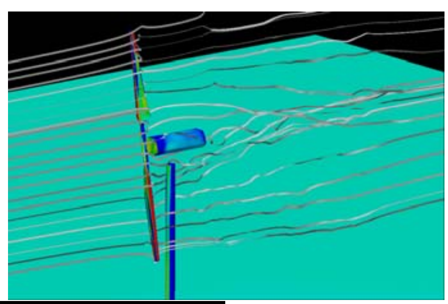
Ogee tip

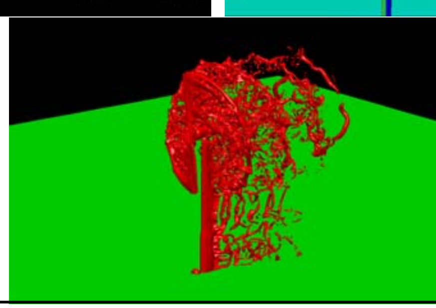
5 – 6 dBA noise reduction by going to advanced tips

2 – 4 dBA noise reduction by going to serrated trailing edges

Associated Aeroacoustics computations performed by Alan Cain of ITAC, LLC







Advanced acoustic monitoring

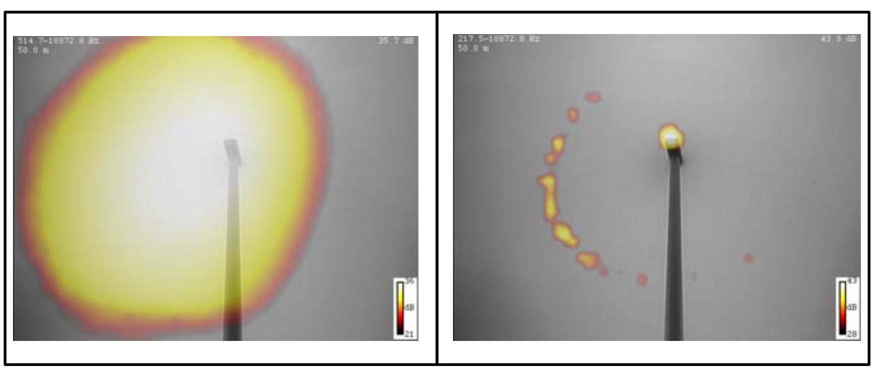
- A phased array can provide information beyond what is necessary for sound level monitoring and local ordinance compliance
- A phased array can give you the relative dominance of various noise sources on a wind turbine. The array is unaffected by ground reflections, background noise and noise from adjacent wind turbines.
- A phased array can be used to assess the health of a wind turbine (eg., a gearbox failure is accompanied by some acoustic precursors that can be detected)
- A phased array can be used for better wind turbine and blade design and can validate improvements in-situ under various wind conditions

A compact phased array is desired for wind farms

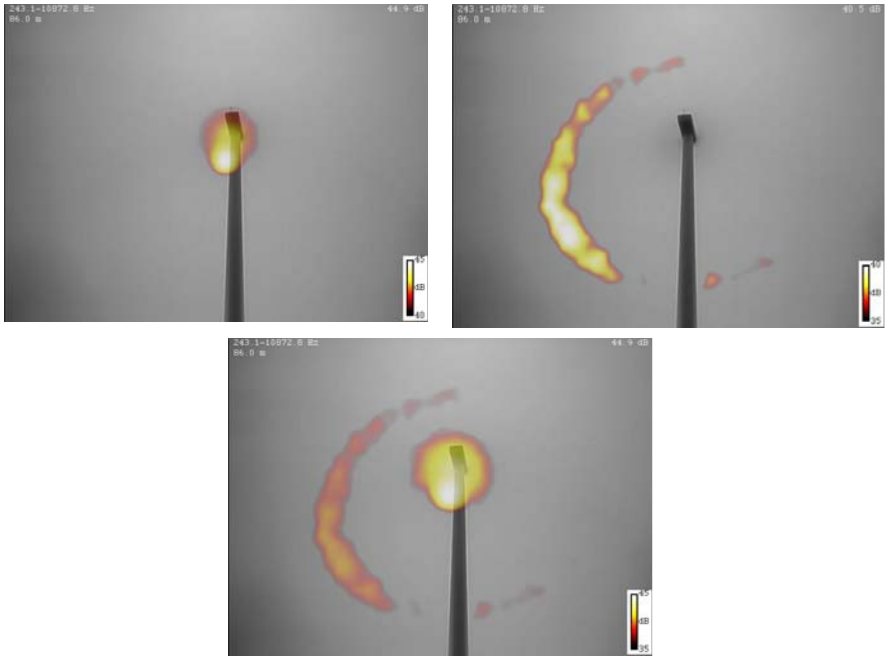
•The challenge for us is to show that compact phased arrays can be used with advanced beam forming algorithms to make credible measurements of wind turbine noise

Phased array measurements in progress

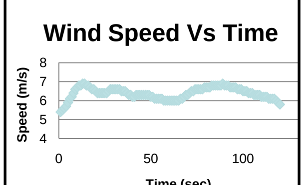
Conventional Beamforming & Advanced Beamforming Algorithm



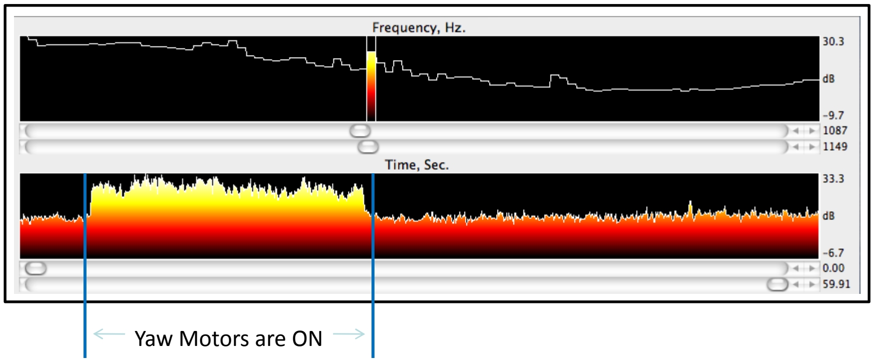
- Using conventional beamforming with a small phased array will result in a blurry image.
- It cannot locate sources at low frequencies which is where the wind turbine makes much of the noise.
- By using advanced algorithm we are able to separate the various sources on the wind turbine, such as, the blade tip vortex noise and the cooling fan noise from the hub.



Advanced Beamforming Algorithm (TIDY) - Movie

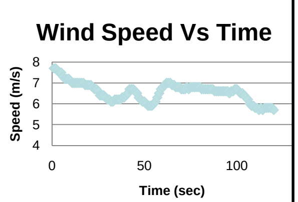


Differentiating Noise Sources



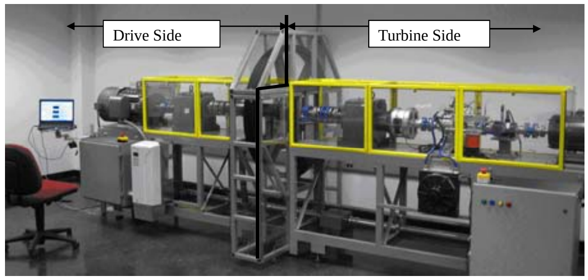
- The use of phased array is very useful in differentiating the noise sources.
- In this case we observe that the Yaw motor makes noise at a particular frequency (1100 Hz).

Differentiating Noise Sources – Movie



- When the yaw motor is OFF the hub noise level is 7.7 dB and when the yaw motor is ON the hub noise level is around 24.3 dB.
- We see the component of noise that is associated with the yaw motor.

Drive Train – in the laboratory

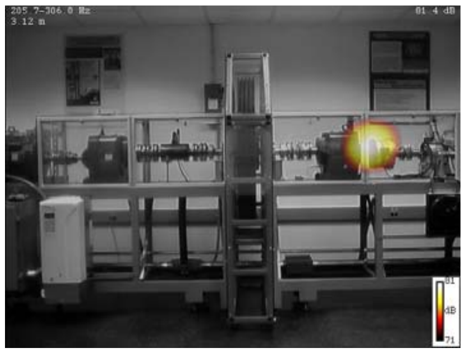


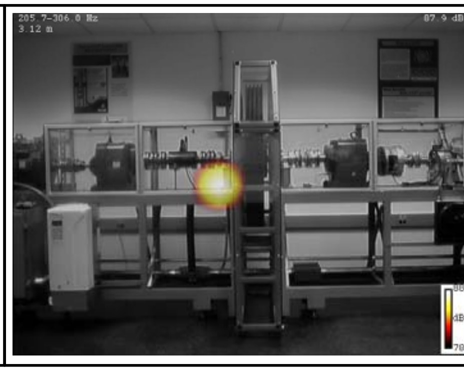
- Facility houses two sides: a drive side and the turbine side.
- On the drive side,
  - a drive motor
  - a gear box (Continuously variable planetary (CVP) gearbox)
  - an inertia wheel that compensates for the absence of blades.
  - a torque transducer.
- On the turbine side,
  - turbine driveline
  - a torque transducer.

Drive train tests

Parameters	Test 1	Test 2
Wind speed (m/s)	20	6
Turbulence	0	0
Input torque (Nm)	400	400
Transmission ratio	0.8	1.5
Power factor	ON	ON
Power (kW)	3.7	1.5

Results





- Frequency 205-306 Hz
- TIDY
- CVP and Fly Wheel
- 81.4 dB and 87.9 dB (Test 1)
- 74.2 dB and 80.8 dB (Test 2)

Concluding remarks

- Emerging technologies for wind turbine aeroacoustics include:
  - Advanced acoustic source localization and wind turbine health monitoring methods
  - New computational tools in aeroacoustics
  - New blade designs
- Preliminary tests were conducted on the GE wind turbine installed at a wind farm and a Viryd wind turbine drive train installed in the lab.
- Future work will focus on identifying subcomponents of wind turbine noise and working towards noise reduction solutions.