Small-scale wind turbines in cities and suburbs: Current practice

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Current Status

- Basically none

- Some attempts at horizontal axis wind turbines over past 20 years
  - not successful
- Recent attempts with vertical axis wind turbines (VAWTs)
  - promising
  - too new to conclude much

Introduction

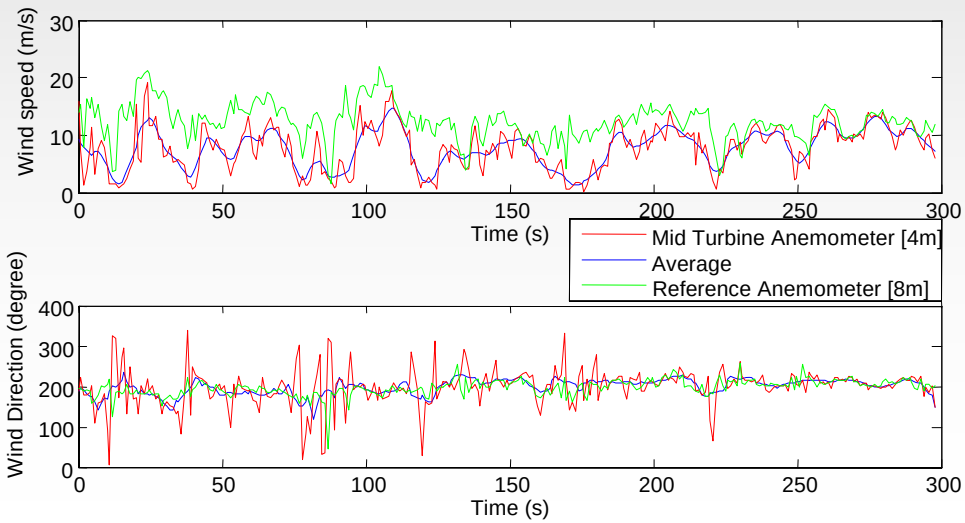
- Small wind
  - <200 m^2 = 16 m diameter (< ~80kW)
  - typically smaller <10kW
- Cities and suburbs
  - “dirty” wind
  - rooftop mounting
- Reputation

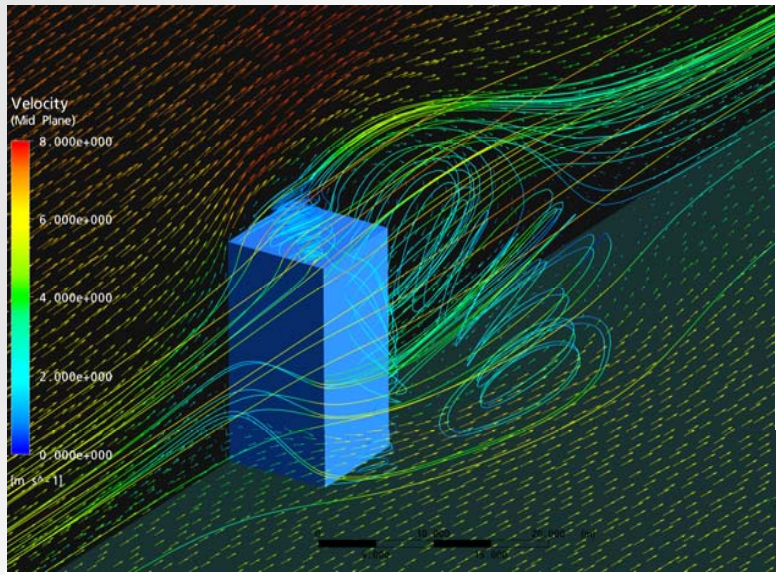
Main Issues

- Technical
  - power performance
  - noise
  - vibration
  - safety
  - structural integrity
  - reliability
  - icing
- Regulatory
  - certification
  - grid connection
  - bylaws
- Economic
  - cost and payback
  - incentives

Urban wind

- Lower wind velocity due to larger ground roughness within urban environments
- Complex vortical flow structures over and around buildings
- High turbulence levels





Numerical Modelling of a Building with Normal Flow to the Building's Face

Horizontal axis small wind turbines

- Numerous suppliers of turbines for tower/field installation
- Yaw to face wind -
  - high mount and blade loads with rapid yaw
    maintenance, servicing, warranties
- Non-uniform wind into turbine
- High tip speeds lead to noise

Vertical axis wind turbines

- Combination of blade rotation and incident wind give blade lift (torque)
- Research and commercialization of medium/large VAWTs in 1970s & 1980s
- Small VAWTs mainly H-type

Sandia 34 m Darrieus
Sandia National Labs

Cleanfield VAWT

VAWTs in “dirty” air

- Non-directionality
- Ability to handle unsteady, non-uniform, turbulent wind
- Renewal of interest in VAWTs for urban installation
  - Turby
  - Quiet Revolution
  - Cleanfield Energy
- Issues
  - power performance
  - noise
  - vibration

Quiet Revolution QR5

Cleanfield VAWT

Power performance

- Power is proportional to turbine area - small turbines produce small amount of power
- Small wind is less efficient than larger (>100kW) turbines
- Rated power is at high windspeeds (12-14 m/s = 43-50kph)
- Urban installation
  - depends on wind (location of town/city, local conditions)
  - ability of turbine (and its controller) to respond to dirty air
  - cannot expect to achieve rated power

Noise

Noise is proportion to blade velocities

- Small horizontal axis turbines can have high tip speeds
  - loud
- VAWTS have lower blade speeds than HAWTs
  - no high speed tips
  - actual blade speeds are low relative to HAWTs
  - low noise

Vibration

- Coincidence between structural modes and excitation frequencies.
- Structural modes affected by installation, tower, turbine
  - mainly whirl mode (whole turbine sways or rotates)
- Sources of excitation:
  - unbalance,
  - aerodynamic loading of blades
- Magnitude of excitation is small (depends on turbine power), but at coincidence there is little damping so vibration magnitude can grow to be large
- Rooftops are not usually designed or built for such loads

Vibration reduction

- Reduce excitation
  - helical blades
  - low RPM (high solidity)
  - blade design
- Controller deadbanding (don’t let turbine run in coincidence RPM ranges
- Isolation, damping (not ideal and not so applicable - better to avoid problem occurring)

Other Technical Issues

- Safety, structural integrity and reliability
  - really just proper engineering, construction and installation
  - safety includes use of monopole towers to prevent people climbing the tower
- Icing
  - not really an issue for large turbines with no people around
  - in cities, icing conditions will produce ice on flagpoles, buildings etc and ice will fall off in slabs (on to populated areas)
  - only difference for urban wind turbine is that if turbine runs with ice on it, it can lead to vibration problems if ice remains attached, or the ice slabs could be thrown a distance

Conclusions

- “Dirty” air in urban environment is unsuited to traditional small-scale HAWTs
- Small VAWTs are able to handle the “dirty” air
- Main technical issues
  - power
  - noise
  - vibration

Before looking at technologies, some basic questions:

1. What is the objective or role of municipalities with respect to wind power?
   - Provide clean/green power to municipal buildings?
     - laudable, but small-scale wind is small - often just a tiny fraction of building power use
     - have to look at payback period (not great)
     - community scale (100-750kW) or large (750kW+) wind turbines/farms would make better economic sense, but should the municipalities be in the business of running wind farms (the power gen business)?
     - if not in the power gen business, is the argument that small wind is for local use only enough reason to be generating small amounts of power?

- For the municipal government to be seen to be doing “something” clean/green power-wise?
  - fair enough (optics can be important)
  - urban small-scale wind is certainly visible (reliability is key so as to not show that renewables don’t work)
  - is this where a wind energy company partnership makes sense?
    - cost and risk sharing between company and municipality
    - each gets a pilot or demo facility

- Municipalities should foster small/urban wind energy even if it is not ***presently*** economic?
  - someone has to champion new technologies to help drive them over market hurdles (getting to market, reducing unit costs…)
  - renewable/green/clean energy officials in municipalities see this as part of their role

- Provide bylaws and zoning to permit (encourage?) small scale wind turbines by residential and commercial buildings?
  - residential use is marginal (noise, towers, is selling power back a commercial enterprise?, safety assurances)
  - but can argue that with existing (eg noise) and new regulation should let the market decide (or let market forces lead to better products)
  - commercial (suburban/industrial) buildings should be easier to let building/property owners do what they want (larger or more small-scale turbines) within limits

2. What are the drivers of the push for small-scale urban wind?
   - Municipal energy officiers

     Or is it mainly driven by companies that see that municipalities have a “pot” of money to spend on clean/green technologies?
   - Or by councillors
     - they’ve been approached by companies
     - they want to have a visible green/clean showcase