Wind Monitoring for Wind Energy

Jim Salmon

York University ESS 5210
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Toronto, Ontario, Canada
Wind Monitoring Stations

Wind Energy

MSC
## Wind Measurements

<table>
<thead>
<tr>
<th></th>
<th>Wind Energy</th>
<th>MSC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal</strong></td>
<td>(Long-term) energy production from wind project via (long-term) wind speed frequency distribution</td>
<td>Synoptic data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Climatological data</td>
</tr>
<tr>
<td><strong>Primary measurements</strong></td>
<td>Wind speed, wind direction, temperature, bar. pressure</td>
<td>Wind speed, wind direction, temperature, pressure, humidity, precipitation, weather</td>
</tr>
<tr>
<td><strong>Interval</strong></td>
<td>10 min (true averaging)</td>
<td>1 hr (2 or 10 min pseudo-average before hour)</td>
</tr>
<tr>
<td><strong>Height (wind measurements)</strong></td>
<td>40, 50, 60 m (80, 100, 120 m)</td>
<td>10 m (WMO standard)</td>
</tr>
</tbody>
</table>
# Wind Measurements

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<tbody>
<tr>
<td><strong>Period</strong></td>
<td>9 months minimum; usually not more than 4 years</td>
<td>Climatic (30 yr +)</td>
</tr>
<tr>
<td><strong>Anemometer</strong></td>
<td>3-cup, Class 1 preferred; prop-vane accepted</td>
<td>Heavy-duty 3-cup (45B, U2A, etc.); RM Young 05103 Wind Monitor prop-vane anemometer at automatic stations</td>
</tr>
<tr>
<td><strong>Instrument accuracy</strong></td>
<td>1% for calibrated anemometers</td>
<td>Unknown for 45B, U2A; about 3% for Wind Monitor</td>
</tr>
<tr>
<td><strong>Archiving resolution</strong></td>
<td>High</td>
<td>1 knot (can create issues with binning of data)</td>
</tr>
</tbody>
</table>
AEP Calculation

Annual Energy Production

\[
AEP = \left(\frac{\rho_{Ave}}{\rho_{Po}}\right) \cdot 8766 \cdot \sum_{n=1}^{N} Fr(U_n) \cdot Po(U_n)
\]

Frequency (\%)

0

10

20

30

40

50

60

70

80

90

100

Power (kW)

0

100

200

300

400

500

600

700

800

900

1000

Production (kWh)

0

50,000

100,000

150,000

200,000

250,000

300,000

350,000

400,000

Wind Speed at hub-height (m/s)

0

5

10

15

20

25

30

362 kW

4.76\% \times 8766 \text{ hr/yr} = 417 \text{ hr}

\[\rho_{Ave}\]

\[\rho_{Po}\]

\[\sum_{n=1}^{N} Fr(U_n) \cdot Po(U_n)\]

150,954 kWh
80 m turbine
50 m mast
60 m mast
**Tower**
- size = Level of Effort
- cost (including labour)
- cost of anemometer maintenance
- transportation

**Anemometers**

**Direction Vanes**
- type
- accuracy and confirmation
- reliability
- durability
- resistance to icing
- resistance to discharge
- cost

**Boom Arms**
- design to avoid tower and boom shadowing

**Dataloggers**
- reliability
- durability
- communication capability
- data capacity
- cost
Anemometers

propeller-vane anemometer

cup
anemometers

wind vanes
Power Supply
- AC supply if available
- solar panel and rechargeable batteries
- replaceable batteries (at data collection)
- do not undersize if cellular comms are being used

Temperature
- an inexpensive and useful measurement for air density calculations

Barometric Pressure
- an expensive measurement
- can be omitted

Lightning Protection

Grounding
- protection from electrostatic discharge
- prevents lightning - does not mitigate it
Tubular Towers
NRG Systems 60 m TallTower wind monitoring mast
Enclosure with datalogger, cellular communications, battery, charger

Screw anchor

Mast base mounting plate

Solar panel, directional cellular antenna
Lattice Towers

Personnel Safety

Equipment Safety
  • ice falls

Equipment Handling

Booms
  • more difficult design
References

IEC Standard

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC

61400-12-1

First edition
2005-12

Wind turbines –
Part 12-1:
Power performance measurements of electricity producing wind turbines

IEA Guideline

RECOMMENDED PRACTICES FOR WIND TURBINE TESTING

11. WIND SPEED MEASUREMENT AND USE OF CUP ANEMOMETRY

1. EDITION 1999

Edited by

Raymond S Hunter
Renewable Energy Systems Ltd
Scottish Regional Office
11 Elm Bank Street
Glasgow G2 4PB
United Kingdom

B Maribo Pedersen, Danish Technical University, Denmark
Troels Friis Pedersen, Risø National Laboratory, Denmark
Helmut Klag, DEWI, Germany
Nico van der Borg, ECN, Netherlands
Neil Kelley, NREL, USA
Jan Åke Dahlberg, FFA, Sweden

International Energy Agency

http://domino.iec.ch/webstore/webstore.nsf/artnum/035360
Boom design parameters

Boom to anemometer

Anemometer to tower
Boom design parameters

Tower to anemometer distance:

- **IEA Guidelines**
  - 1% deficit: 6 mast diameters
  - 0.5% deficit: 8.5 mast diameters
- **IEC Standard**
  - 1% deficit: 6.1 mast diameters (IEC goal)
  - 0.5% deficit: 8.2 mast diameters

Boom to anemometer distance:

- **IEA Guidelines**
  - 12 to 15 boom depths
- **IEC Standard**
  - 0.5% uncertainty goal
  - 15 boom diameters

Boom direction: 45° to prevailing wind
Boom design parameters

Tower to anemometer distance:

- **IEA Guidelines**
  - Complex calculation depending on mast ‘porosity’
- **IEC Standard**
  - Complex calculation depending on mast ‘porosity’ (same as for IEA)

Boom to anemometer distance:

- **IEA Guidelines**
  - 12 to 15 boom depths
- **IEC Standard**
  - 0.5% uncertainty goal
  - 15 boom diameters

Boom direction: 90° to prevailing wind
Installation and Maintenance

Station Installation
- should be well planned
- make careful measurements and keep good documentation
- cost is proportional to tower size and complexity

Station Monitoring Strategy
- plan regular station visits
- document carefully
- keep and bring spares
Data Collection Strategy
— Plan in advance!

In-Situ
• labour intensive - can be costly

Land-line Telephone
• generally the cheapest alternative if service easily available
• generally the most reliable

Cellular Telephone
• generally the easiest logistically
• cell service not always available
• cost is generally reasonable
• can cause power problems if AC is not available
• can be reliable if carefully done

Other Options
• short haul modems
• satellite
• meteorburst
• Internet

Data Handling Strategy

• check data regularly to make sure instruments are in good working order
• QC/QA data regularly and archive
• back-up data
Data Required

At each wind measurement level:

- **Mandatory**
  - 10-min average scalar wind speed (ms\(^{-1}\))
  - 10-min standard deviation of wind speed (ms\(^{-1}\))
  - max sampling-interval gust wind speed in 10-min interval (ms\(^{-1}\))
  - max 3-sec gust wind speed in 10-min interval (ms\(^{-1}\))
  - 10-min (true) average wind direction (°)

- **Optional**
  - 10-min standard deviation of wind direction (°)
  - 10-min vector wind speed (ms\(^{-1}\))

Near the ground:

- **Mandatory**
  - 10-min average temperature

- **Optional**
  - 10-min average barometric pressure
Data Required

Additional useful data

• Optional
  • Datalogger battery voltage
  • Max datalogger battery voltage
  • Min datalogger battery voltage
  • Datalogger temperature
  • Max datalogger temperature
  • Min datalogger temperature
  • Cell phone strength
  • Datalogger internal parameters
  • etc...
80 m turbine
50 m mast
60 m mast
Sodar Sound Detection and Ranging

- sends out sound pulse (chirp) - measures doppler shift and intensity of returned echo
- measures speed, direction, vertical speed, temperature, others...
- can achieve 5 m resolution from ground to 200 m (or higher) with 3% accuracy
Sodar

Advantages

• Quick and relatively easy to set up – can be mounted in a trailer and towed to the site
• No requirement for expensive and lengthy (relatively) tower installation
• Provides a complete profile of the wind speed and direction from near the ground to the top of the rotor
• Less expensive than Lidar
Sodar

Considerations

• Siting can be difficult to avoid potential for fixed echoes – e.g., nearby trees, buildings, etc.
• It is necessary to supply a significant continuous power supply - AC power or an expensive remote generation capability
• Ambient noise can degrade results
• Electronic noise can also be an issue
• Precipitation renders data invalid; must be removed
• Snow or ice in the Sodar renders data invalid – must be cleared
  • Newer Sodars may mitigate this
Sodar

Considerations (cont.)

• Plotting and examination of time series, average wind profiles is necessary for data QC
• Neutral atmosphere and atmospheric attenuation can create signal strength problems
LIDAR Light Detection and Ranging

Sgurr Gallion

Qinetiq ZephIR

Leosphere/NRG WINDCUBE
**Lidar**

- Fixed frequency (pulsed or continuous laser) EM wave is broadcast to the atmosphere (vertically upwards)
- The wave interacts with aerosol scatterers in the atmosphere; some of the broadcast wave is reflected back to detector
- Return “echo” is detected, Doppler shift is measured, and wind speed is determined
Lidar

Advantages

• Quick and relatively easy to set up – can be mounted in a trailer and towed to the site
• No requirement for expensive and lengthy (relatively) tower installation
• Provides a profile of the wind speed and direction at a number (about 5) of levels from near the ground to the top of the rotor
• Lidar exhibits no side lobes (Sodar issue)
• Is not prone to data quality problems due to fixed object reflections (Sodar issue)
• Is not prone to data quality problems due to ambient noise (Sodar issue)
Lidar

Considerations

• Expensive – theft or vandalism could be an issue
• Requires a substantial continuous power supply
WIND RESOURCE ASSESSMENT HANDBOOK

Fundamentals for Conducting a Successful Monitoring Program

Prepared By:
AWS Scientific, Inc.
3 Washington Square
Albany, NY 12205

April 1997