Optimization of a Mini H.A.W.T. to Increase Energy Yield During Short Duration Wind Variations

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for tomorrow

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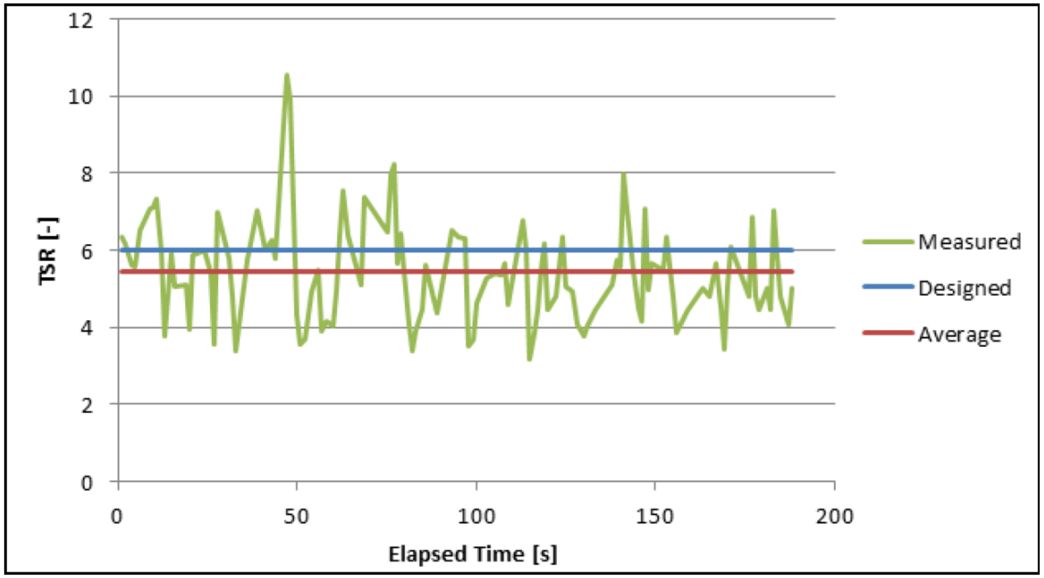
Contents

Justification - Reports

- In general poor performance in built environment.
- Warwick Wind Trials:
  - 26 small scale turbines.
  - 168 950 hours logged.
  - Capacity factor of 0.85% (4.15%).
- Energy Saving Trust:
  - Average 3% capacity factor.
  - Compared to 19% rural.

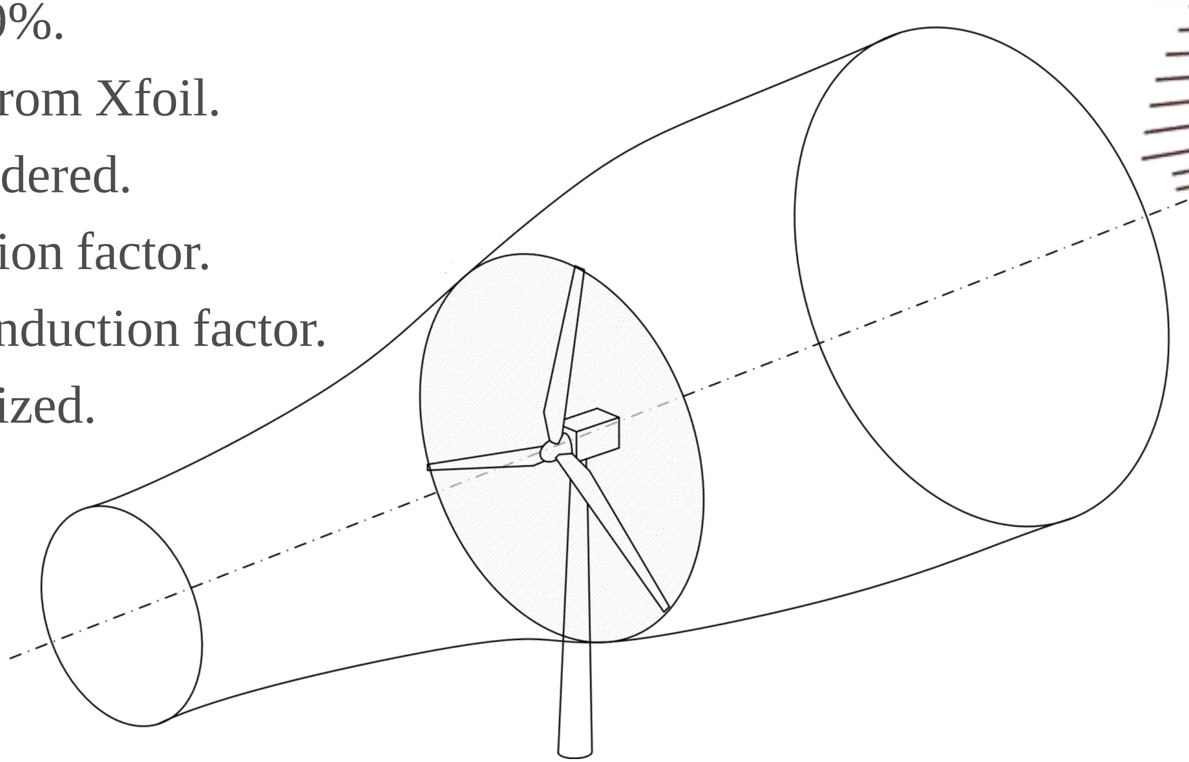
Justification - Challenges for Small Wind Turbines

- Short term wind variations:
  - Gusts.
  - Turbulence.
  - Horizontal component fluctuations.
  - Vertical component fluctuations.
- Very low Reynolds number:
  - Low urban wind velocities.
  - Small blade chord length.
- Startup wind speed:
  - Extremely low Reynolds number.
  - Very high angle of attack.
  - No pitching mechanism.
  - Blade torque only.
- Urbanization:
  - Low wind speeds.
  - Gusty and turbulent winds.
  - Noise.

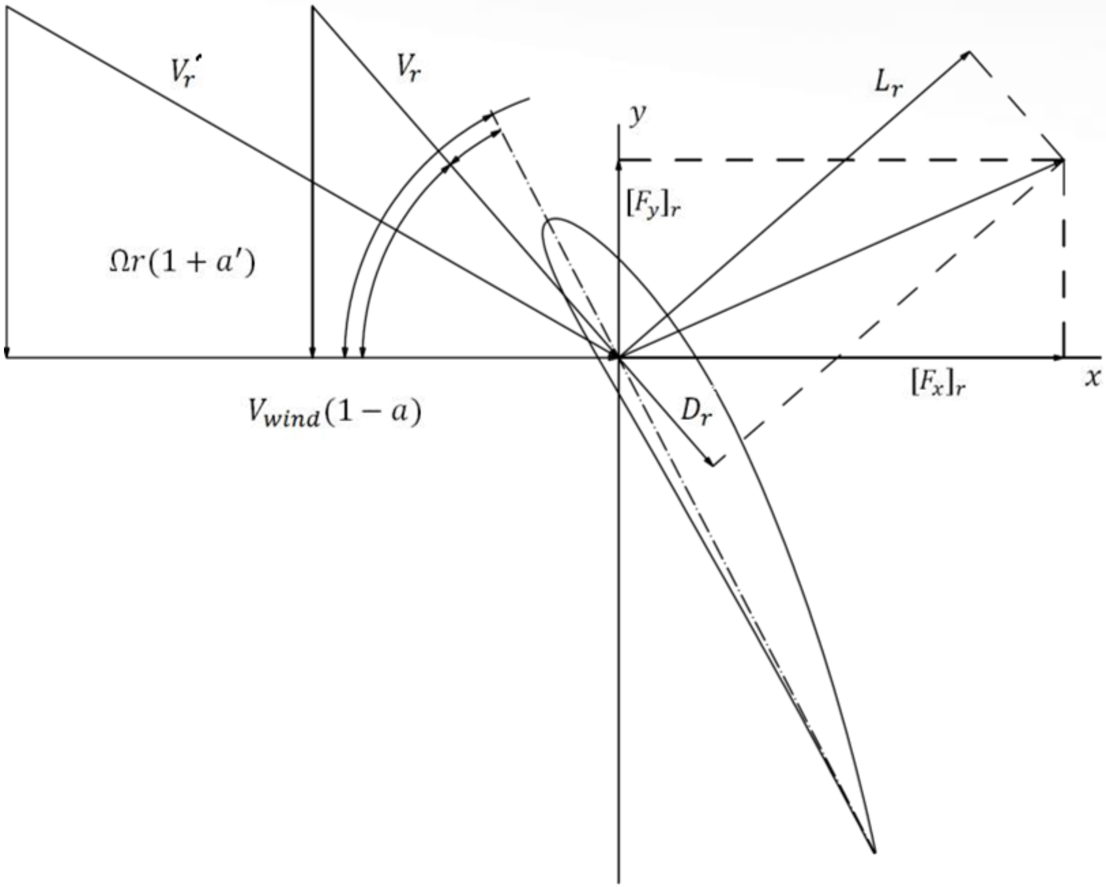


Theory - Blade Element Momentum Theory

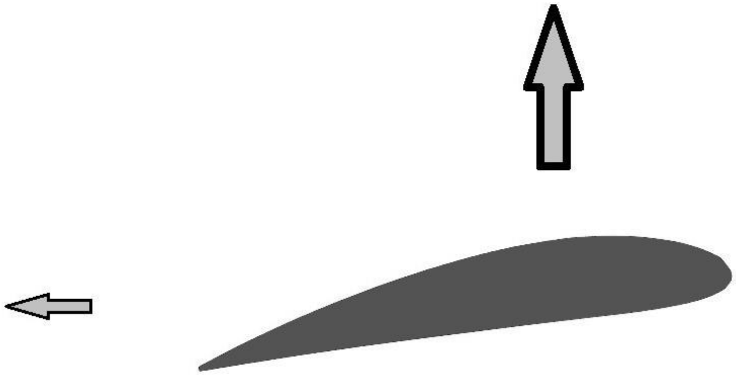
- Betz Limit = 59%.
- Airfoil results from Xfoil.
- No losses considered.
- a – axial induction factor.
- a' – tangential induction factor.
- Lift/drag optimized.
- NACA 4412.



Theory - Resultant Diagram

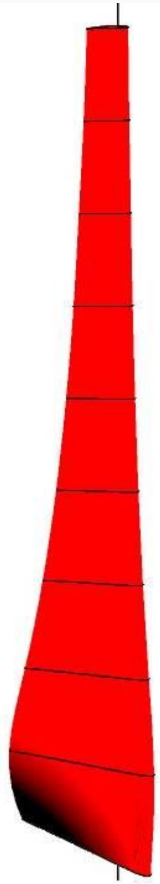


Theory - Proposed Solution

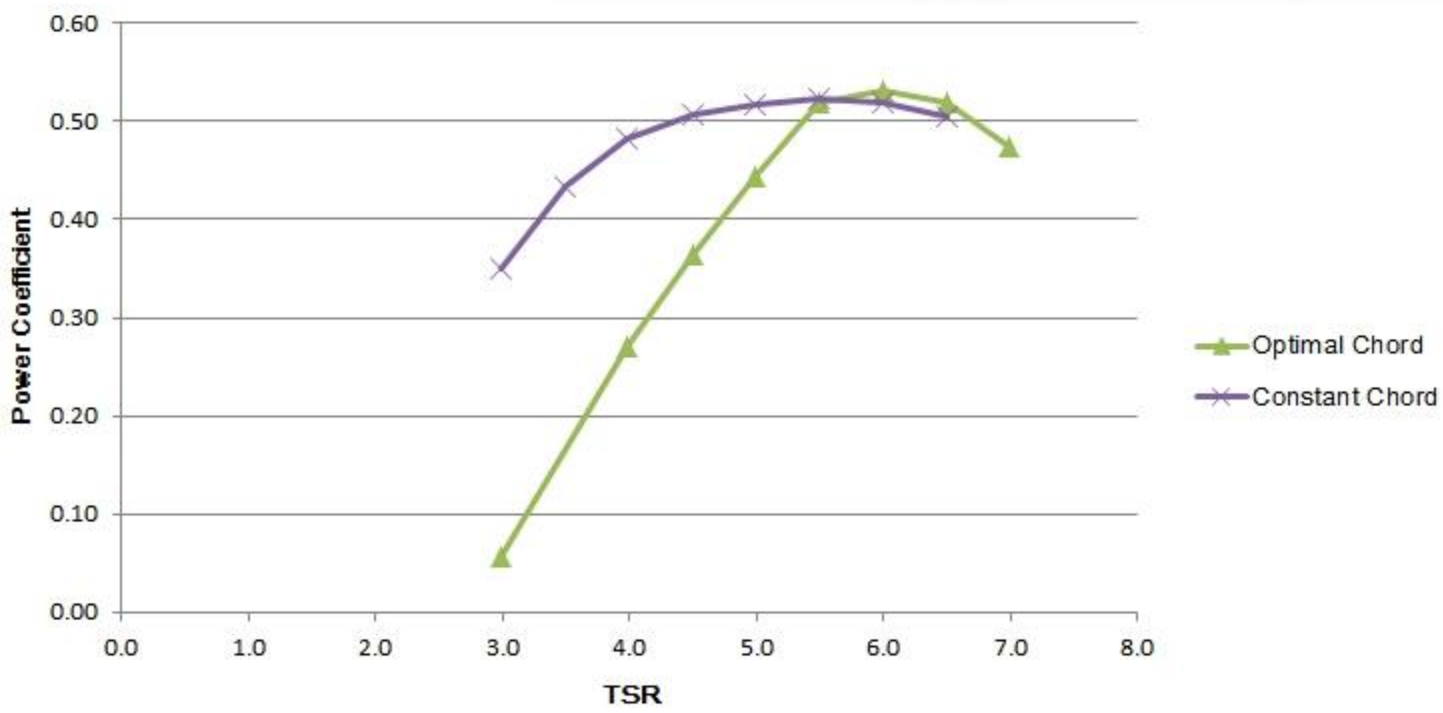


- Increase blade chord length.
- Maintain lift.

Theory - Blade Profiles

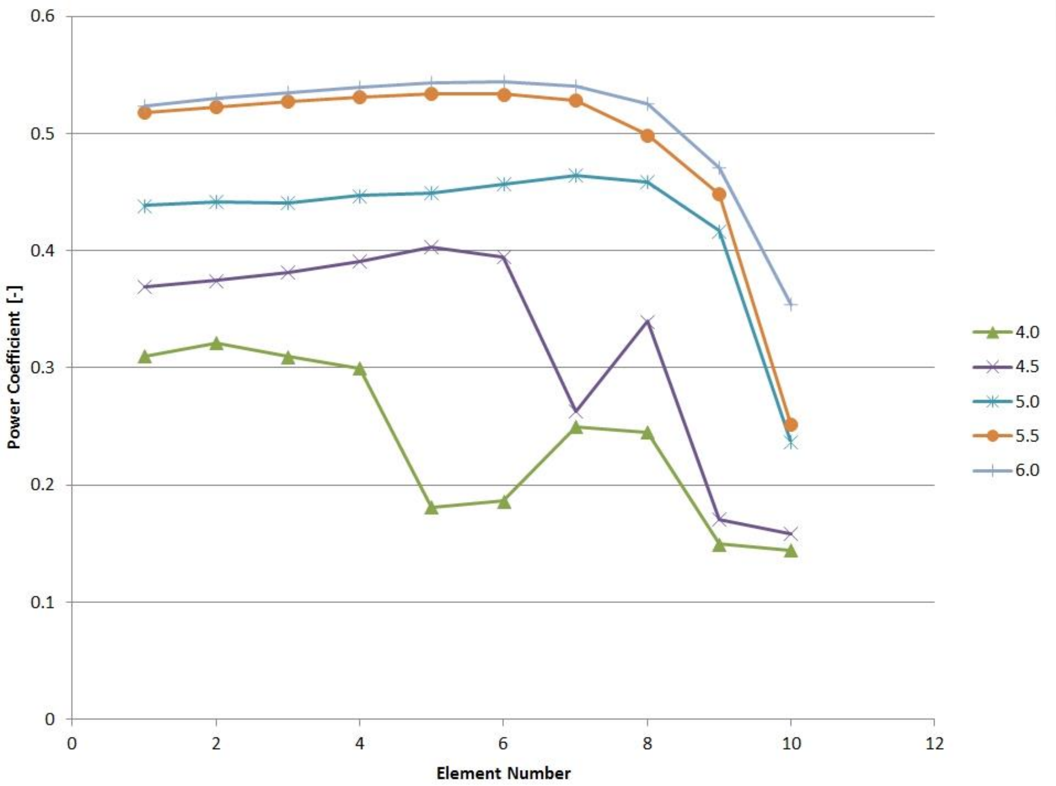


Results - BEM Theory



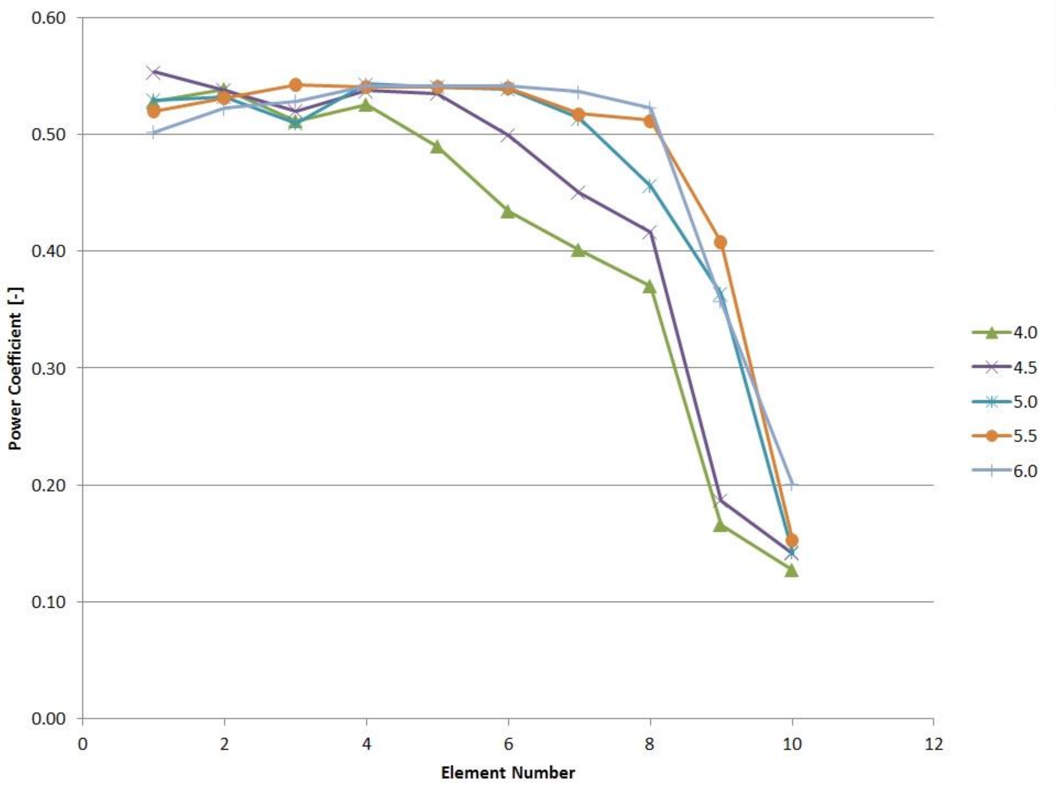
Designed for 8m/s at TSR = 6. Diameter 3m. Constant chord 4 blades. Optimal 3 blades.

Results - Cp Values (per Element)



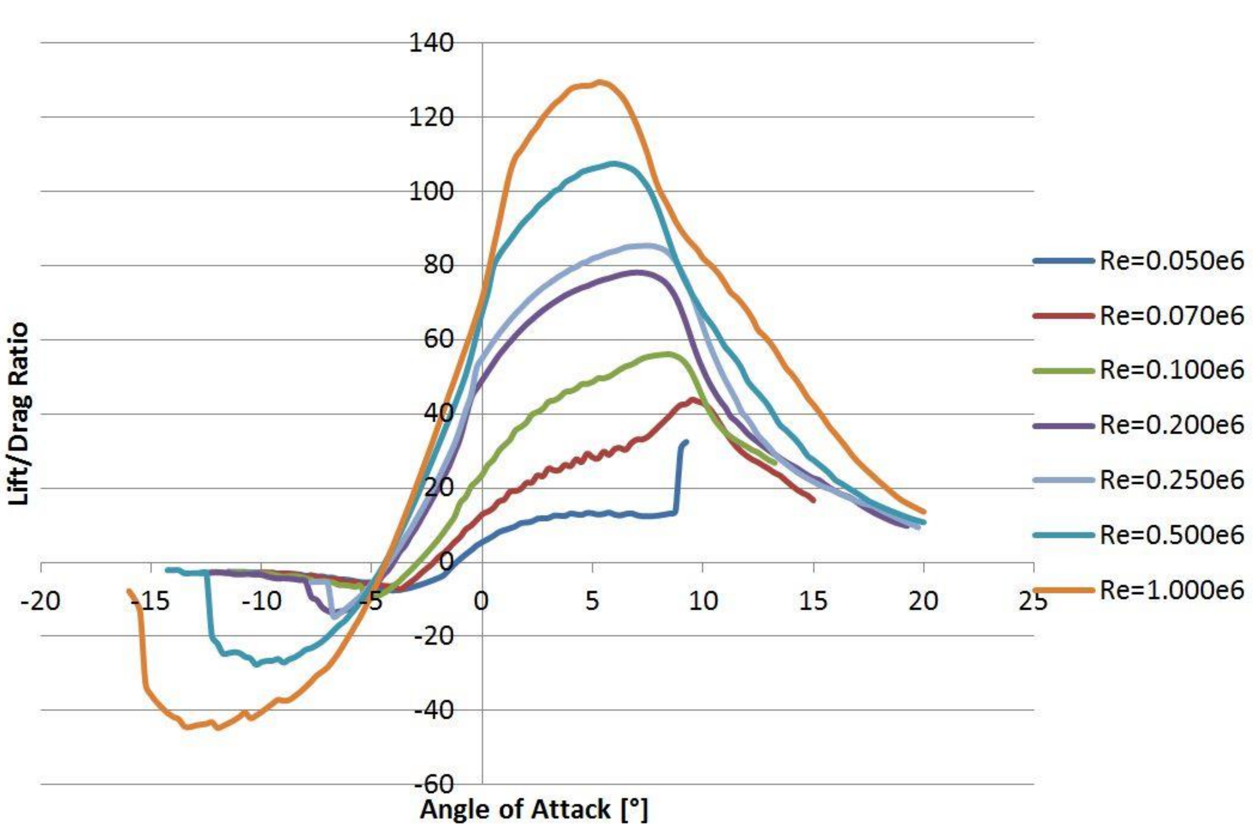
Designed for 4m/s at TSR = 6. Diameter = 3m. Number of blades = 3. L/D OPTIMAL CHORD.

Results - Cp Values (per Element)



Designed for 4m/s at TSR = 6. Diameter = 3m. Number of blades = 3. CONSTANT CHORD.

Results - L/D Ratio vs Reynolds Number



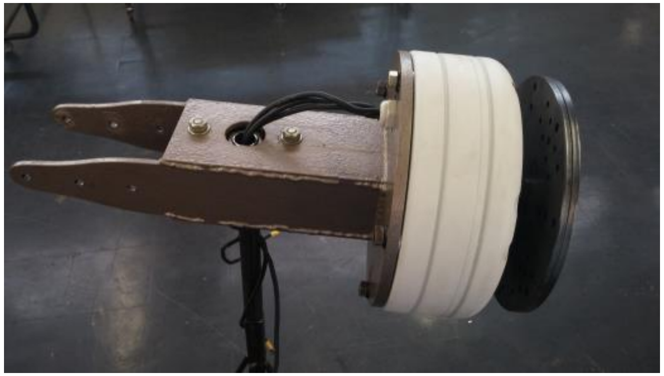
NACA 4412 Aerofoil. XFOIL results. Visc flow. Ncrit = 9.

Conclusion - Benefits of “Oversized” Design

- Short term wind variations:
  - Better utilization of gust energy.
  - Better utilization of higher turbulence energy.
  - Better utilization of non ideal wind angles: horizontal and vertical component fluctuations.
- Very low Reynolds number:
  - Much larger Re number (about 2.5 times) when compared to conventional L/D optimization.
- Startup wind speed:
  - Larger Re number.
  - Higher solidarity.
  - Lower angle of attack.
  - Increased blade torque.
- Urbanization:
  - Low wind startup.
  - Gust/Turbulence optimized.
  - Less blade noise due to lower angle of attack.

Conclusion – The Way Forward

1. 3D printer to prototype blades.
2. 2 turbines for simultaneous testing.
3. Labview interface to record data and control the turbines.
4. 3D sonic anemometer to measure wind quality and quantity.



Feedback?

Thank you