UMassAmherst
College of Engineering
Mechanical and Industrial Engineering

Senior Capstone Design Project

Fall 2022 – Final Report

Remote Monitoring of Wind Turbines

Team 1508
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Objective

Using only industrial commercial off-the-shelf (COTS) components, develop an autonomous data-logging system to remotely monitor, test, and evaluate small-scale turbine performance and operating conditions.

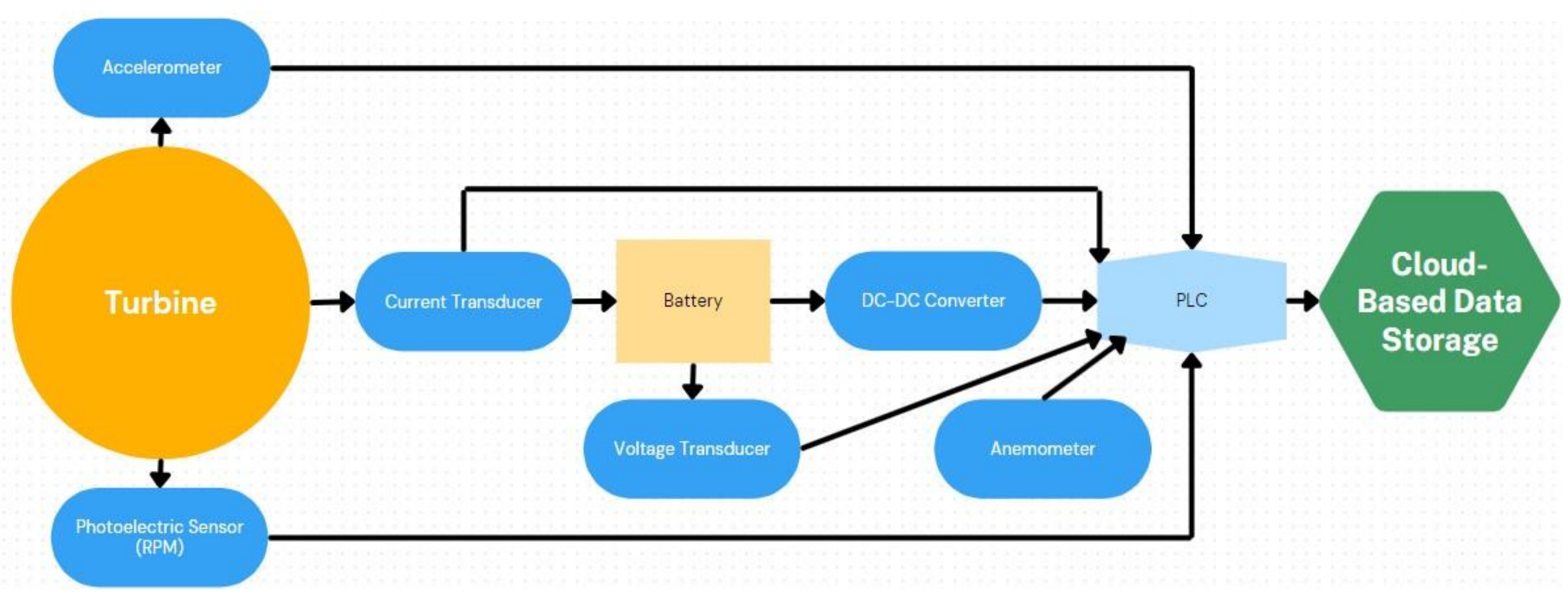
Motivation

Wind turbines often experience frequent maintenance needs due to the large number of working components and harsh operating environments. A remote data-logging system will eliminate the need to be on-site to conduct testing, reducing travel time and costs.

Specifications

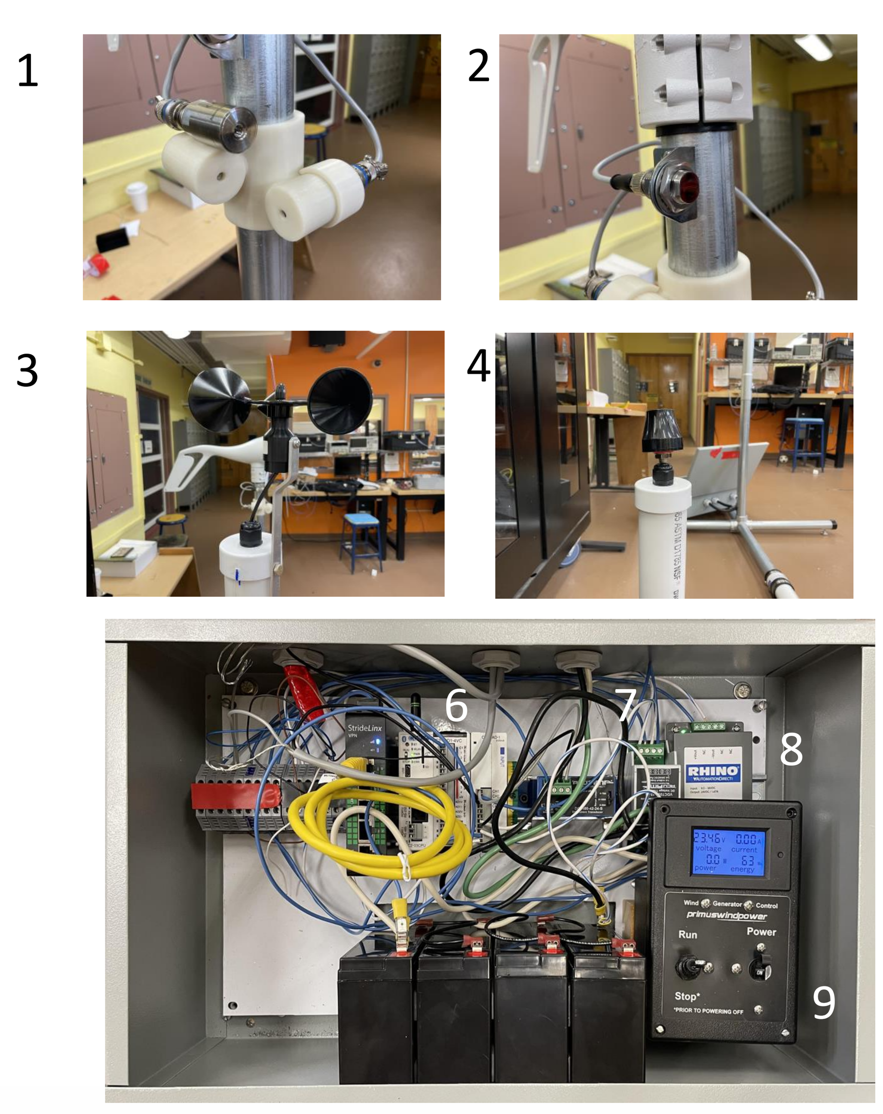
Sensor	Requirement	Spec	Power Supply	Input
Photoelectric Sensor (RPM)	With a factor of safety of 10, a frequency of 750 Hz is needed to read the turbine's maximum speed of 600 rpm	Frequency of 1.5 kHz	24V	Discrete Voltage (sink)
Accelerometer	Read expected natural frequency of turbine (.8-2.12 Hz)	Reads within 3 dB rated for 1.0 Hz- 2.0 kHz	24V	Analog Current (4-20mA)
Anemometer	Read between the rated cut-in (7 mph) and cut-out (90 mph) wind speeds of the turbine	Reads within 5% rated for 8-100 mph	24V	Discrete Voltage (sink)
Current Transducer	Read maximum current output from turbine - 18.75 Amps	Reads within .5% 0-500 amps	24V	Analog Current (4-20mA)
Voltage Transducer	Read between min and max battery % (23-26 VDC)	Reads withing 1% 0-50 VDC	24V	Analog Current (4-20mA)
DC-to-DC Converter	Ensure 24V to power terminals, ride through voltage sags	±2.0% max. Voltage set accuracy	24V	24V to power terminals

Functional Decomposition



Design Rationale

1. *Photo-electric Sensor*: measures RPM of the rotor using reflective material
2. *Accelerometer*: measures vibrations in the turbine tower
3. *Cup Anemometer*: measures wind speed along the same plane as turbine
4. *VPN Antenna*: separate mount to receive good signal
5. *Cable Glands/Rubber Grommets*: keeps enclosure & towers watertight
6. *PLC + I/o Modules:* read and interpret signals from sensors
7. *Current/Voltage Transducer*: Measure current and voltage from turbine
8. *DC-to-DC Converter*: ensures 24V power supply, provides power during voltage sags
9. *Digital Panel Meter*: displays current, voltage, power, energy, load diverter

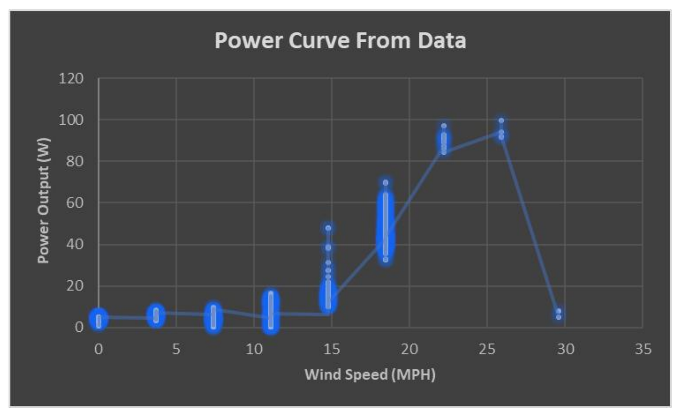


Proof of concept Implementation

Autonomously log accurate data; User-friendly interface

Performance Evaluation

- Evaluation method - Variable wind speed testing conducted in Wind Tunnel
  1. Control Panel and StrideLinx show agreement in power measurements (+/- 5%)
  2. 24V battery charges while turbine is in motion
  3. Power Curve comparison:



Supporting Engineering Analysis

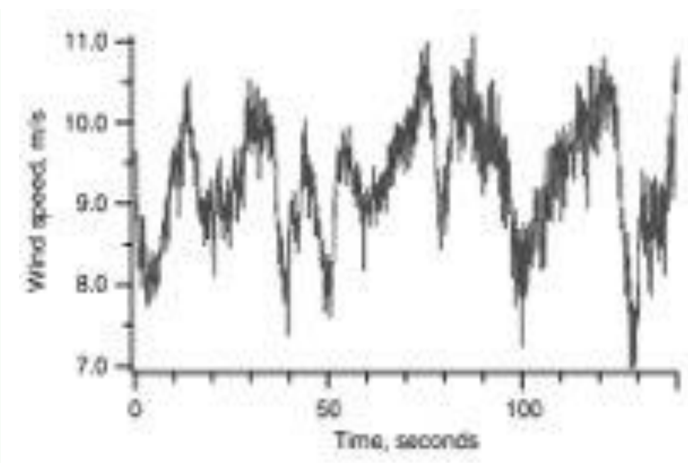
$rpm_{Max} := 1350 \cdot rpm$ *Max. RPM of turbine* $r := 190.5 \cdot mm$ *Radius @ Reflector*

$V := rpm_{Max} \cdot r = 26.931 \frac{m}{s}$ *Linear Speed @ reflector*

$D_{reflector} := 25 \cdot mm$ $t := \frac{D_{reflector}}{V} = \left(9.283 \cdot 10^{-4}\right) s$ *Time for reflector to be seen*

$f_{required} := \frac{1}{t} = \left(1.077 \cdot 10^{3}\right) \frac{1}{s}$

$f_{actual} := 1.5 \cdot kHz$



Wind Speed Vs. Time; used to find wind logging speed

Remaining Issues/ Recommendations

- Improve Anemometer, Photoelectric, and accelerometer placement as they are close to the blades
- Yaw-Enabled Photo-Electric Sensor Mount
- Increase stiffness of Accelerometer mount to reduce vibrational noise
- Invest in lithium-ion battery for faster charging speeds

Wiring Diagram