NERGICA Renewable Energy Research and Innovation

Marinvent Airfoil Performance Monitor

Integration to a wind turbine

Partners:

marinvent AERAS

ΣEED AI

Funding:

NSERC CRSNG

CRIAQ

Dominic Bolduc, Expert Analyst
Canadian Wind Energy Research Network
2022-04-04

How to detect aerodynamic performance?

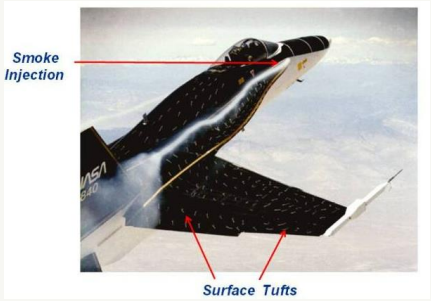
On sailboats

Source: North Sails

Source: SailingWorld.com

On aircraft

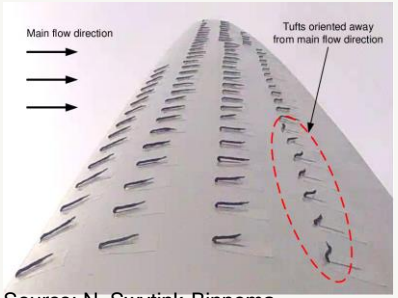
Source: Honda Aircraft Co.



Source: NASA

On wind turbines

Source: Smart Blade GMBH

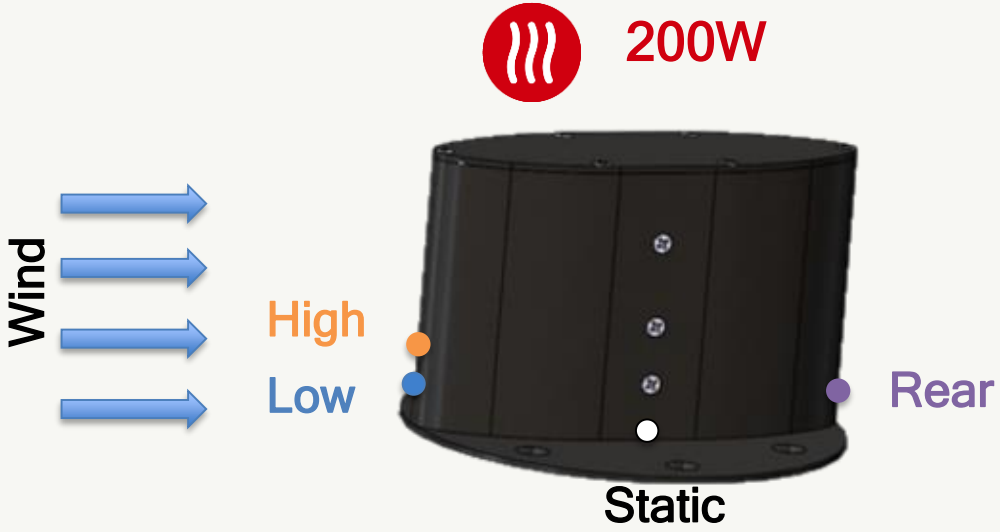


Source: N. Swytink-Binnema

What is Marinvent Airfoil Performance Monitor (APM)?

Source: Marinvent

Highly sensitive electronic wind tufts that measures the non-dimensional turbulence intensity ratio R



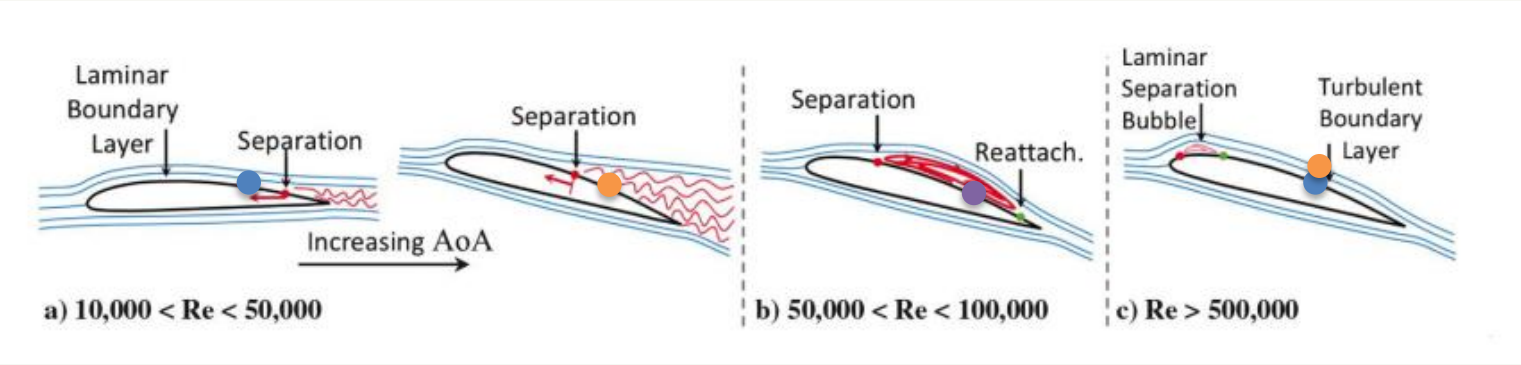
$$R \propto AoA$$

What APM can detect

BL separation with Low or High sensor

Flow recirculation with Rear sensor

Turbulent BL with both front sensors

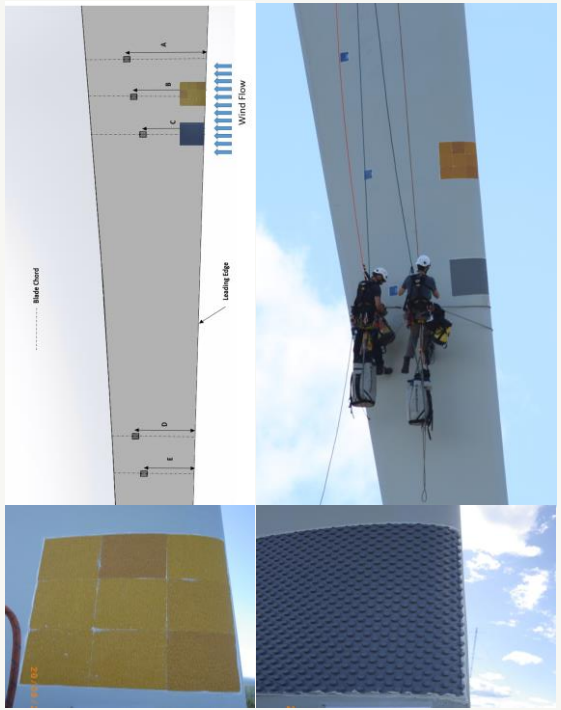


Source: Winslow and al.

Caused by:

- Increasing AoA (>10deg)
- BL triping from airfoil shape modification
- Surface roughness increase

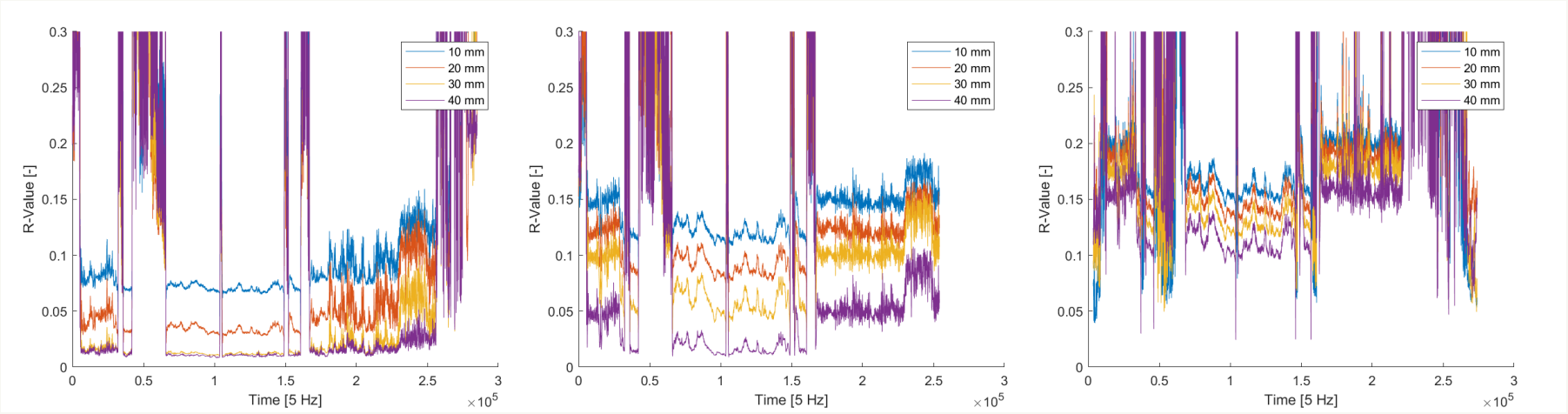
Proof of concept in 2018



- 5 battery powered APMs on the suction side of 1 blade with 4 front sensors heights(10, 20, 30 an 40mm)
- Differents spanwise and chordwise locations:
  - Spanwise: 44% to 69% from the root
  - Chordwise: 60% to 75% from LE
- 2 levels of artificial contaminants:
  - 40 grit sand paper
  - Plastic bubble wrap
- 3 short test runs:
  - Run 1: ~3 hours (day)
  - Run 2: ~14 hours (overnight)
  - Run 3: ~4 hours (day)

Results of 2018

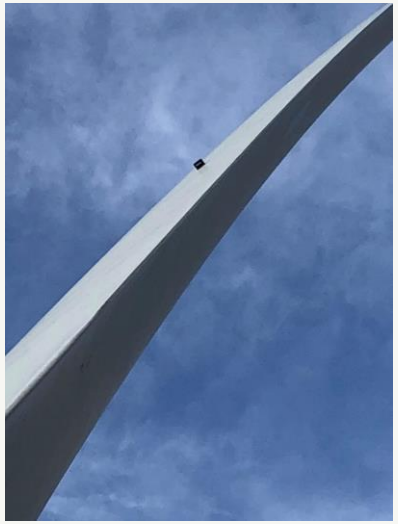
- APM is able to detect very light contaminant on the leading edge.
- Different sensor sensitivity at different heights from the airfoil surface



Clean | Simulated Frost (40 grit) | Simulated Ice (bubble wrap)

Long term APM install – 2 years (NSERC, CRIAQ)

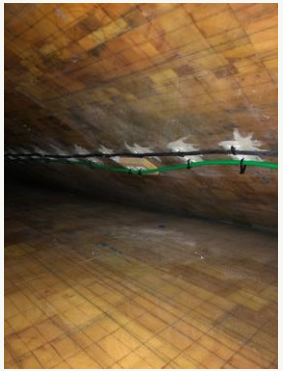
- Installation of one APM per blade
- Spanwise location is 18m from root
- Chordwise is 65%, 70% and 75%
- Cabling for data, heating and lightning protection
- Data acquisition at 10Hz and recorded in OsiSoft PI at 1Hz
- Synchronization with turbine SCADA data
- Icing assessment with Nergica HUBCAM every 10min



Project objectives

- Design instrumentation
- Validate installation procedures
- Optimize data acquisition configuration
- Analyze aerodynamics characteristics during icing

Done



- Incorporate AI algorithm to data analysis
- Investigate other potential application
- Integrate APM data and ice detection signal to turbine SCADA

On-going

SEED AI

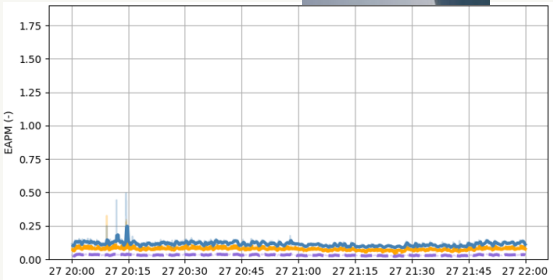
bachmann.

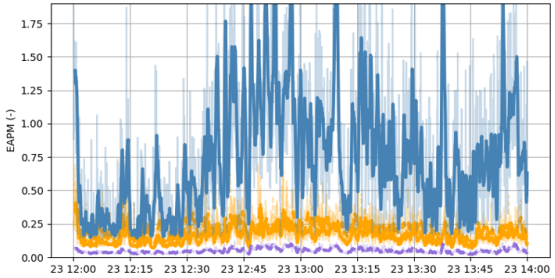
Preliminary results - Turbine Running

No Icing

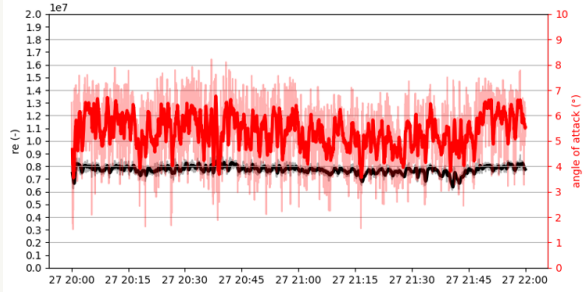
Moderate Icing

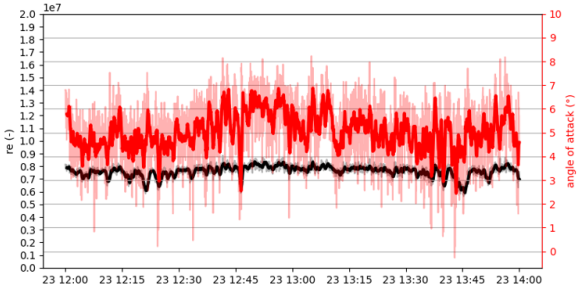
R value





AoA + Re





Time **Time**

- Low BL1
- High BL1+2
- Rear BL2

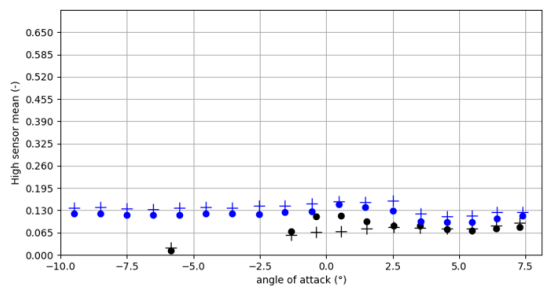
AoA(~4-7deg)

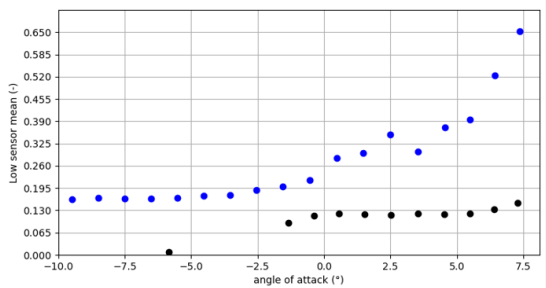
Re (750K)

Preliminary results - Turbine Running

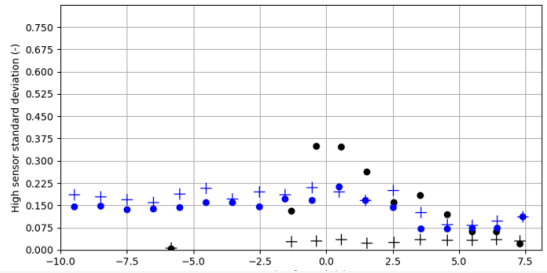
High BL1+2 | Low BL1

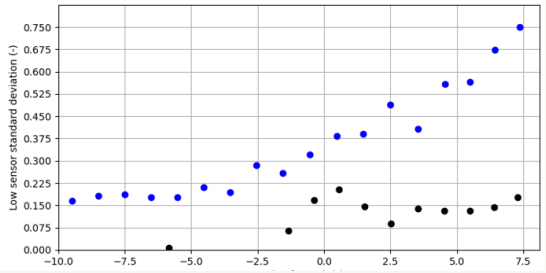
R - Avg





R - Stdv





AoA | AoA

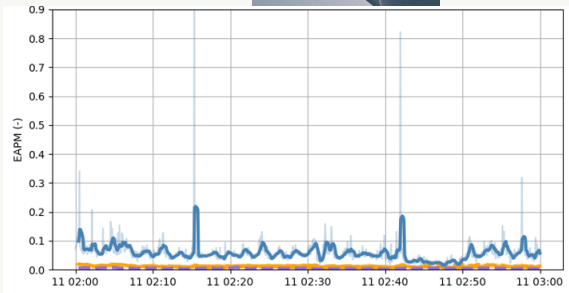
- ● Icing BL1
- \+ Icing BL2
- ● No ice BL1
- \+ No ice BL2

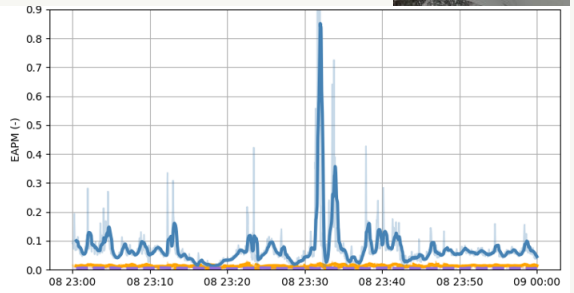
Preliminary results - Turbine Stopped

No Icing

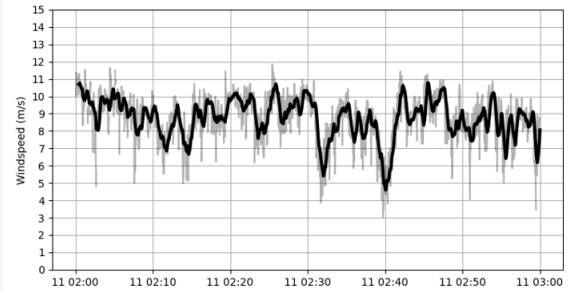
Moderate Icing

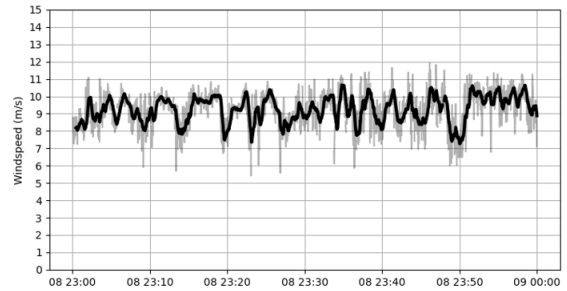
R value





Wdspd





Time

Time

- Low BL1
- High BL1+2
- Rear BL2

- Wdspd

NERGICA

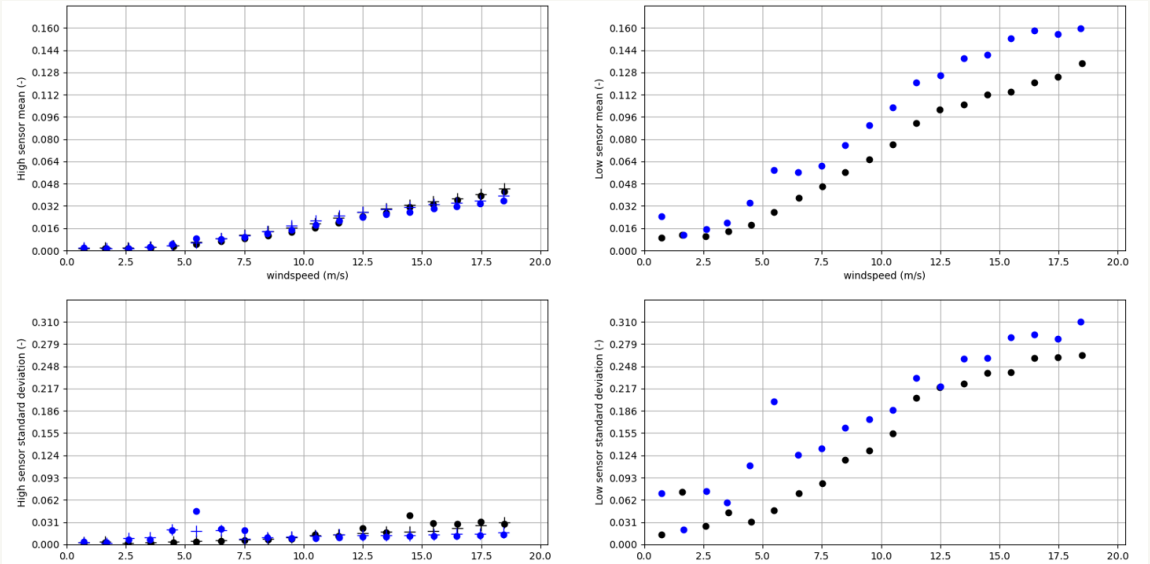
Preliminary results – Turbine Stopped

High BL1+2

Low BL1

R - Avg

R - Stdv



Wind speed

Wind speed

- ● Icing BL1
- \+ Icing BL2
- ● No ice BL1
- \+ No ice BL2

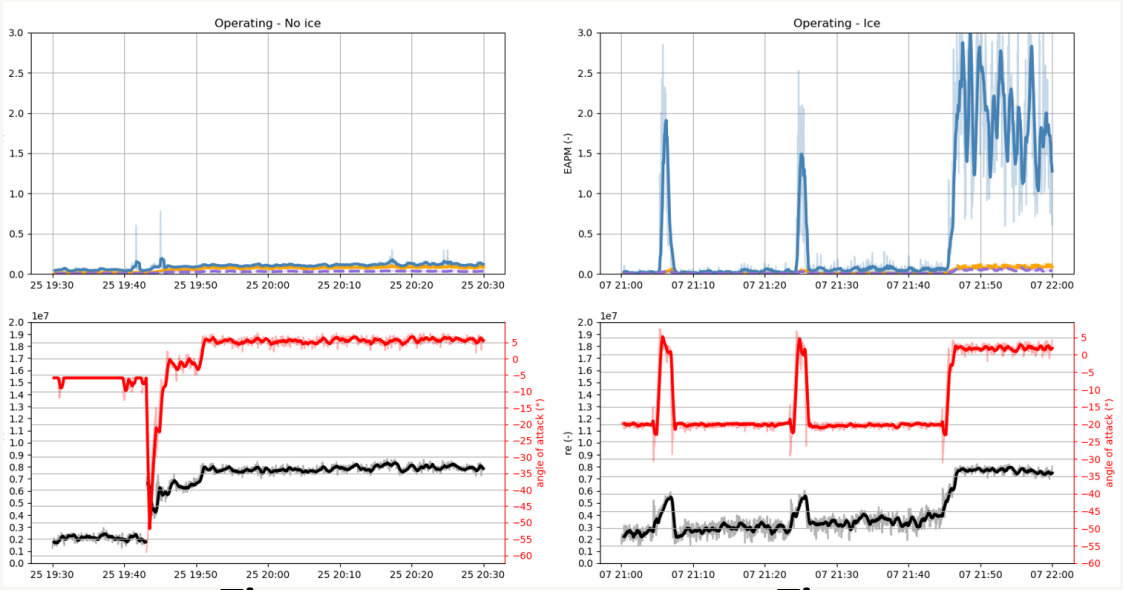
Preliminary results - Turbine Restart

No Icing

Severe Icing

R value

AoA + Re

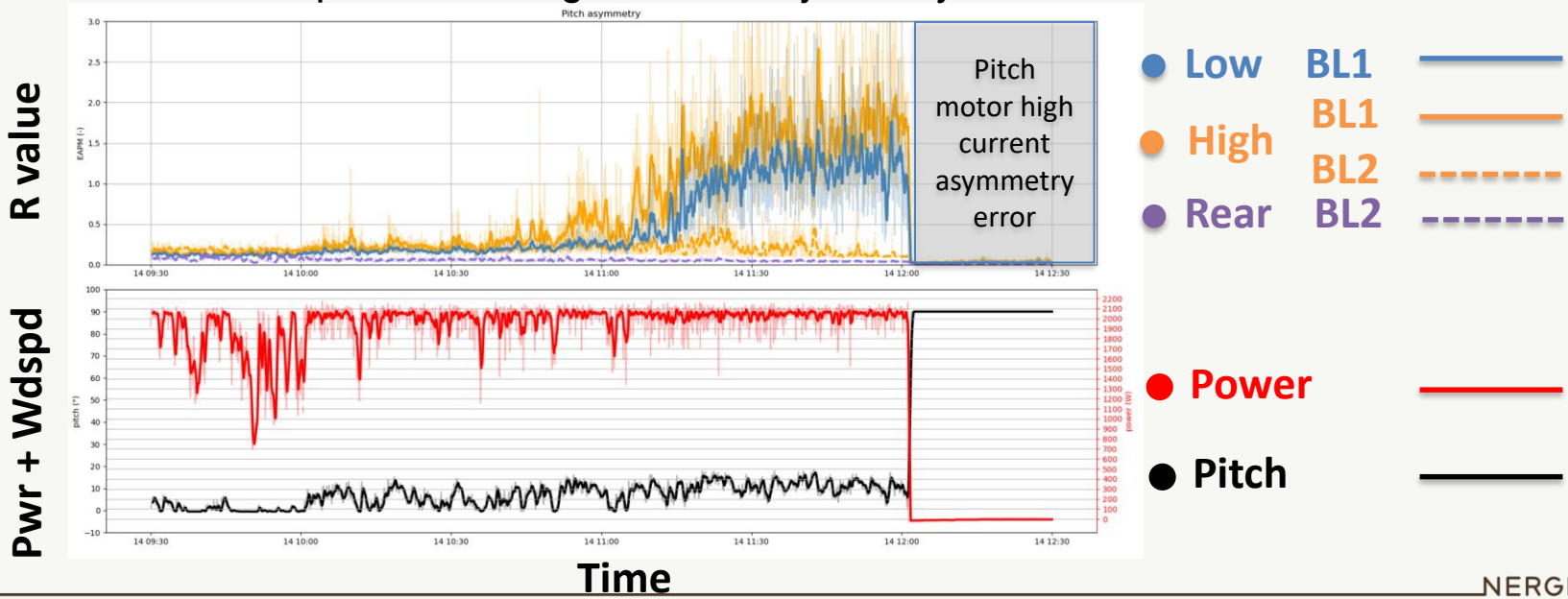


- Low BL1
- High BL1+2
- Rear BL2

- AoA(var)
- Re (var)

End of test – January 2022 – Blade 1 pitch failure

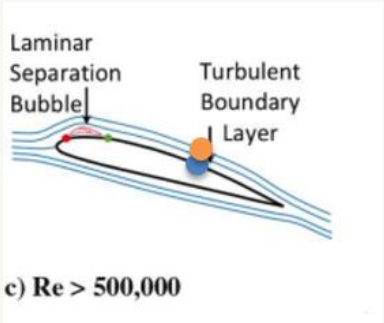
- High asymmetry between blade 1 & 2 R values (8X)
- Blade 1 pitch motor high current asymmetry error 1 hours after



Key points takeaway

$$R \propto AoA$$

- APM signal highly correlates with AoA
- APM can detect icing <u>mostly</u> with the low sensor <u>at mid-span</u>
  - During standstill ✚
  - At restarts ✚ ✚ ✚ ✚
  - During operation ✚ ✚ ✚ ✚
- At mid-span APM signal is mostly affected by surface roughness change and turbulent boundary layer
- APM can detect pitch asymmetry between blades



Source: Winslow and al.

Error: pitch motor high current asymmetry

Next steps

- Install APM closer to the tips of the blades
- Fully integrate to a turbine controller
- Demonstrate other turbine under-performances related to APM signal
  - Pitch asymetry
  - LE erosion
  - Complex terrain effects
- Develop a wireless version of the APM
- Technology demonstration

Turbine manufacturer requested

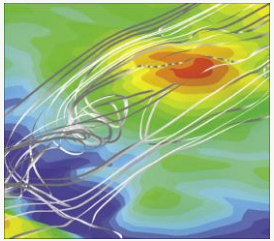
Vestas

ENERCON ENERGY FOR THE WORLD

SIEMENS Gamesa RENEWABLE ENERGY

GE Renewable Energy

Source: Weather Guard Litghning Tech



Source: Windpower Eng. & Dev

NERGICA

70, rue Bolduc, Gaspé, QC G4X 1G2
nergica.com

T +1 418 368-6162 | info@nergica.com

Our main financial partners

Développement économique Canada pour les régions du Québec
Canada Economic Development for Quebec Regions
Québec

Our mission

Creating new opportunities for renewables

Nergica is a centre of applied research that stimulates innovation in the renewable energy industry through research, technical assistance, technology transfer and technical support for businesses and communities.

In concrete terms, Nergica is synonymous with an accomplished expert team and unique research infrastructures installed in a natural environment and unavailable elsewhere in Canada.

Activity Sectors

Wind Power
Energy in the Air

Trusted partner of the growing wind sector since 2000, Nergica boasts undisputed expertise in the field of optimizing wind farm performance.

Increased production in cold climates, best O&M practices: get the most out of your wind farms.

PV Solar
Energy Shining Bright

Centre of expertise in a rapidly expanding sector, Nergica puts its know-how to work to promote the optimal integration of solar PV.

Energy supply for remote communities and off-grid sites; solar arrays; industrial, commercial and residential applications: take the leap into solar!

Renewables Integration
Redefining Energy Supply

It's a well-known fact that energy issues are at the core of community life and development. This is why Nergica lends its expertise to innovation as it relates to integrating renewables.

Energy transition, smart grids: en route to a sustainable energy supply.

Services

- Technology Development and Assessment
- Operation and Maintenance
- Cold Climate Suitability
- Commercialization of Innovations
- Events Organization
- Applied Meteorology and Resource assessment
- Microgrids
- Energy Storage and Grid Management

Research infrastructures in a natural setting

- 4 MW windfarm
- 16 kW solar plant
- 230 kW wind-solar-diesel-storage microgrid
- Fully instrumented metmasts (2 x 126 m, 80 sensors)
- Lidar