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USERS CONFERENCE 2011

Turning **insight** into **action**.

Strategies for Running Advanced Analytics Using MATLAB and PI System

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Power Performance Evaluation and Improvement of Operational Wind Power Plant

Partners:

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CARTIER

helimax
Membre GL Group Member

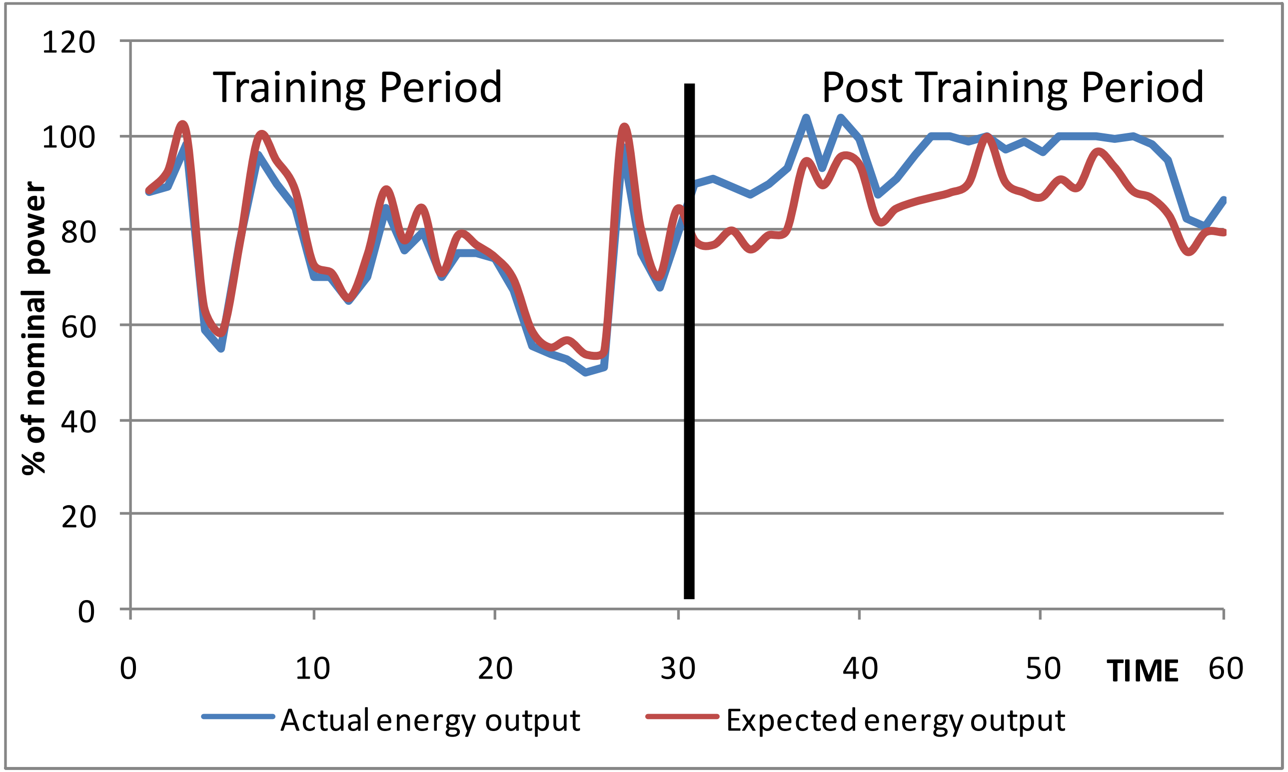
GL
OPERATING 24/7

AEMN
Chaire de recherche du Canada sur l'aérodynamique des éoliennes en milieu nordique

WESNet

École de Technologie Supérieure

Desired Results



Project’s Objectives

1. Improve Actual Power Performance Evaluation Techniques (Power curve modelling)

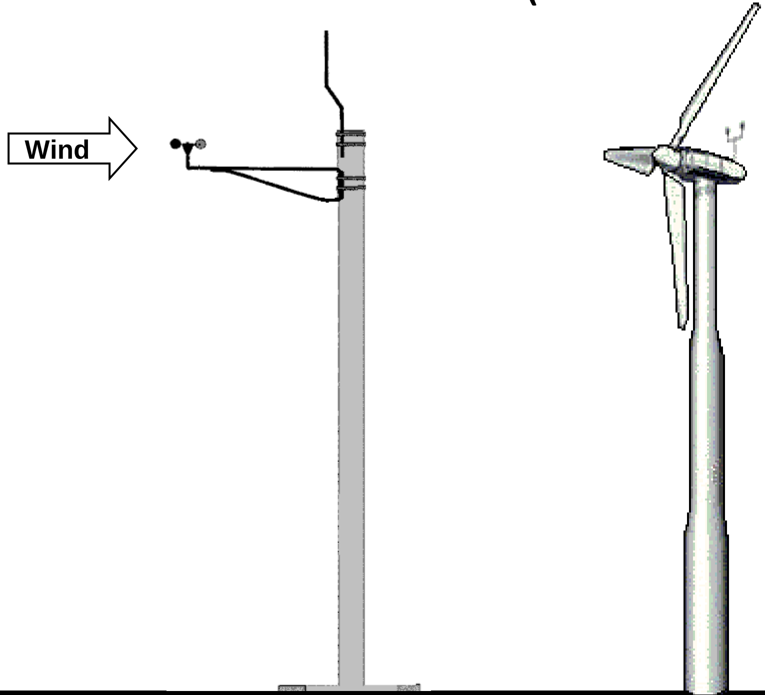
2. Improve Power Performance of Operational Wind Power Plant

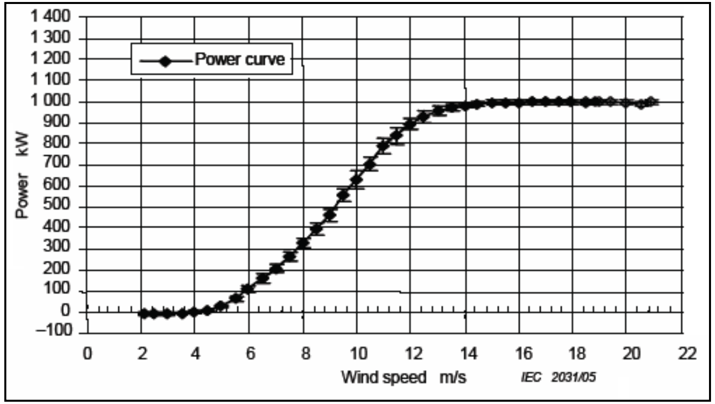
(1% increase in energy yield could represent a benefit of $4-5 M)

(assuming a 100 MW wind power plant)

1st Objective: Power Curve Modelling

- IEC61400-12-1 (meteorological mast)
- IEC61400-12-2 (nacelle anemometry)





Assessments on:

- Temperature (air density)
- Turbulence Intensity (TI)
- Wind shear, etc

Review of Literature – Power Curve Modelling

Discrete models (Bin)
- P=f (WS@nacelle)
- IEC61400-12-1
  - Air density correction
  - TI correction
  - Multivariate analysis
- IEC61400-12-2

Parametric models
- Polynomial functions
- Logistic function with 4 parameters (G.A.)
- Power curve partitions (3 regions)

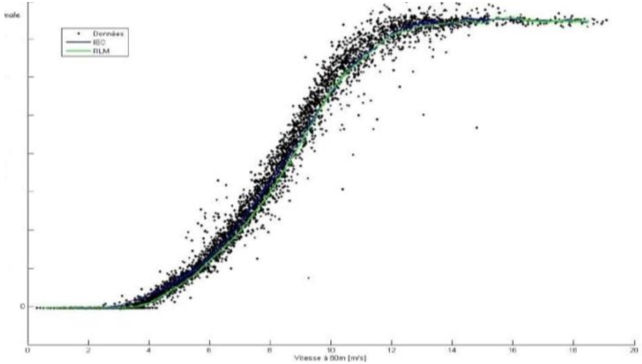
Stochastic models
- Markov Chain

Non-parametric models
- K-NN
- SVM
- Boosting Tree
- ANN
- etc.

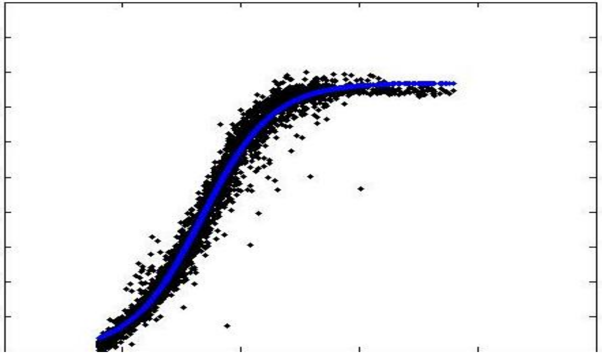
Data Reduction Techniques
- PCA
- Self Organizing Map (SOM)

Sample Results – Power Curve Modelling

Multi-Linear Regression

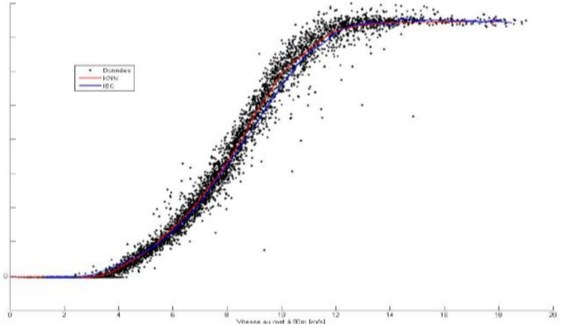


Logistic Regression - 4 parameters

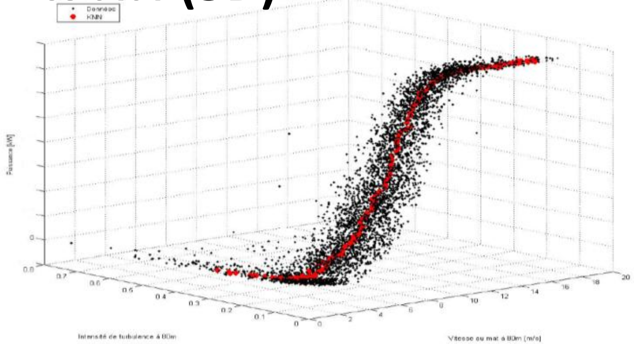


SOLUTION throughout GA:
a= 2.8011
M= 1.9692
N= 0.0036
Tau= -1.483

K-NN



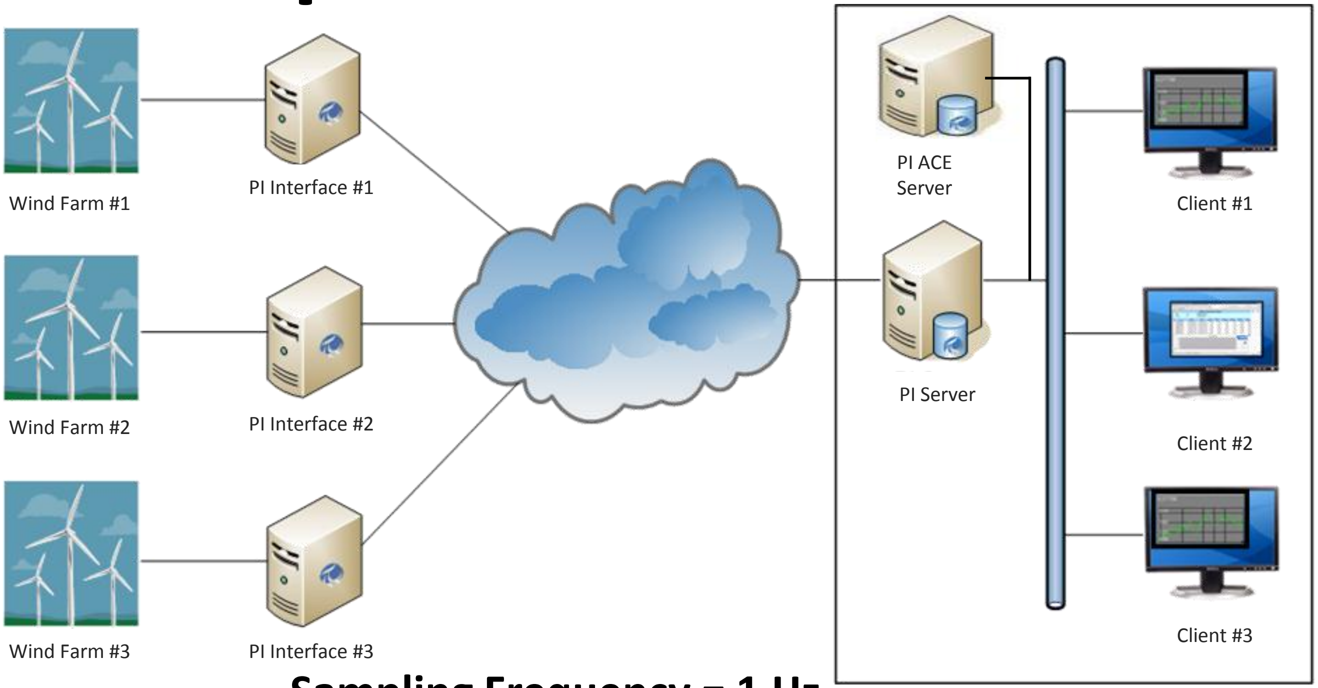
K-NN (3D)



Modelling Strategy

1. Define modelling objectives
2. Data acquisition
3. Variable identification
4. Quality control
5. Calculated variable and recoding
6. Reduction of variable
7. Selection of variable
8. Modelling with ANN
9. Modelling validation

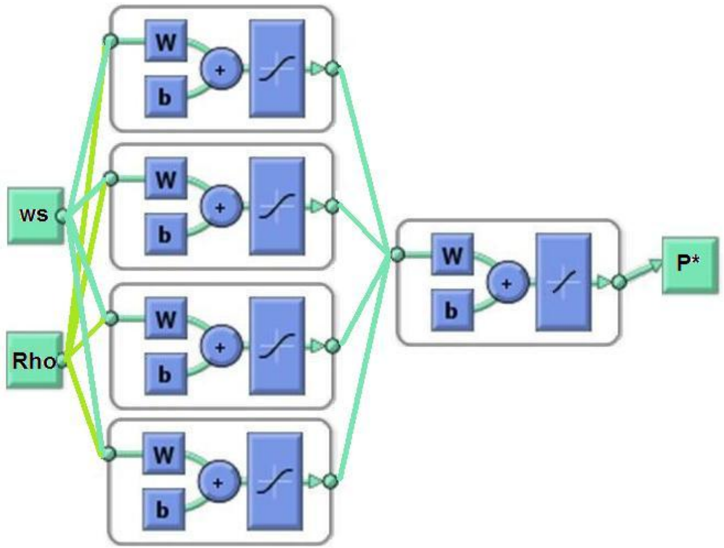
Data Acquisition



PI ProcessBook
PI Data Link
MATLAB (direct link)

Sampling Frequency = 1 Hz
Number of tags per second ≈ 100 000
PI System disk space per year ≈ 0.6 Tbyte / year

Power Curve Modelling with ANN

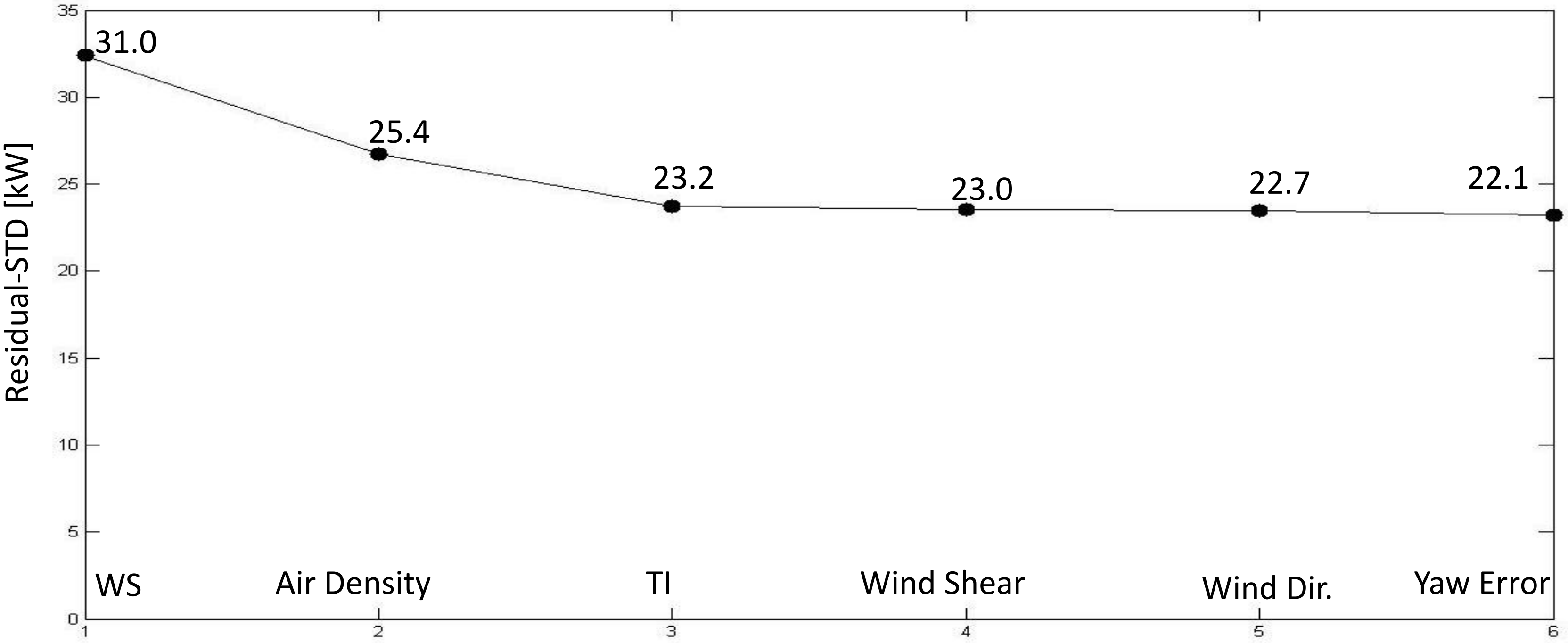


- Topology : 2 hidden layers
- # of neurons:
  - 1st layer: 4 nodes
  - 2nd layer: 1 node

Universal Approximator

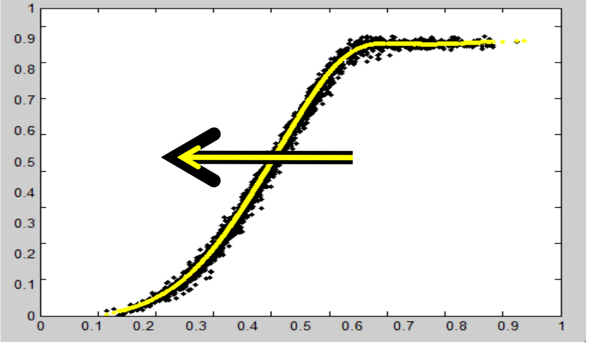
- Activation function:
  - 1st layer: tangsig
  - 2nd layer: linear
- Training: Levenberg-Marquardt
- Performance: Mean Square Error
- Stopping criteria:
  - Max # of iterations = 1000
  - Gradient = 1^E-10
  - Mu = 1^E-10
  - Cross-validation = 20 successive iterations
- Data division 70-15-15

Improved Repeatability

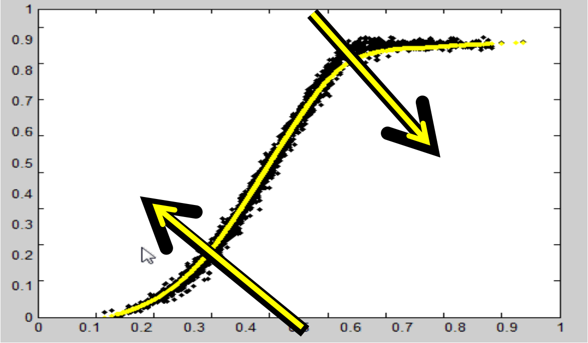


Sample Results

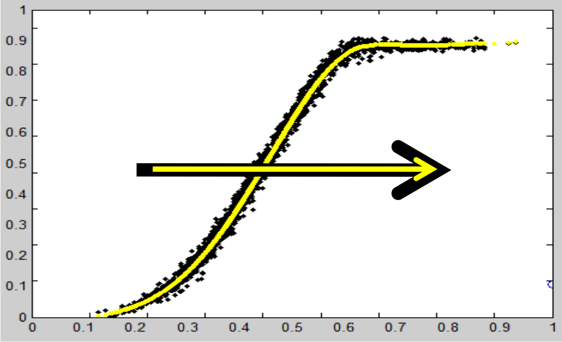
Air Density



Turbulence Intensity



Wind Shear

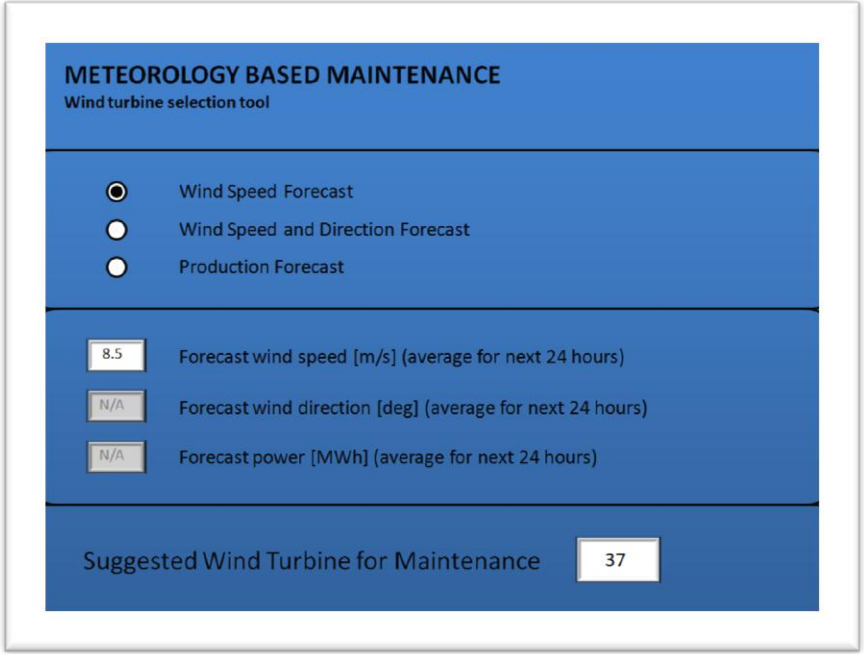


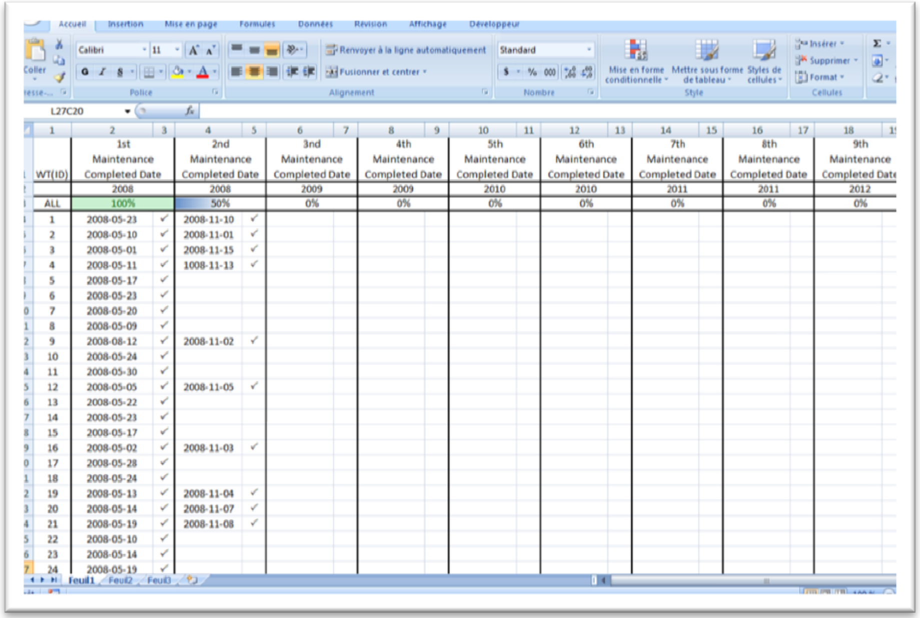
2nd objective: Improve Power Performance of Operational Wind Power Plant

Opportunities for Power Performance Improvement:

1. Improve Technical Availability
   - 1.1 Faults analysis
   - 1.2 Online condition monitoring
   - 1.3 Meteorology-based maintenance
   - 1.4 Icing
2. Improve Operational Power Performance
   - 2.1 Underperformance detection tools
   - 2.2 Wind turbine settings
   - 2.3 Control management
   - 2.4 Icing

Meteorology-based Maintenance

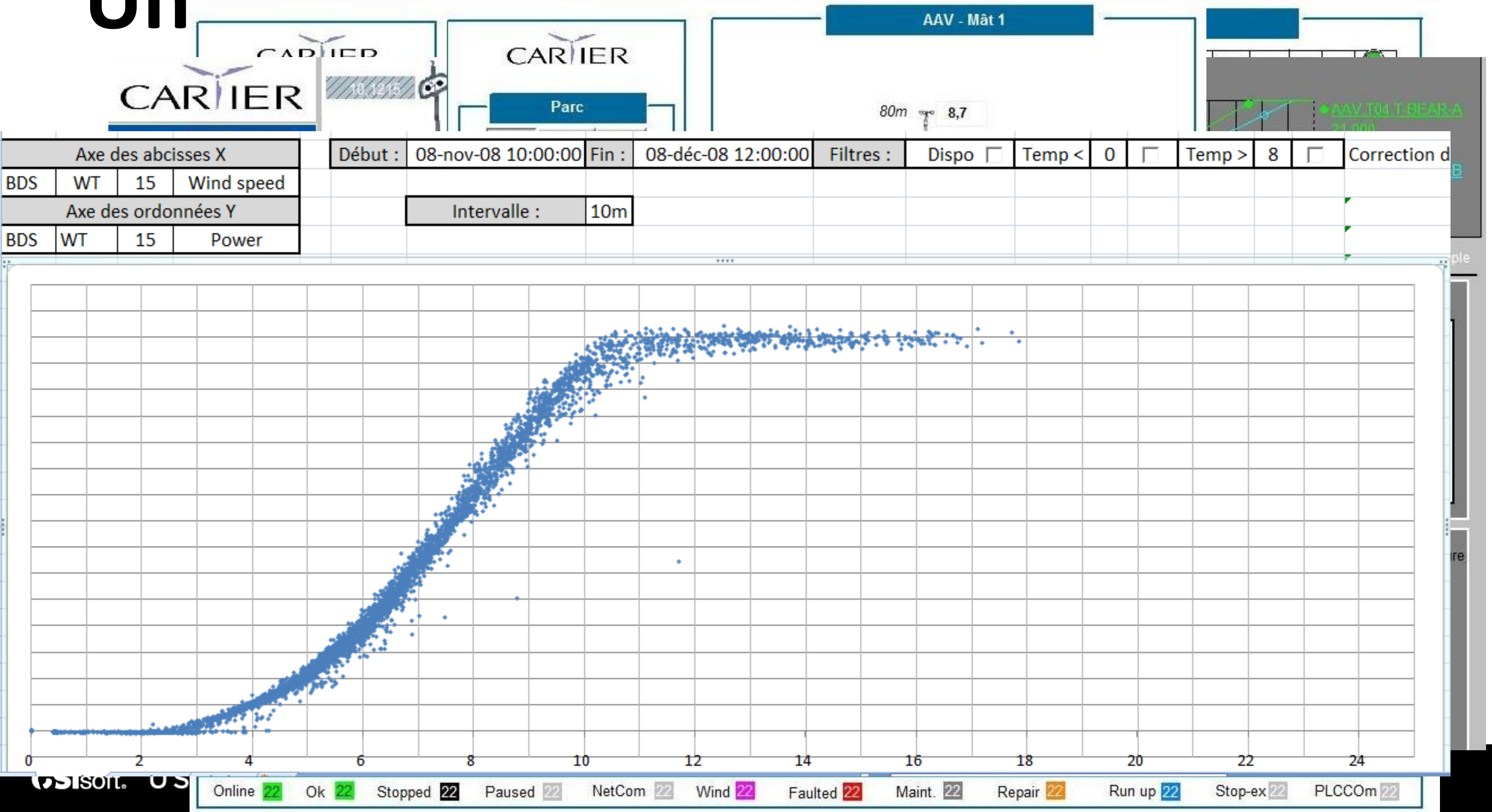




WT(ID)	1st Maintenance Completed Date	2nd Maintenance Completed Date	3nd Maintenance Completed Date	4th Maintenance Completed Date	5th Maintenance Completed Date	6th Maintenance Completed Date	7th Maintenance Completed Date	8th Maintenance Completed Date	9th Maintenance Completed Date
	2008	2008	2009	2009	2010	2010	2011	2011	2012
ALL	100%	50%	0%	0%	0%	0%	0%	0%	0%
1	2008-05-23 ✓	2008-11-10 ✓							
2	2008-05-10 ✓	2008-11-01 ✓							
3	2008-05-01 ✓	2008-11-15 ✓							
4	2008-05-11 ✓	1008-11-13 ✓							
5	2008-05-17 ✓								
6	2008-05-23 ✓								
7	2008-05-20 ✓								
8	2008-05-09 ✓								
9	2008-08-12 ✓	2008-11-02 ✓							
10	2008-05-24 ✓								
11	2008-05-30 ✓								
12	2008-05-05 ✓	2008-11-05 ✓							
13	2008-05-22 ✓								
14	2008-05-23 ✓								
15	2008-05-17 ✓								
16	2008-05-02 ✓	2008-11-03 ✓							
17	2008-05-28 ✓								
18	2008-05-24 ✓								
19	2008-05-13 ✓	2008-11-04 ✓							
20	2008-05-14 ✓	2008-11-07 ✓							
21	2008-05-19 ✓	2008-11-08 ✓							
22	2008-05-10 ✓								
23	2008-05-14 ✓								
24	2008-05-19 ✓								

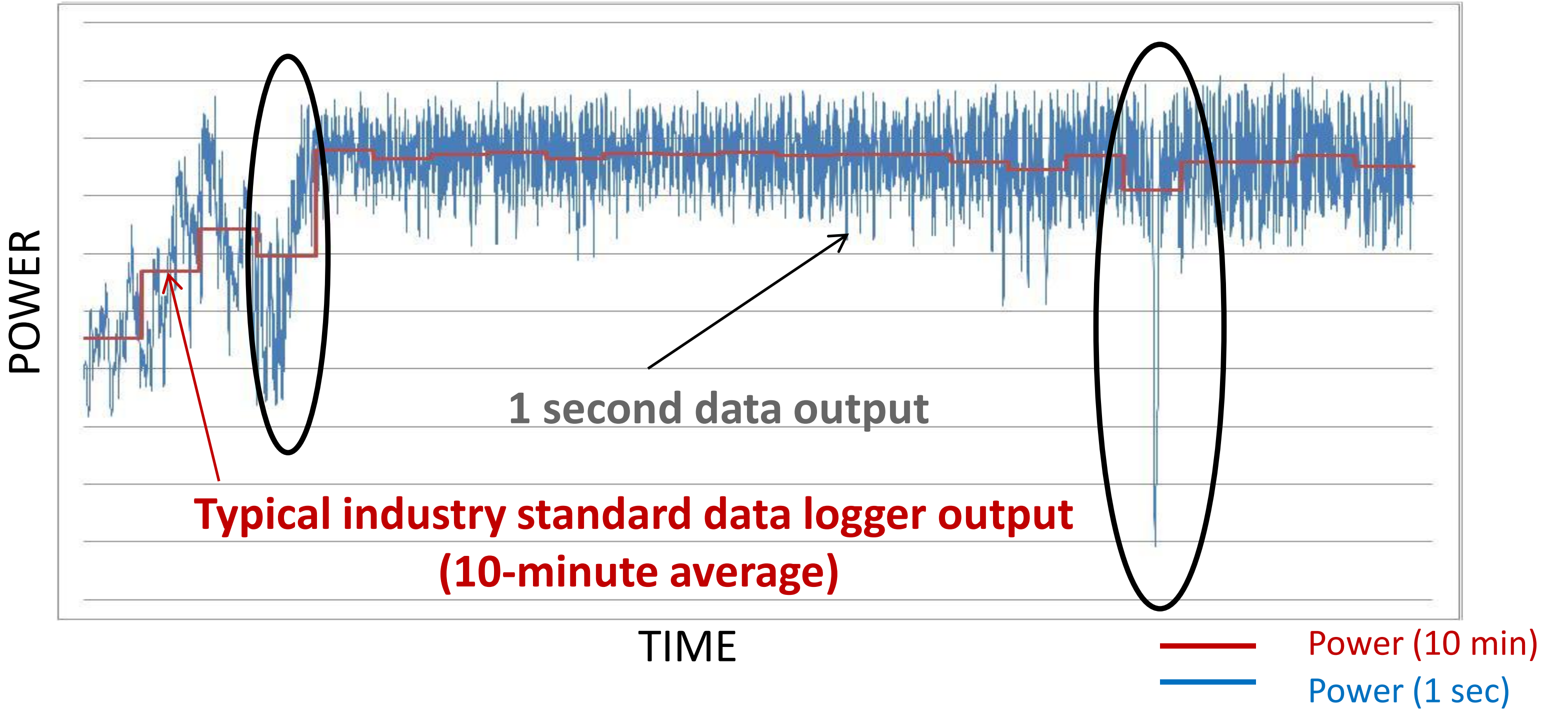
Source: PELLETIER, F., MASSON, C., Meteorology Based Maintenance. Poster presented at AWEA 2009: Windpower Conference and Exibition Show, Chicago, USA, 4-7 May 2009.

Underperformance Detection Tools



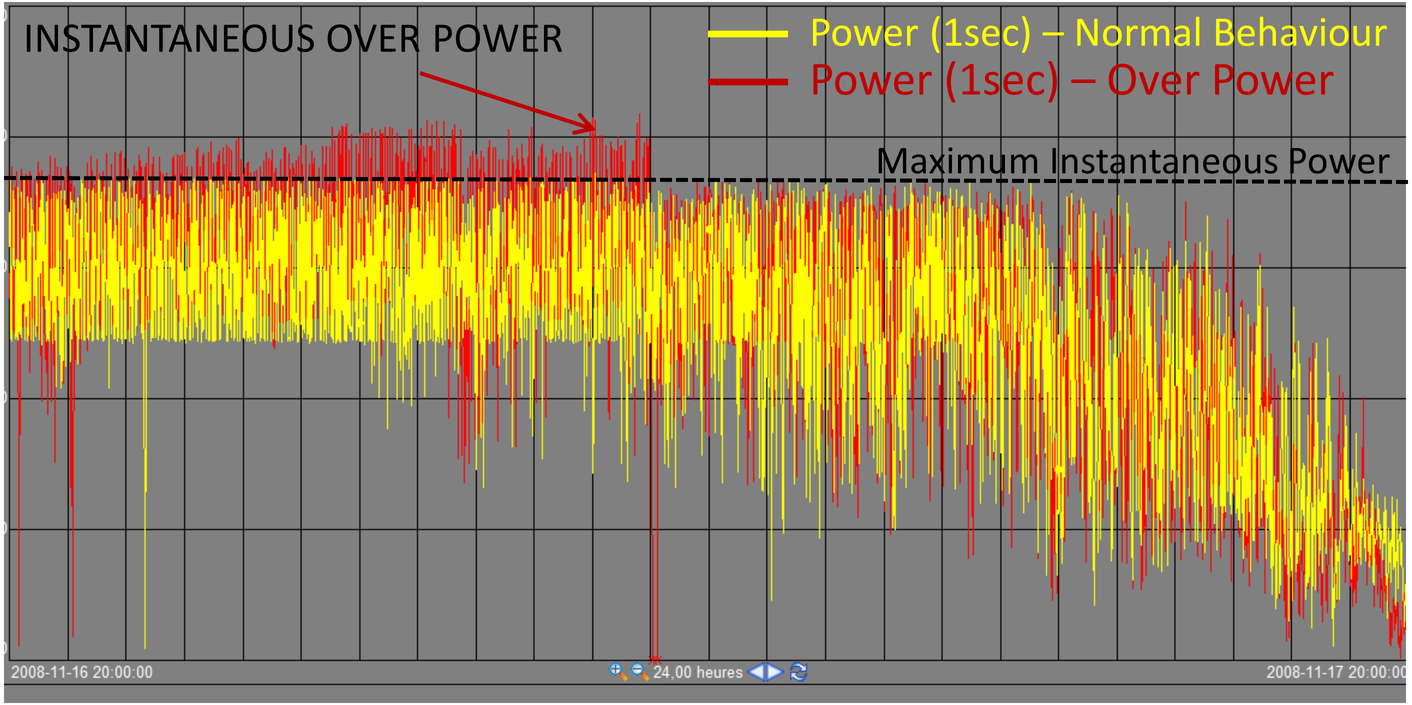
Underperformance Detection Tools

Industry standard vs. high-frequency data sampling (10-minute average vs. 1 sec.)



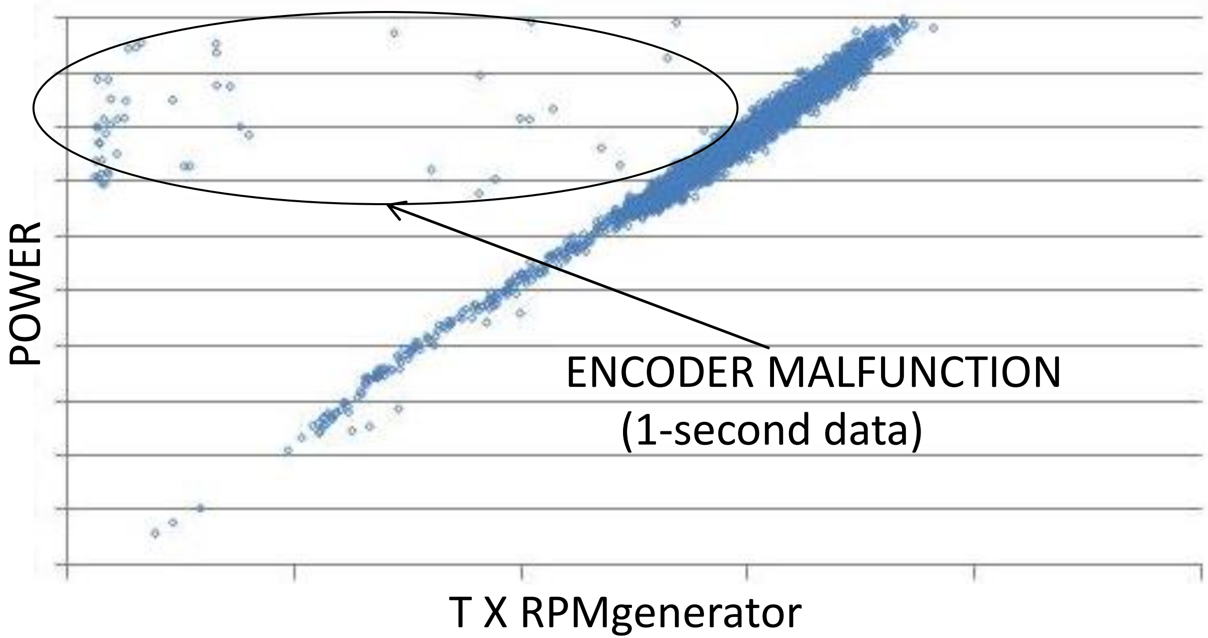
Underperformance Detection Tools

Enhanced troubleshooting possibilities related to high-frequency data sampling



Underperformance Detection Tools

Enhanced troubleshooting possibilities related to high-frequency data sampling

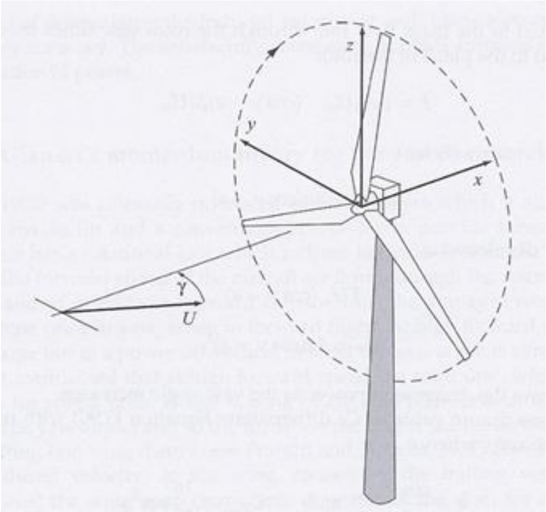


Other Opportunities Related to High-frequency Data Sampling

- New faults and underperformance investigations techniques
- Availability calculation/validation
- Support for insurance or legal claims (e.g.: gearbox, blade damage, etc.)
- New statistical metrics (skewness, Kurtosis, 5-min average, etc.)
- Condition monitoring (e.g.: FFT analysis, etc.)
- Forecasting improvement (Ramp)
- Improve quality control of data (Outlier's identification)
- Derivatives / filters / smoothing / dynamic response
- Wake validation and investigation
- Control validation and optimization
- Etc.

Wind Turbine Settings

Yaw Offset Optimization

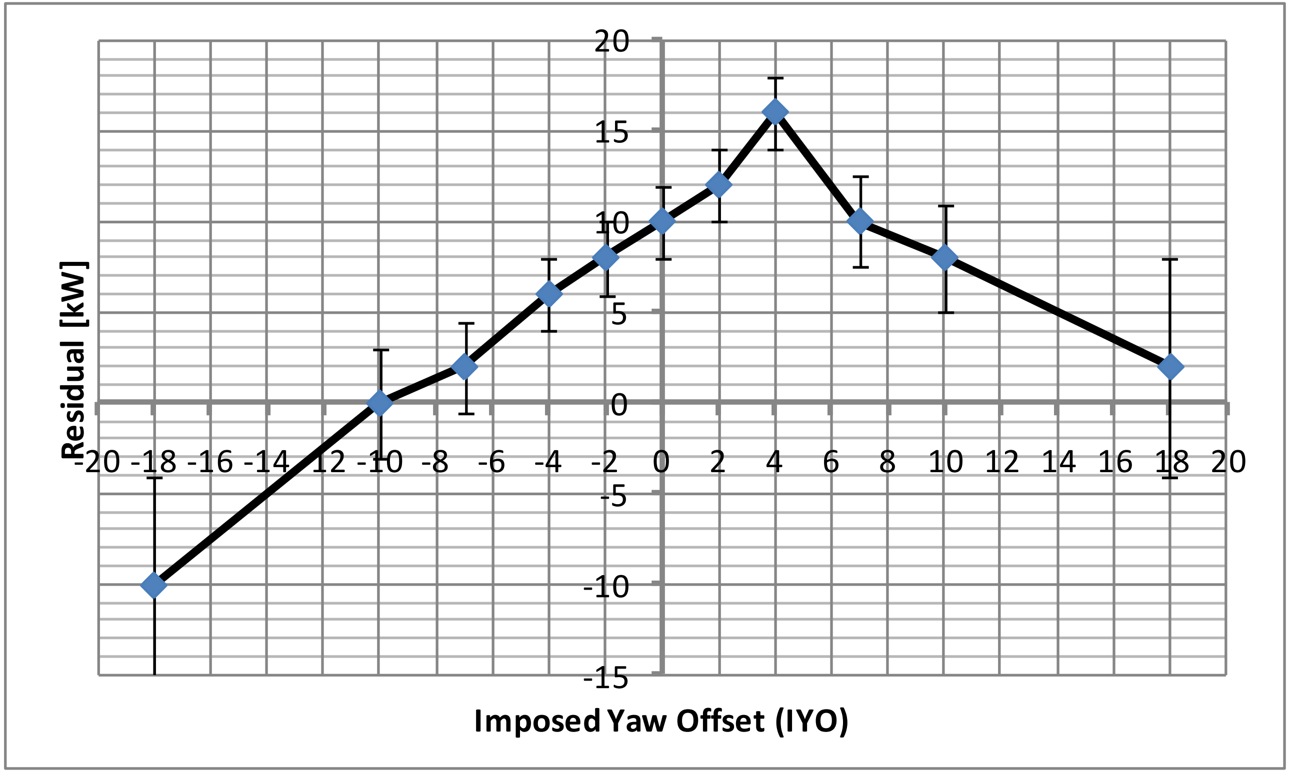


The **yaw offset (or yaw chronic)** is defined as the long-term yaw error average. May be due to:

- control algorithm systematic offset;
- misaligned wind vane;
- aerodynamic effects on wind vane;

Testing on two wind turbines will begin soon.

Anticipated Results (hopefully!!!)



Thank you!!!

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Questions???

Thank you