# Application of a SCADA Data Monitoring Methodology

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# Agenda

- Introduction
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- Approach and methodology
- Challenges
- Application
- Conclusions
- Next steps

# Introduction

- Bojan Alavanja
- BSc University of Belgrade
  Electrical Engineering
- MSc Uppsala University
  Wind Power Project Management
- Master Thesis Project
  Mecal Wind/Energy (The Netherlands)
- Currently
  Technical Support Engineer at Nordex Sweden

# Rationale

- Why condition monitoring?
- Market oriented and practical approach in mind!
- Utilize the available SCADA data at Mecal
- Use a developed methodology for SCADA data monitoring
- Develop a Matlab code for applying the chosen methodology
- Create a tool for wind turbine condition monitoring!

# What is SCADA data?

- Supervisory Control And Data Acquisition
  - An industrial control system architecture used to monitoring processes and basic remote control

| Wind turbine ID | TIME | Active Power (avg ) | Generator speed (avg ) | Turbine OK counter | Generator Rpm (avg ) | Rotor Rpm (avg ) | Main Bearing Temperature (avg ) |
|---|---|---|---|---|---|---|---|
| WTG 1 | 24.09.2016 18:10:00 | 871.329 | 1071.04 | 600 | 1071.38 | 14.9114 | 30.4896 |
| WTG 1 | 24.09.2016 18:20:00 | 631.667 | 987.85 | 600 | 988.256 | 13.7514 | 30.492 |
| WTG 1 | 24.09.2016 18:30:00 | 929.679 | 1077.07 | 600 | 1077.48 | 14.994 | 30.5094 |
| WTG 1 | 24.09.2016 18:40:00 | 875.361 | 1062.14 | 600 | 1062.5 | 14.7872 | 30.5478 |
| WTG 1 | 24.09.2016 18:50:00 | 992.273 | 1076.44 | 600 | 1076.78 | 14.9866 | 30.6053 |
| WTG 1 | 24.09.2016 19:00:00 | 1786.28 | 1127.87 | 600 | 1128.15 | 15.7026 | 30.634 |

# Wind turbine condition monitoring

- The Condition Monitoring Systems use additional sensors for monitoring parameters other than those found in SCADA
- The main bearing, gearbox and generator are monitored through two widely used CMS methods - oil monitoring and vibration analysis
- Significant efforts have been made to interpret SCADA data and use it for artificial neural networks, signal trending or physical models

# Monitoring methodology

- Research lead to a methodology from a published paper - *Wind turbine condition monitoring by the approach of SCADA data analysis* (Yang, W., Court, R. & Jiang, J., 2013)

- The methodology from this paper takes advantage of the most commonly monitored SCADA parameters and their correlation

- "**The proposed CM technique has shown powerful capability in detecting WT blade and drive train faults**. Moreover, it also shows amazing ability in tracing the further deterioration of these faults. **So, it potentially can be a cost-effective tool for WT CM applications.**"

# Monitoring methodology

- How does it actually work?

$$\{x_i, y_i\}(i = 1,2, \ldots, n)$$

where $x_i, y_i$ are couple of SCADA data parameters
(for example $x_i$ =Gearbox temperature, $y_i$=Rotor RPM)

$$\hat{y}_i = a_0 + a_1 x_i + a_2 x_i^2 + \cdots + a_k x_i^k \longrightarrow \boldsymbol{Y} = \boldsymbol{X} * \boldsymbol{A}$$

where $\hat{y}_i$ is an estimation of parameter $y_i$,
$a_i$ are coefficients representing parameters dependency

$$\boldsymbol{X} = \begin{bmatrix} 1 & x_1 & \cdots & x_1^k \\ 1 & x_2 & \cdots & x_2^k \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_n & \cdots & x_n^k \end{bmatrix} \quad \boldsymbol{A} = \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_k \end{bmatrix} \quad \boldsymbol{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} \longrightarrow \boxed{\boldsymbol{A} = (\boldsymbol{X}^T \boldsymbol{X})^{-1} \boldsymbol{X}^T \boldsymbol{Y}}$$

# Monitoring methodology

- Matrix $\boldsymbol{A}$ represents the dependency of parameters from one period
- Matrix $\boldsymbol{B}$ can be calculated the same way for another period of time
- Calculate the difference between the dependencies from two periods
- Coefficient $c$

$$c = \frac{\int_{x_{min}}^{x_{max}} \left| \sum_{j=0}^{k} (a_j - b_j) x^j \right| dx}{x_{max} - x_{min}}$$

- "The more serious the fault, the larger the value of $c$ tends to be"

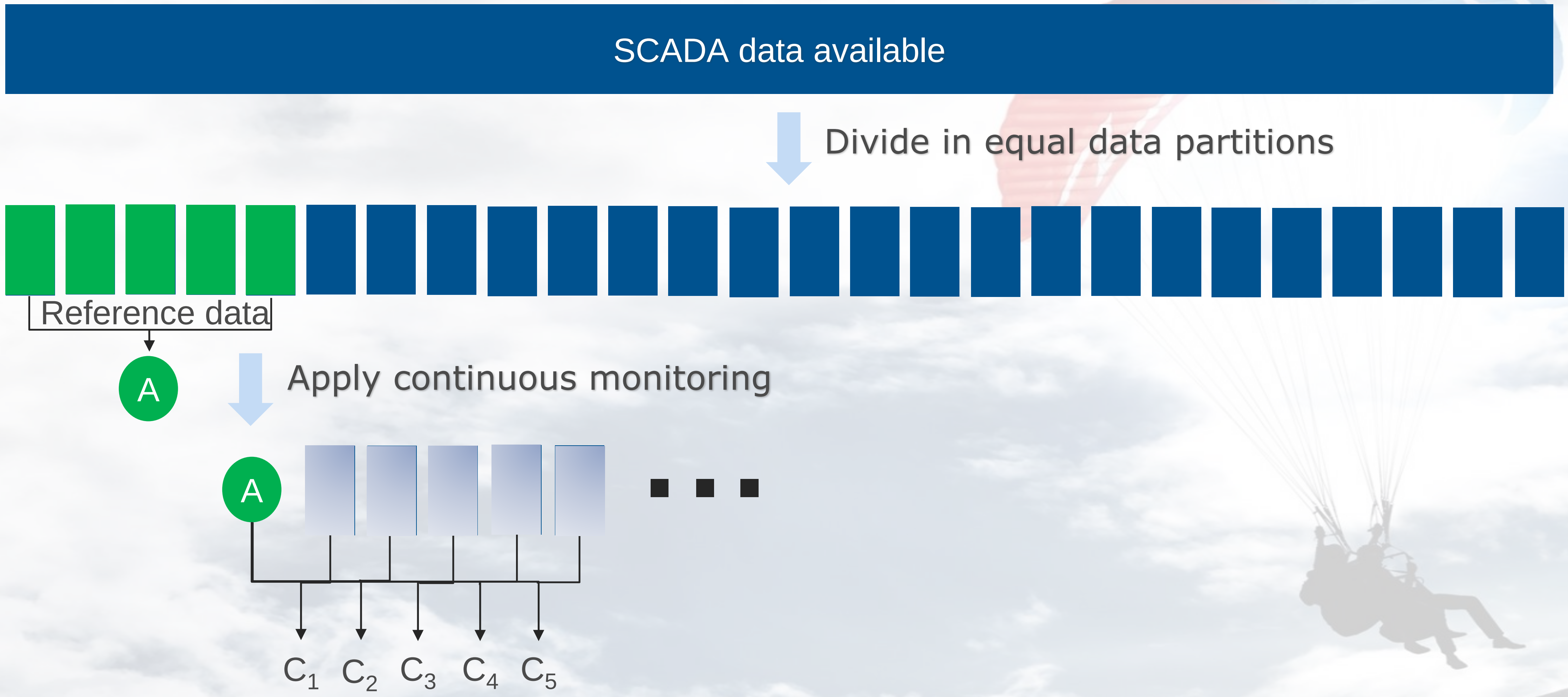
# Challenges

- How to clean the "raw" SCADA data?
  - Remove corrupt data and data when turbine wasn't producing energy

- How to achieve continuous monitoring?
  - Reference matrix A to compare with new matrix B in every iteration

- How frequently can the calculation be performed?
  - From what was seen in testing phase at best once a month

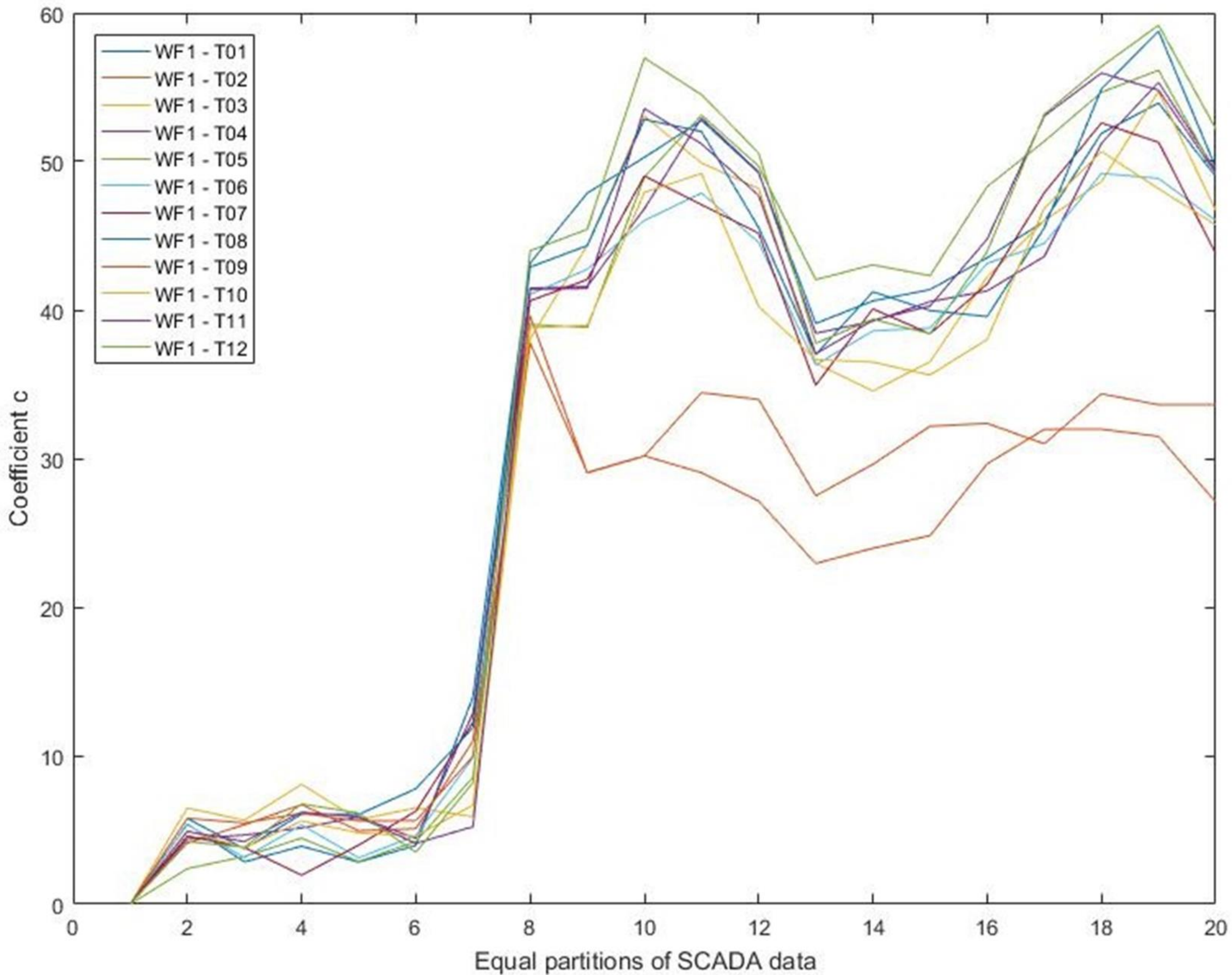
# Application



# Application

- Wind farm data for testing
  - 12 turbines (2 MW rated power)
  - Available 32 months of SCADA data (from commissioning)
  - Cleaned and synchronized data from all wind turbines
  - Fixed historical data (matrix A) and 20 iterations (matrix B)
  - Monitoring the **generators**
  - Parameters generator speed (RPM) / active power

# Results



WF1 - T01
WF1 - T02
WF1 - T03
WF1 - T04
WF1 - T05
WF1 - T06
WF1 - T07
WF1 - T08
WF1 - T09
WF1 - T10
WF1 - T11
WF1 - T12
Coefficient c
Equal partitions of SCADA data
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20

# Conclusions

- A tool for SCADA data processing and analysis was created, the aim of the project was fulfilled!
- Couples of SCADA parameters that are proposed for monitoring specific turbine components are not always directly connected to only one component
- The coefficient $c$ is always a positive value and disregards the possibility of improving components health
- Using the approach described has to be met with a certain amount of knowledge for interpretation of the results

# Next steps

- At Nordex Acciona there is a vast amount of SCADA data that can be used for further improvement of the application
- Important next step would be to try and utilize real-time data instead of 10-minute average SCADA values!
- However, Nordex Acciona has a dedicated Data Analysis team that is performing similar calculations and analysis of SCADA data
- Technical Back Office in Uppsala will further develop and test this methodology in order to get the most out of already available data!

# Thanks for your attention!

Bojan Alavanja
Technical Support Engineer

Nordex Sverige AB
Kungsängsvägen 25 B
SE- 753 23 Uppsala
Sweden

phone: +46 (0)18 18 59 00
mobile: +46 (0)70 646 41 70
email: balavanja@nordex-online.com
web: www.nordex-online.com