Making wind turbines smart – accessing and evaluating operational data of a research wind turbine

Michael Pagitsch, Georg Jacobs, Dennis Bosse

Valencia, 2017-11-09
Contents

- From “Industrie 4.0” towards “Smart Wind Energy”
- Operational data – the SCADA system
- Benefits of evaluation of SCADA data
**“Industrie 4.0” and smart wind energy**

**4th industrial revolution**

- Caused by introduction of Internet of Things and Services into the manufacturing environment
- Global networks with Cyber-Physical Systems of machinery, warehouses and production facilities
- Technical integration of CPS in product development, production, and logistics
- Research and development activities need to be accompanied by appropriate industrial policy decisions
Examples for smart services: Smart farming services – today
Examples for smart services: Smart farming services – tomorrow

[Diagram depicting the integration of various elements including tractors, harvesters, machines, mobile radio, GPS, and service platform. The diagram shows the flow of data from farmers to service platforms and various service providers including agricultural advisors, agents, contractors, traders, and OEMs.]
Examples for smart services: Smart energy services – today

Energy suppliers

Loose customer connectivity due to undifferentiated supply

Consumer & Prosumer

Energy ↔ Cash

Source: BTC
Examples for smart services: Smart energy services – tomorrow

Serviceplatform: App-Store related to transition of energy

Close customer connectivity due to attractive, taylor made supply

Energy suppliers

Further service providers

Energy <-> Cash <-> Data, Information

Source: BTC

[SmartServiceWelt2015]
“Industrie 4.0” and smart wind energy

“Smart wind turbine”

- **Smart maintenance**: Combination of maintenance activities across wind farms
- **Communicating smart grids**: Quick and “optimized” response to requests from grid operators
- **Online state information**: Detailed real-time state analysis and display in web-based dashboards
- **Intelligent wind farms**: Wind farm controllers operate based on grid requirements and optimal utilization of individual WTGs
- **Predictive maintenance**: Intelligent scheduling of maintenance activities (prior to damages)
## Examples of smart services

<table>
<thead>
<tr>
<th>Level</th>
<th>Addressee</th>
<th>Manufacturer</th>
<th>Service</th>
<th>Operator</th>
<th>Local resident</th>
</tr>
</thead>
</table>
| Wind turbine| • Intended load spectrum  
• Remaining lifespan  
• Service report  
• Documentation of life cycle | • State of maintenance  
• Remaining lifespan  
• Service report | • Production of energy  
• Remaining lifespan  
• Service report | • Shutdown function | |
| Wind farm   | • Load-reducing strategy of operation  
• Wind forecast | • Identification of malfunctions  
• Maintenance plan | • Identification of potentials for yield increases  
• LCOE forecast | • Noise forecast  
• Shadowing forecast | |
| Power system|                   |                                                                              | • Operational management optimized for maximum yield and minimum load  
• Security of supply |                  |                      |
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Operational data – the SCADA system

Main elements of a SCADA system

- Field data interfaces (RTUs, PLCs)
  - Sensors, actuators

- Communications system
  - Equipment for data transfer
  - TCP/IP networks, field bus systems

- Central host computer / server
  - Data processing unit
  - Human machine interface

- Operator workstations and software components
  - Collection of standard and/or custom software
Smart wind: The path towards full deployment of SCADA data

**WT DATA**

**Time-variant data**
- SCADA, SHM, CMS
- Data from additional sensors

**Documentation**
- Type & location of WT
- Schedule & journal of maintenance

**DATA INFRASTRUCTURE**

- Aggregation & distribution
- Storage (data security & integrity)
- WT onboard analytics

**DATA ANALYSIS**

**Data-based analysis**
- Machine learning algorithms (Neuronal networks)
- Knowledge discovery and data mining (KDD)
- Statistical methods

**Model-based analysis**
- Observer-based condition monitoring
- Functional models
- Operational models
- Fatigue / wear / remaining lifespan
The CWD’s research turbine – “FVA-Nacelle”

4 MW Direct-drive
5 DOF wind loading unit
FVA-Nacelle: 2.75 MW research turbine
The CWD’s research turbine – “FVA-Nacelle” in Hardware-in-the-Loop-operation

- 1 DOF
- 5 DOF
- Wind loads
- SCADA system
- Pitch angles, rot. speed
- Windfield simulation
- Electrical grid

Input-variables:
- $v_{\text{Wind}}$, $T_1$, angular deviation

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Overview of available signals and their origin

- T
- OpState
- Rot. Speed
- Torque (calc.)
- Wind/Pitch/Yaw
- u, i

Converter System
Accessing SCADA data in a "standard" WT

**Data source**
- FVA-Nacelle
  - WT-Ctrl
  - HIL-Ctrl

**Onboard processing**
- Raspberry Pi
  - Data pre-processing
    - (calculation of statistics and derived quantities)

**Server-side processing**
- CWD server infrastructure
  - Message queue
  - Data processing
    - Python
  - Web frontend
    - Apache
    - d3.js

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Possible deployment of SCADA data

Snapshot of the WTG’s current state

- SCADA-based condition monitoring
- Detection of “intended state” of WTG
- Comparison of current and intended state for selected quantities

RMS error: 0.023
Possible deployment of SCADA data

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Error detection and optimization of wind farms

- E.g. based on a comparison of power curves
  - Across wind farms
  - Comparison between intended and actual power curve
- Long-term monitoring allows for detection of anomalies
- Early detection and correction for higher energy output
Possible deployment of SCADA data

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"Smart wind energy"

- Industrie 4.0
- Smart services
  - Smart farming services
  - Smart energy services

The SCADA system

- Introduction of CWD's research turbine
- Available data and how to access them

Deployment of SCADA data

- SCADA-based condition monitoring
- Detection of malfunctions
Thank you for your attention.