Increasing Wind Farm Profitability with WINDcenter Services at STEAG

3 November, 2017
Dr. Christoph Guder
WINDcenter presentation:
who we are and how we support wind farm O&M

The WINDcenter’s method:
early knowledge of upcoming failures

Profitability increase with the WINDcenter:
actual case studies

Final notes
WINDcenter presentation: who we are and how we support wind farm O&M

The WINDcenter’s method: early knowledge of upcoming failures

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Final notes
STEAG’s proven track record is a solid basis for future success

1937 Foundation of STEAG

1996
Leuna (Germany)
162 MW Refinery

2002
Illmenau (Germany)
5 MW Biomass

2003
Köln-Godorf (Germany)
211 MW Refinery

2009
Karstädt (Germany)
1 MW Biogas

2013
Ridham Dock (UK)
25 MW Biomass

2014
Ullersdorf (Germany)
43 MW Wind

2017
TA Lauta
20 MW
IKW Rüdersdorf
35 MW Municipal solid waste

1937 Foundation of STEAG


1999
Termopaipa (Colombia)
165 MW Hard coal

2003
Iskenderum (Turkey)
1,320 MW Hard coal

2006
Mindanao (Philippines)
232 MW Hard coal

2013
Walsum 10 (Germany)
790 MW Hard coal

2014
Crucea North (Romania)
108 MW Wind

2015
Süloğlu (Turkey)
66 MW Wind

about 8,000 MW commissioned coal fired power plants in the Rhine-Ruhr and Saar regions

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Wind Power Portfolio at STEAG group

Wind Farms at STEAG:
- WF Crucea North (Romania) 108 MW
- WF Süloglu (Turkey) 66 MW
- WF Ullersdorf (Germany) 43 MW
- 8 Wind Farms in France, altogether 106 MW
- 2 Wind Farms in Poland, altogether 20 MW
- 6 further Wind Farms in Germany, altogether 60 MW

Installed wind power altogether 403 MW (onshore)

O&M at STEAG Energy Services do Brasil:
- 9 Wind Farms in Brazil with a total capacity of > 1000 MW
  O&M of transmission system plants / remote operation

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Overview of STEAG Energy Services Group

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STEAG Energy Services Group

Revenue € 134 million (consolidated)
Employees 1,790 (consolidated)

data 2016

Business units involved in the WINDcenter

STEAG Energy Services

Energy Technologies
Design, site supervision and commissioning of power plants

Plant Services
Operation & Maintenance of Power Plants incl. training; personnel services

Nuclear Technologies
Decommissioning and dismantling of nuclear plants, safety, radiation protection and realization of final disposal sites

System Technologies
Energy Management Systems, process optimization by sensor-based solutions, user trainings

Information Technologies
Operation Management Systems, Communication Technologies, Site IT

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Our Services Energy Technology: Planning

STEAG-Services:
- Technical project management
- Time scheduling for the whole project
- Preparation of technical specification
- Evaluation of bids
- Preparation and management of technical contract negotiations
- Supply Contract Management
- Supervision of erection and commissioning
- Interface Management
- Design review
- Complete design of grid connection
- Support in licensing management

Reference projects:
WF Crucea North and WF Süloglu:

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Flexible and Sustainable. Know-how and Processes Based on Practical Field Experience

Customized operational leadership:

- O&M Support: as consultant for customers;
- O&M Management: responsible management by key experts at site;
- O&M Management & Staff: responsible management and execution of O&M activities including full workforce;
- Full Scope O&M: comprehensive O&M as above including spares;
- Efficient and trustworthy operational management, combined with maintenance of the technical equipment that is supported by IT tools that were developed through practical experience;
- Professional Training and development of staff;
- Application of customized power plant simulators.
Products of the SR-family have been applied for over a decade in practically all large German conventional power plants.

The system applied by the WINDcenter has a successful track record in 13 of those power plants.
The Wind farm Integrated Neural Diagnostics center – the WINDcenter – bundles the know-how and experience of STEAG’s engineering, IT and O&M teams to monitor, analyze and evaluate wind farms’ processes and components.

Main outputs of the WINDcenter are:
- non-availability allocation and
- early knowledge of upcoming failures.

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WINDcenter’s track record

<table>
<thead>
<tr>
<th>Remarks</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software provision:</td>
<td>1</td>
</tr>
<tr>
<td>Offshore:</td>
<td>3</td>
</tr>
<tr>
<td>Predictive analysis:</td>
<td>4</td>
</tr>
<tr>
<td>Retrospective analysis:</td>
<td>9</td>
</tr>
<tr>
<td>OEMs:</td>
<td>9</td>
</tr>
<tr>
<td>Total power (MW):</td>
<td>~1250</td>
</tr>
</tbody>
</table>

Map source: Google Maps
WINDcenter’s Services
In-house Services for STEAG Wind Farms

WINDcenter services for STEAG’s wind farms:

- Server capabilities for the data reception from the SCADA and CMS system
- Analysis of the SCADA data
- Continuous online monitoring of wind turbines and wind farms
- Early detection of creeping process changes and sudden deviations
- Generation of relevant alarms
- Root cause analysis for relevant alarms
- Non-availability analysis
- Estimation of generation loss due to power limitations and/or unplanned shutdowns
- Regular as well as extraordinary reports
- Power Curve analysis

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The WINDcenter’s method: early knowledge of upcoming failures

Profitability increase with the WINDcenter: actual case studies

Final notes
Parameter monitoring
Drift

SCADA alarm values are usually much larger/smaller than normal operational values

➔ A parameter drift within the alarm values would go unnoticed
SCADA alarm values are usually much larger/smaller than normal operational values

→ A parameter drift within the alarm values would go unnoticed
Parameter monitoring
Behavioral change

SCADA alarm values are usually much larger/smaller than normal operational values

→ A behavioral change within the alarm values would go unnoticed
Parameter monitoring
Behavioral change

SCADA alarm values are usually much larger/smaller than normal operational values

➡️ A behavioral change within the alarm values would go unnoticed
A reference value is used to define the “Key Performance Indicator” (KPI). It is a normalized value indicating the current status of the monitored parameter.

\[
KPI = \frac{\text{Actual value}}{\text{Reference value}}
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\[
\text{KPI} = \frac{\text{Actual value}}{\text{Reference value}}
\]
WINDcenter’s method
Practical implementation

1. Early warning system for the detection of process changes through statistical analysis of available raw process data
2. Event root cause analysis (RCA)

1. Actual value

2. Learning process

3. Actual and reference values

4. KPI = (Actual/Reference)

5. Statistical analysis

6. RCA

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The system generated a low production alarm for all WTs of this wind farm. It was established that the reason for reduced power was blade icing. The WTs remained in operation under these conditions for 24h before being stopped. Lost production in this case was ~170 MWh.
Example 2: Early detection
Gear bearing temperature actual value

The longtime temperature trend of the gear bearing shows, in retrospective, a creeping process change. However, its detection would be extremely unlikely without the implementation of an online monitoring system.
Example 2: Early detection
Gear bearing temp.: actual and reference values

1. First WT warning: September 22\textsuperscript{nd}, 2012
2. First WT shut-down: May 15\textsuperscript{th}, 2013

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Example 2: Early detection
Gear bearing temp.: statistical analysis

0. First WINDcenter alarm:
   May 13th, 2012

1. First WT warning:
   September 22nd, 2012

2. First WT shut-down:
   May 15th, 2013

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Example 3: Instantaneous detection
Main bearing temperature actual value

This example analyzes the same WT as in example 2. The main bearing temperature trend alone shows seasonal effects, but no obvious process change.
Only after comparing actual and reference values, discrepancies from May 2013 onwards can be observed.
Example 3: Instantaneous detection
Main bearing temp.: statistical analysis

Shortly after the semestral maintenance was performed, the WINDcenter detected a change in the temperature behavior.
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Profitability increase with the WINDcenter: actual case studies

Final notes
Case study 1: Gear oil pressure
Alarm generated by WINDcenter’s system

A WINDcenter alarm indicated that gear oil pressure was higher than expected.
Case study 1: Gear oil pressure
WINDcenter’s root cause analysis

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Case study 1: Gear oil pressure
WINDcenter’s root cause analysis

Cooling water temperature no longer regulated

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Case study 1: Gear oil pressure
WINDcenter’s root cause analysis

WINDcenter’s RCA determined that the 3-way-valve was defective. The WINDcenter recommended immediate valve repair/replacement on November 14th, 2014.

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Case study 1: Gear oil pressure
Production loss due to event

In this case, the 3-way valve was replaced on January 7th (two months later). With decreasing winter temperatures, gear oil became so viscous that the WT itself limited its output to 40% for self protection. This caused a production loss of 185 MWh.

Later on, similar behavior was observed on two other WTs. In these cases, timely response from the service provider avoided further unnecessary production losses.
Case study 2: Generator winding temperature
Alarm generated by WINDcenter’s system

A WINDcenter alarm indicated that generator winding temperature was higher than expected.
Case study 2: Generator winding temperature
WINDeCenter’s root cause analysis

High cooling water pressure was detected by WINDeCenter’s RCA

The WINDeCenter recommended cooling water filter replacement on November 14th, 2014

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The service team replaced the cooling water filter on November 21st and again on December 8th.

The filter was clogged on both occasions.
Production loss in this case was 75 MWh. Additional losses due to consequential damages (e.g. isolation loss due to high temperature) are yet to be observed.

Similar behavior was observed on two other WTs. Further losses were avoided.

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## Profitability increase: case study

**Analyzed wind farm:**
- 36 WTs, 3 MW each, \( \mu_{Cf} \approx 34\% \)
- 1st operation year

### Avoidable losses [MWh]

<table>
<thead>
<tr>
<th>Case study</th>
<th>#</th>
<th>Avoidable losses [MWh]</th>
<th>AEP increase ( \approx 0.5% )</th>
<th>Financial impact for same wind farm in different markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case study 1</td>
<td>1</td>
<td>185</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case study 1.1 and 1.2 (estimated)</td>
<td>2</td>
<td>370</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case study 2</td>
<td>1</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case study 2.1 and 2.2 (estimated)</td>
<td>2</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (1 year, 10 KPIs, measurable)</strong></td>
<td><strong>6</strong></td>
<td><strong>780</strong></td>
<td><strong>69.000 €</strong></td>
<td><strong>151.000 €</strong></td>
</tr>
<tr>
<td><em><em>Total (1 year, 10 KPIs</em>, estimated)</em>*</td>
<td><strong>12</strong></td>
<td><strong>~1.600</strong></td>
<td><strong>142.000 €</strong></td>
<td><strong>310.000 €</strong></td>
</tr>
</tbody>
</table>

### Financial impact for same wind farm in different markets

<table>
<thead>
<tr>
<th></th>
<th>DE onshore 89 €/MWh</th>
<th>DE offshore 194 €/MWh</th>
<th>UK offshore £ 155/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case study 1</td>
<td>16.000 €</td>
<td>36.000 €</td>
<td>£29.000</td>
</tr>
<tr>
<td>Case study 1.1 and 1.2 (estimated)</td>
<td>33.000 €</td>
<td>72.000 €</td>
<td>£57.000</td>
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<tr>
<td>Case study 2</td>
<td>7.000 €</td>
<td>15.000 €</td>
<td>£12.000</td>
</tr>
<tr>
<td>Case study 2.1 and 2.2 (estimated)</td>
<td>13.000 €</td>
<td>29.000 €</td>
<td>£23.000</td>
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<td><strong>Total (1 year, 10 KPIs, measurable)</strong></td>
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<td><strong>151.000 €</strong></td>
<td><strong>£121.000</strong></td>
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<tr>
<td><em><em>Total (1 year, 10 KPIs</em>, estimated)</em>*</td>
<td><strong>142.000 €</strong></td>
<td><strong>310.000 €</strong></td>
<td><strong>£248.000</strong></td>
</tr>
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</table>

*10 KPIs were applied in the first year. 30 already developed KPIs potentially increase avoidable losses

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The above listed avoidable losses refer only to directly measurable production losses

- Payback period < 1 year from avoidable losses alone

**Further benefits:**
- Detection and remediation of underperformance
- Improved maintenance strategy
- Improved planning of maintenance timing, logistic, and resources
- Avoided consequential damages

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Final notes
Yearly financial impact for 36x3MW wind farm in different markets

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Key facts:
- AEP increase ≈ 0.5%
- Optimized maintenance
- Safe assets
- Payback period < 1 year

We uncover the hidden value of your SCADA data.

- This is our way of increasing your wind farm profitability!

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