Condition Monitoring Systems (CMS) in wind turbines

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Intelligent vibration monitoring of wind turbines

- Targets
  - Permanent plant/system protection
  - Reduction of maintenance costs
  - Increased availability due to permanent online monitoring
  - Planning of repair
  - Cause analysis by documenting damage events
  - Avoidance of unplanned production downtimes
  - Condition-based maintenance to DIN 31051 "Fundamentals of maintenance"
Monitoring possibilities on wind turbines

- Rotor blades (safety)
- Drive train (diagnosis)
- Motors and pumps (diagnosis)
- Tower vibrations (safety)
Possible failures on wind turbines

- As stated by the insurer German Lloyd

<table>
<thead>
<tr>
<th>Mechanical Component</th>
<th>Failure Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Gearbox</td>
<td>32 %</td>
</tr>
<tr>
<td>Generator</td>
<td>23 %</td>
</tr>
<tr>
<td>Main Bearing</td>
<td>11 %</td>
</tr>
<tr>
<td>Rotor Blades*</td>
<td>&lt;10%</td>
</tr>
</tbody>
</table>

*Blade resonances lead to fatigue failures
Saving potential using the example of a gearbox on a wind turbine

- **Cost factors of a gearbox:**
  - A new gearbox costs approx. 160,000 €
  - The delivery time for a new gearbox is approx. 6 months
  - A mobile crane causing the following costs is needed to replace the gearbox
    - Transport of the crane to the wind turbine: approx. 30,000 €
    - Daily user costs: 4,000 €

- **Cost advantages when using Condition Monitoring Systems:**
  - Damage can be detected in good time
  - Repair costs are considerably lower than replacement costs
  - Repairs on the nacelle can be carried out at an early stage.
Possible applications of Condition Monitoring Systems

**Gearbox**
- Wear, break in teeth
- Displacement, eccentricity of toothed wheels

**Generator/network coupling**
- Winding damage
- Rotor asymmetries, bar break
- Overheating

**Rotor**
- Fatigue, crack formation
- Blade adjustment error
- Damages (e.g. via lightning strike)

**Bearings, shafts**
- Wear, defects of bearing shells and rolling elements
- Fatigue, crack formation in shafts

**Nacelle adjustment**
- Yaw error (drive & motor)
- Monitoring of the friction bearing

**Tower vibration**
- System performance
- Environmental influences
- Crack formation, fatigue
Basic advantages of the system efector octavis

- Permanent protection of wind turbines
- Detailed diagnosis rotor, gearbox, generator and other parts
- Cause analysis by documenting damage events
  - Trend recording (route cause analysis, crash recorder)
  - FFT recorder (FFT: Fast Fourier Transformation)

Frequency analysis and evaluation
Technical possibilities of the efector octavis product series

- Wear/condition monitoring in real time and history (long-term diagnosis, trend memory / ring memory with freely adjustable time intervals)
- Frequency-selective diagnosis of the damaged objects in acc. with the following methods:
  - Fast Fourier Transformation / FFT (for e.g. unbalance, meshing frequency, gears)
  - Envelope curve analysis / HFFT (for e.g. bearing condition, sideband analysis)
- Broad-band monitoring of general characteristic vibration values (to DIN ISO 10816)
- Maintenance message as digital alarm signals or data transfer to higher-level systems (OPC, visualisation, SCADA)
The digital alarm signals of efector octavis

Switch-off times of up to 10 ms are achieved!
Technical advantages of the system efector octavis

<table>
<thead>
<tr>
<th>Online Diagnostics</th>
<th>ifm electronic</th>
<th>competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic values with FFT analysis (FFT: Fast Fourier Transformation)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Diagnostic values with envelope curve analysis (HFFT)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Up to 7 (VE) or 24 (VSE) characteristics can be monitored in parallel</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Characteristic values in the time domain (real time diagnosis)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>DIN ISO 10816 characteristic values (real time diagnosis)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Observance of process conditions for diagnosis</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Observance of process conditions for alarm</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine protection</th>
<th>ifm electronic</th>
<th>competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarms directly to the PLC (without PC software)</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Differentiated alarms directly to the PLC</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Real-time data acquisition</td>
<td>✔</td>
<td>✗</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trending / Root cause analysis</th>
<th>ifm electronic</th>
<th>competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal data recording with time stamp</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Open data interface (e.g. for visualisation and databases)</td>
<td>✔</td>
<td>✗</td>
</tr>
</tbody>
</table>

FFT Fast Fourier Transformation
Process conditions: e.g. performance and rotational speed

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Vibration sensors VSA with extended diagnostic electronics VSE1xx

**Product characteristics:**

- Ethernet interface / OPC interface
- Evaluation of up to 4 vibration sensors (0...10 mA) per diagnostic electronics possible
- Overall velocity monitoring to DIN ISO 10816.
- Up to 24 online diagnosis characteristics consisting of max. 80 individual frequencies
- Internal history memory up to 30,000 entries including time stamp (real-time clock)
- 2 x static inputs 0/4...20 mA / 0...10 V or pulse 24 V for process quantities (e.g. load and rotational speed)
- 2 x digital alarm outputs (PNP 100 mA) or 1 x digital alarm output + 1 analogue output 0/4...20 mA / 0...10 V
- 8 x digital outputs/inputs ((freely configurable) (PNP 100 mA) as trigger or alarm signals
Vibration sensors VSA with separate diagnostic electronics VSE0xx

Product characteristics:

- Ethernet interface / OPC interface
- Evaluation of up to 4 vibration sensors (0...10 mA) per diagnostic electronics possible
- Overall velocity monitoring DIN ISO 10816.
- Up to 24 online diagnosis characteristics consisting of max. 80 individual frequencies
- Internal history memory up to 30,000 entries including time stamp (real-time clock)
- 2 x static inputs 0/4...20 mA or pulse 24 V for process quantities (e.g. load and rotational speed)
- 2 x digital alarm outputs (PNP 100 mA) or 1 x digital alarm output + 1 analogue output 0/4...20 mA / 0...10 V
- Use of vibration sensors type VSA001 up to +125 °C
Compact vibration diagnostic units type VE

Product characteristics:

- Sensor and diagnostic electronics in one housing (no control cabinet required!)
- LED display on the unit.
- Overall velocity monitoring to DIN ISO 10816.
- Up to 5 online diagnosis characteristics consisting of max. 20 individual frequencies
- History memory / trend curve in the sensor (up to 2,850 values or hours per object)
- 2 x digital alarm output (PNP 100 mA)
- Data transfer of diagnostic data optionally also over long distances (RS485 / Profibus DP via gateway)
- Can be used as a mobile measuring system (analyzer)
- Available in ATEX 2D/2G
Compact vibration diagnostic units type VK

Product characteristics:

- Compact vibration monitor with transmitter and switching output
- For permanent machine protection
- Permanent vibration monitoring according to DIN ISO 10816.
- Switching output with adjustable switch point and response delay (PNP 500 mA)
- Analogue output signal 4...20 mA (4 mA = 0 mm/s; 20 mA = 25 mm/s) for direct display at the control desk
- LED display on the unit.
- Easy adjustment via two setting rings allowing optimum read-out.
Data transfer of online vibration diagnosis type VSE

**Process control and planning level**

Real Time Maintenance project implementation

Optional data acquisition

Router / switch

Data server with OPC server and visualisation

**CMS Condition Monitoring Systems**

Parameter setting

Diagnostic electronics VSExxx

Binary and analogue alarm signals

Analogue load signal

Further input signals

Temperature sensor

Vibration sensors VSAxxx

Parameter setting

Diagnostic electronics VSExxx

Analogue load signal

Analogue speed signal

Inductive sensor for speed monitoring

Vibration sensors VSAxxx

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Condition monitoring in wind parks via Ethernet / OPC interface

Information on processor performance:
To sample one value via OPC at a sampling rate of 1 sec takes 1 MHz processing power. Example: 2.4 GHz = 2400 values.

Information on OPC server:
The number of VSE units depends on the number of transmitted variables and the bandwidth of the network.
Condition monitoring in wind parks via VSE recorder software. Detailed in-depth analysis as FFT or envelope curve FFT spectrum.

Information on VSE recorder:
Software for triggered recording of FFT spectrum in form of a file when alarm is exceeded.

Possibility to save automatically when triggered by:
- status signal
- time signal
- analogue input signal

Service company for maintenance
SCADA system (control system)
Wind park operator

Data evaluation from wind turbine PCs
Technical overview

- Signal evaluation already in the system
- Online vibration diagnostics at an excellent price / performance ratio
- Decentralised monitoring of plant and equipment integrated into the machine.
- Different designs:
  - Compact field devices (type VK / VE) or control cabinet modules (type VSE)
- Internal trend recording of all monitored diagnosis values (type VE / VSE)
- Both process quantities (e.g. load and rotational speed, temperature and pressure, etc.) can be monitored with regard to whether the actual value is above or below the limit value and can be saved in the history memory.
- Digital and analogue alarm outputs
- Gateway function for additional process signals
- Standard data interface (OPC) for integration into higher-level systems (type VSE)
The right product for each application

<table>
<thead>
<tr>
<th>Design parameters</th>
<th>Target</th>
<th>VK</th>
<th>VE</th>
<th>VSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine vibrations in general</td>
<td>PROTECTION</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Internal trending</td>
<td>DOCUMENTATION</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>EARLY DAMAGE DETECTION</td>
<td>×</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Network compatible</td>
<td>SYSTEM</td>
<td>×</td>
<td>X</td>
<td>✓</td>
</tr>
</tbody>
</table>
Example applications in wind power stations

- "Economy" CMS: Condition Monitoring System for generator + gearbox + rotor bearing
- "Premium" CMS: Condition Monitoring System for generator + gearbox + rotor bearing
- Rotor blade monitoring via vibration diagnosis
- Diagnosis of pumps and motors in the periphery
"Economy" Condition Monitoring System for generator + gearbox + rotor bearing under 1000 €*

Characteristic data:
- online diagnosis + alarm message + trend recording under 1000 €*
- consisting of 4 vibration sensors VSA001 and 1 diagnostic electronics VSE002
- 1) monitoring bearing, converter
- 2) monitoring bearing, rotor
- 3) monitoring bearing, rotor shaft (end of gearbox)
- 4) monitoring rotor bearing
- 9) speed input (pulse, 4-20 mA)
- 10) load input (pulse, 4-20 mA)
- 11) alarm output (2 to 10 alarm outputs)
- 12) data interface TCP/IP
- 13) PC for configuration or data storage
- 14) diagnostic electronics VSE

Diagnostic data:
ISO RMS, bearing state (BPFO, BPFI, BSF), cage frequency (FTF), a_peak, a_rms

* referred to price list Germany 2009
"Premium" Condition Monitoring System for generator + gearbox + rotor bearing

**Characteristic data:**

- online diagnosis + alarm message + trend recording
- consisting of 8 vibration sensors VSA001 and 2 diagnostic electronics VSE
- 1) monitoring bearing, converter
- 2) monitoring bearing, rotor
- 3) monitoring bearing, rotor shaft (end of gearbox)
- 4) monitoring rotor bearing
- 5)-8) vibration monitoring gearbox
- 9) speed input (pulse, 4-20 mA)
- 10) load input (pulse, 4-20 mA)
- 11) alarm output (2 to 10 alarm outputs)
- 12) data interface TCP/IP
- 13) PC for configuration or data storage
- 14) diagnostic electronics VSE

**Diagnostic data:**

- ISO RMS, bearing state (BPFO, BPFI, BSF), cage frequency (FTF), meshing, side-band analysis, $a_{\text{peak}}$, $a_{\text{rms}}$
Condition monitoring of the rotor blades

Changes in the condition of the rotor blades caused by cracks and ice formation are detected via the changes in vibration and can be directly evaluated by the diagnostic electronics.

VSE002 efector octavis diagnostic electronics & VSA001 vibration sensor:

- One vibration sensor per rotor blade
- Central evaluation via diagnostic electronics with Ethernet interface in the rotor control cabinet
- Additional evaluation of external sensors (VSE100, binary and analogue)
Diagnosis of pumps and motors in the periphery (offshore)

efector octavis VE1xxx:

- e.g. VE1001 or VE1002
- Detection of damage to rolling element bearings by frequency analysis
- up to 20 frequencies in the spectrum, freely selectable, diagnostic level adjustable
- Compact design: Sensor, evaluation and diagnosis in one unit

In a wind turbine there are often motors and pumps in the periphery which have to be monitored regarding damage to rolling element bearings, unbalance and cavitation. efector octavis provides the user with an optimum plant availability by permanently monitoring these aggregates. Furthermore alignment errors can be detected and meshing can be monitored.
Customer benefits by choosing ifm electronic as the supplier

- Leading supplier of integrated online vibration monitoring systems
- Supplier renowned world-wide for his quality
- Own production with high quality standards, QS certification
- Development and production in Germany
- Notable references in the field of wind power (approx. 1000 systems worldwide, as per 2008)
- Parameter setting software free of charge
- Supplier-independent data evaluation
- Competent local contacts worldwide
- Worldwide consultation, training, and support
Increasing the availability of machines and plants

Reducing maintenance costs

Quality assurance
Product overview of ifm electronic

- **Position sensors and object recognition**
  - Inductive sensors, capacitive sensors, magnetic sensors, cylinder sensors, valve sensors, safety technology, photoelectric sensors, object recognition, encoders

- **Fluid sensors and diagnostic systems**
  - Level sensors, flow sensors, pressure sensors, temperature sensors, diagnostic systems

- **Evaluation systems**, power supplies and switching amplifiers

- **Bus system AS-Interface**

- **Identification systems**
  - RF-identification systems, optical identification systems

- **Control systems**

- **Connection technology**