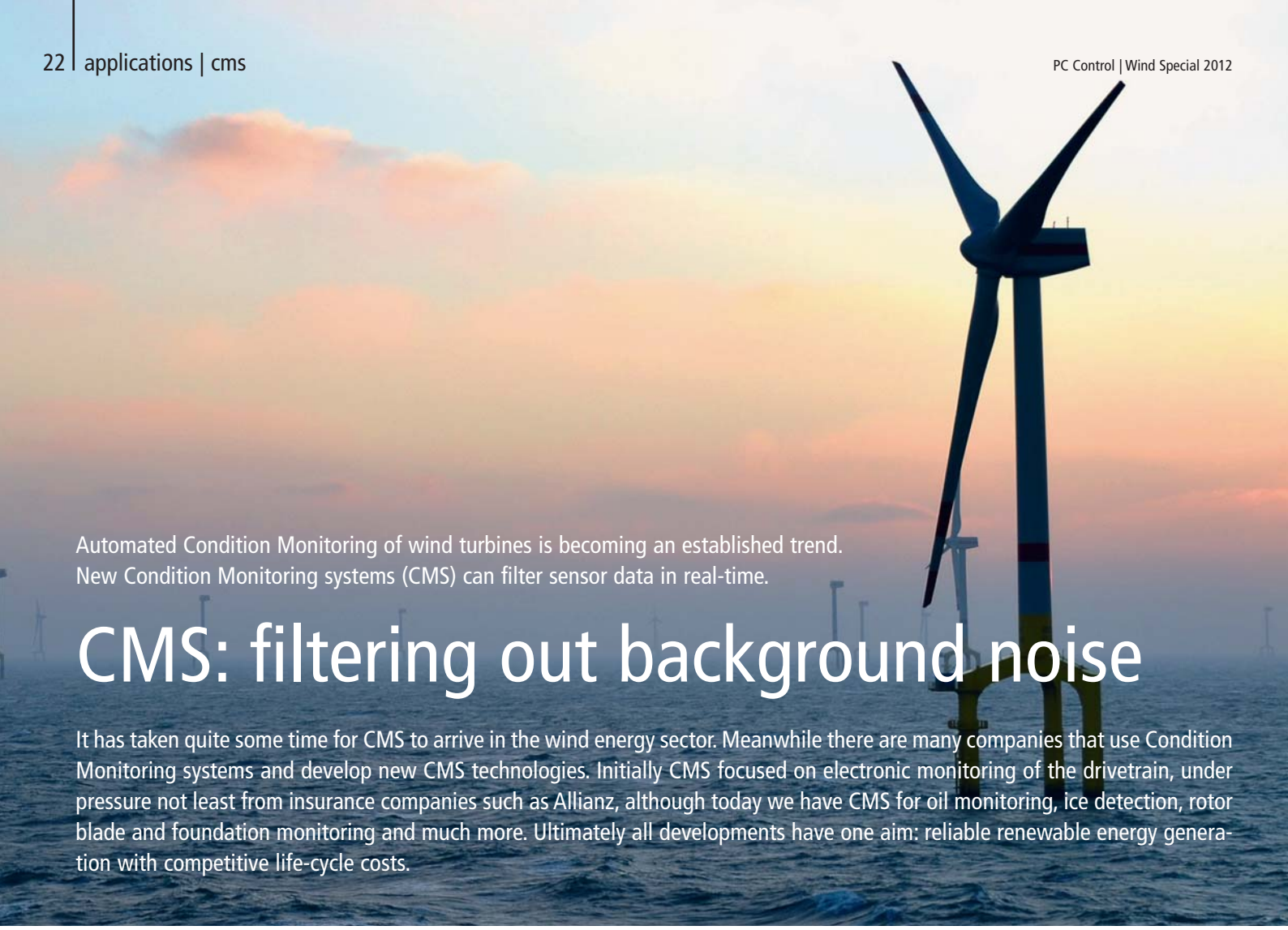


Automated Condition Monitoring of wind turbines is becoming an established trend. New Condition Monitoring systems (CMS) can filter sensor data in real-time.

CMS: filtering out background noise

It has taken quite some time for CMS to arrive in the wind energy sector. Meanwhile there are many companies that use Condition Monitoring systems and develop new CMS technologies. Initially CMS focused on electronic monitoring of the drivetrain, under pressure not least from insurance companies such as Allianz, although today we have CMS for oil monitoring, ice detection, rotor blade and foundation monitoring and much more. Ultimately all developments have one aim: reliable renewable energy generation with competitive life-cycle costs.

In order to keep competitive the total costs of a wind turbine over its entire service life, the risk of failure must be minimized, maintenance costs must be reduced, and system availability and energy efficiency must be increased. Early detection of faults can make an important contribution to achieving this, as can optimized control algorithms that log and process measured data and feed the results into the controller as control variables. The effect is reduced system load and increased efficiency of the turbine movements in the wind field. Prerequisites for improved control algorithms are: individual pitch control for each rotor blade and intelligent control of the yaw motors that align the nacelle with the wind flow.

These new options are available thanks to advanced control systems, which are able to sample and process signals within microseconds. Some companies have developed procedures for carrying out performance analyses using the Scada data which are routinely supplied by the system controller: These analyses show in which areas, torques and wind and weather conditions that the system achieves good results and in which it does not. This enables faster identification and tracking of weak spots, which reduce the energy yield.

Foundation monitoring is also becoming increasingly important: Now that the first offshore turbines have been installed in the North Sea, the structural design and dynamics departments of renowned research organizations are engaged in the development of monitoring techniques and systems for offshore foundation structures. The aim here is to derive information regarding offshore turbine service life and stability. Currently there are no clear findings as to which features a CMS must offer in order to meet the requirements of the Federal Maritime and Hydrographic Agency in Germany, which is responsible for approving wind farms in the North Sea and the Baltic.

Transmission manufacturers increasingly call for a black box approach

Demand for high-quality CMS is expected to grow further: Transmission manufacturers are in fierce competition and are moreover faced with demands for increasingly longer warranty periods. A suitable CMS is seen as a tool to escape the "warranty trap." Transmission manufacturers have been thinking about a black box approach for some time. They want evidence to prove that worn or destroyed transmission units did, in fact, only rotate under the loads forecast by the turbine manufacturers. The data are intended as defense against unjustified warranty claims and as a basis for more realistic design loads for building more reliable transmission units. There is no way around measuring and archiving the actual loads, so that the data can be analyzed in the event of a failure.

"The pertinent developments by controller manufacturers are proof that CMS has not only become acceptable, but offers enormous potential."

Condition Monitoring integrated into the control system

A centralized, PC-based controller is advantageous, in particular if large amounts of data from different devices must be referred to for analysis or if damage frequencies must be evaluated in relation to the rotary speed. Instead of specialized systems with separate CPUs, Condition Monitoring integrates seamlessly into the system controller. To this end, Beckhoff has developed dedicated Condition Monitoring terminals: The EL3632 EtherCAT Terminal enables direct connection of different acceleration sensors via Integrated Electronics Piezo-Electric (IEPE). The data are logged in the EtherCAT Terminal system and made available to the higher-level PC controller, where software is used for the analysis. Warning and switch-off thresholds are specified based on these data. Configurable filters and supply currents enable application-specific adaption of the terminal to different sensors.

> **"One of the advantages of the Beckhoff CMS Terminal system is that it can easily be expanded. Further devices/components, including rotor blades or yaw drives, can be cost-effectively integrated into the monitoring system by adding corresponding measuring terminals."**

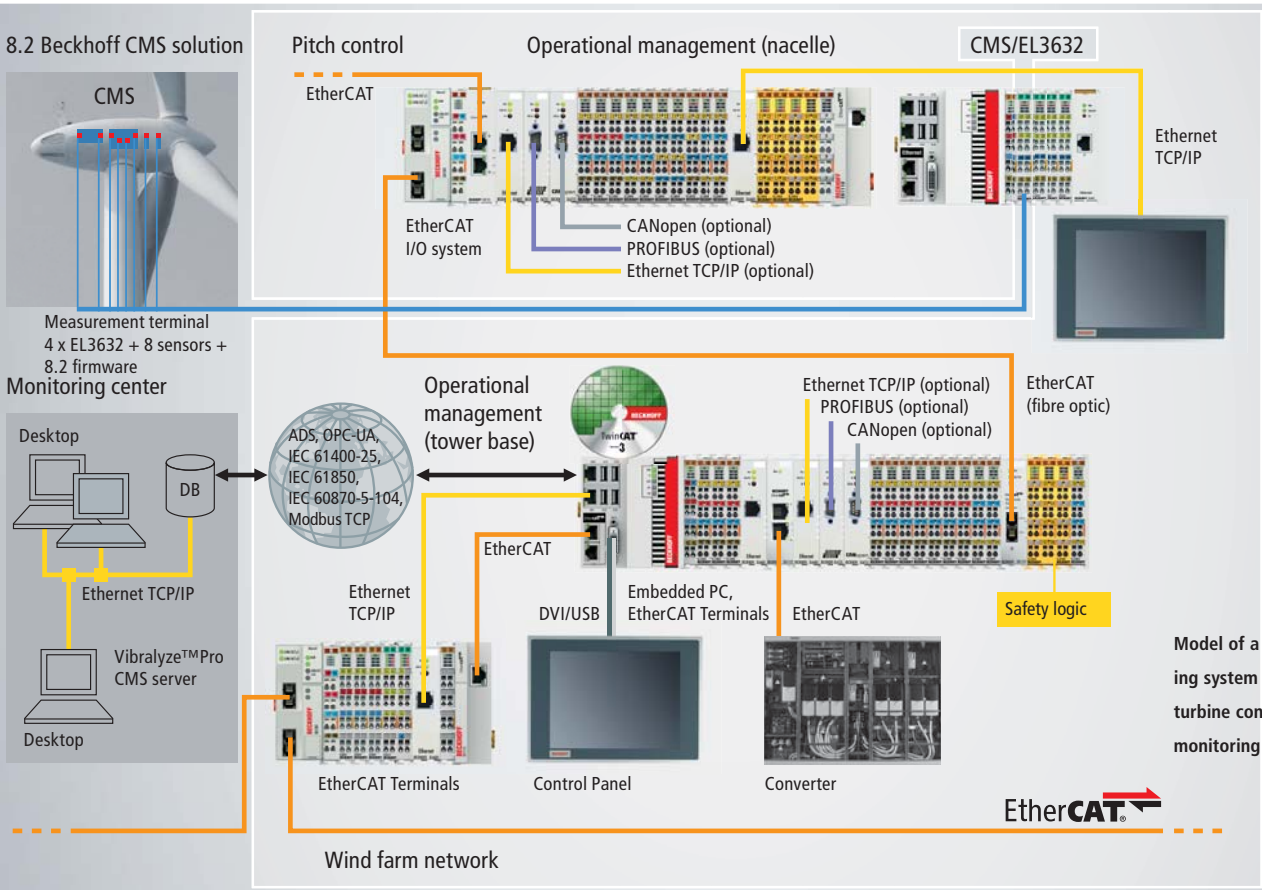
With EtherCAT, a communication system is available for the high-performance relaying of the recorded status data to the PC controller.

In contrast to other CMS providers, which offer complete CM systems with their own hardware and software, 8.2 Monitoring, based in Hamburg, Germany specializes in supporting controller manufacturers. In general controller manufacturers typical have neither the specialized knowledge for developing application-oriented analysis and data management software for larger wind farms, nor do they wish to offer a data analysis services. However, CMS hardware doesn't sell without analysis software and services. To solve this, 8.2 Monitoring offers control manufacturers the firmware, the analysis software and its expertise. With the VibraLyze™Pro solution, the company has developed a user-friendly, industry-specific software platform for generating data, quality assessment and data analysis.

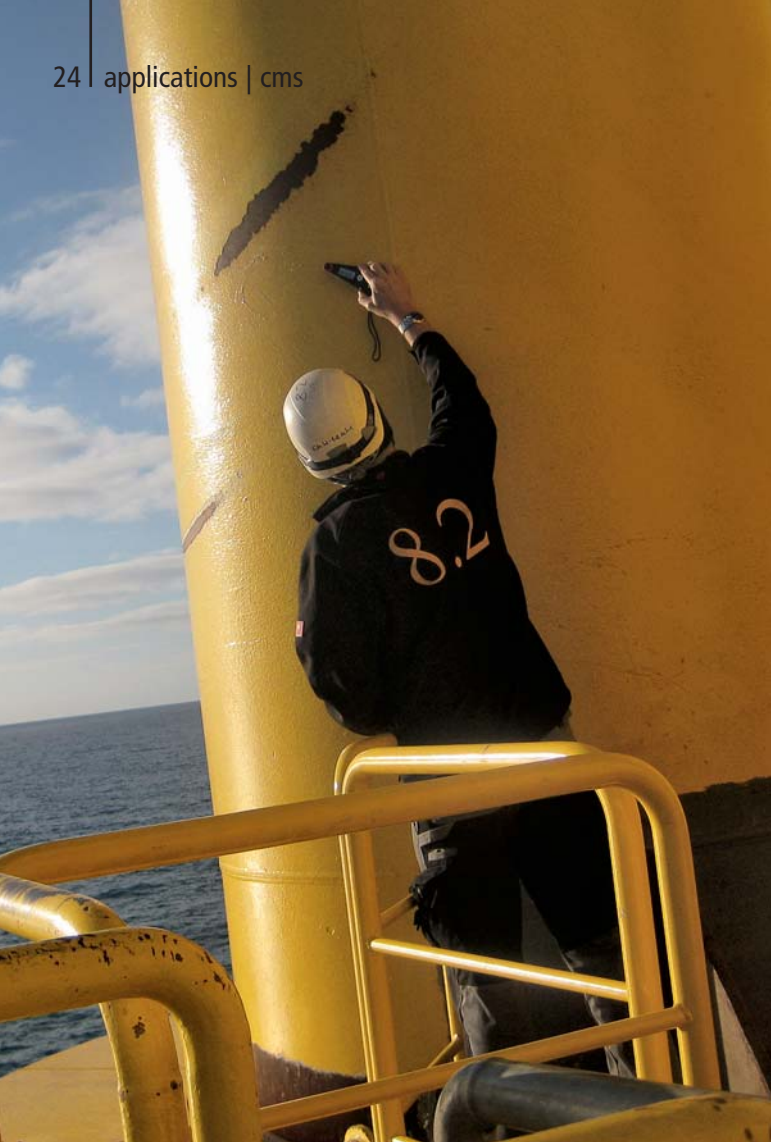
Controller-integrated CMS is "more intelligent"

Anyone dealing with CMS today knows that false warnings and false alarms happen on a regular basis. This is due to the fact that today's standard Condition Monitoring systems essentially still operate in stand-alone mode, i.e. independent of the wind turbine controller. In many cases, particularly in retrofitted systems, the conclusion as to whether an unusual state has occurred is purely based on the speed at which the turbine rotates. In some cases the actual output is used as a supplementary parameter.

However, anyone who has ever been inside a nacelle while the turbine was running will know that there is plenty more that happens up there: continuous acceleration and deceleration, continuous opening and closing of the yaw brake, continuous yawing and pitching of the blades, activation and deactivation of the coolers and interconnections, repeated grid instability, passing through resonances and much more. All this information is unknown to standard CM systems. The only way forward, therefore, is to measure the interference affecting the oscillatory characteristics. The vibration values from external influences and the vibrations of the machine components are then added in order to arrive at a cumulative background noise and an alarm is issued, as appropriate. The situ-



Model of a Condition Monitoring system integrated in a wind turbine controller for component monitoring



ation is similar to a car travelling at 50 or 60 miles per hour on a country road: The driver is used to a certain road noise. Suddenly the road surface changes from concrete to asphalt or vice versa, or potholes appear. Based on experience the driver makes a connection between the change in the road condition and the noise and knows that there is no reason to worry. The alarm bells only start ringing when abnormal noise patterns occur, such as from a burst tire or damaged wheel bearing. Keeping these analogies in mind, it is easy to see that standard CM systems, which don't receive additional information from the controller regarding the external influences under which the machine is currently operating, are prone to issuing false warnings and false alarms.

This is where controller-integrated CM systems come in: Signals provided by the central controller via a direct fieldbus connection can help filter out interference signals, so that the CMS can ignore noise relating to yawing or pitching, activation of auxiliary systems or sub-normal oil temperatures.

"This results in much better raw data quality, which in turn leads to reduced scatter and more uniform trends, so that limit values can be set more precisely and early detection can be improved."

Suitable algorithms in the CPU which log the local data can be used to assess the quality of the stored raw data. At the end of the day (or at a defined time interval) an optimized dataset is available for each defined output class, which is then transferred to the monitoring center via the existing communications infrastructure, where various analyses are performed. In the event of anomalies the affected components and errors are reported.

Hardware-independent and open

8.2 Monitoring has developed the VibraLyze™Pro software, which is based on experience from monitoring customer installations via CMS and on data obtained and analyzed by 8.2 Monitoring during warranty examinations. The company has been looking after a wide range of CMS solutions for years, knows the good and the less than ideal aspects of the respective software packages, and has a clear vision of what an optimum solution should look like in order to service many hundred CM systems cost-effectively. Today, 8.2 Monitoring is able to read in CMS data from virtually any standard system and analyze them under an integrated software interface. In addition, VibraLyze™Pro is currently the only software platform in the market that is also able to service the different controller-integrated CM systems.

Automatic calculation of all monitoring frequencies and characteristic values

8.2 Monitoring also wrote the firmware for logging the data of the CMS hardware components that were developed by Beckhoff. The software not only offers a high degree of automation and integrated fault pattern recognition, but also efficient setup and parameterization. All measurement-related parameters such as sampling rates, measuring intervals and filter settings are set automatically. Inputs are essentially limited to gearing and bearing data and general system data. All monitoring frequencies and characteristic values are calculated automatically. Once a turbine has been set up, a wind farm with a hundred turbines can be configured in just a few seconds. Self-monitoring functions and reporting tools provide operational support. In addition, all signals can be integrated directly or as results of subsystems. This provides the following benefits:

- Data from different CM systems can by analyzed efficiently and cost-effectively with an integrated software interface.
- Operators with a mixed equipment portfolio who want to establish CMS expertise can analyze their data independent of system manufacturers. The software is sold on a license-only basis or with a service package. This is of particular interest during the warranty period. In many cases, documentation of the system state with the aid of CMS data is an important factor for validating claims to system manufacturers.
- System manufacturers using different control systems, which is quite a common scenario in China, become independent of the CMS hardware. They can use hardware from different control equipment suppliers and monitor it with integrated software, which minimizes the need for training and facilitates the buildup of expertise.

China focuses on CMS

While in Germany it took more than 10 years for CMS to become more or less accepted, China is a step ahead in this regard. In November 2011 the government approved a quality offensive, which also included a CMS specification. For Chinese offshore systems CMS is obligatory, just like in Germany. Onshore systems are required to have CMS if the capacity exceeds 2 MW. However, unlike in Germany, this Chinese provision was not driven by insurance companies. The

reason was the ongoing issues power supply companies and system operators have with wind farm availability. It remains to be seen how the policy will be implemented.

A special characteristic of the Chinese market is that system manufacturers tend to have not a single control equipment supplier, but usually two or three. The 8.2 software solution enables them to buy their CMS hardware from different manufacturers and operate it under an integrated software interface. The 8.2/ Beckhoff CMS solution can be retrofitted as a "standard" CMS on any system.

In June 2012 the Chinese system manufacturer Zhejiang Windey commissioned 8.2 Monitoring to equip 66 wind turbines of the 1.5 MW class with Condition Monitoring systems. The "Danjinhe Project" and "Delinha Project" wind farms, each featuring 33 turbines, were equipped with CMS software from 8.2 Monitoring and hardware components from Beckhoff. The system monitors the drivetrain, including the main bearings, gear unit and the generator. The order from Zhejiang Windey wasn't 8.2 Monitoring's the first project in China: At the end of 2010 the first Chinese offshore wind farm was equipped with the VibraLyze™Pro CMS software. In addition, the Chinese manufacturer Guodian United Power commissioned a pilot installation in March 2012.

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Further Information:
8.2 Monitoring GmbH: www.8p2.de/en

Overview of the benefits of controller-integrated Condition Monitoring systems:

Cost benefits:

- lower hardware costs thanks to industrial mass production and fewer components
- lower installation and cabling costs thanks to integration in existing control cabinet and communication with the main controller via bus system
- fewer required parts, since no additional voltage transformers, communication modules, UPS or similar are required
- reduced analysis efforts since fewer false alarms occur

Technical benefits:

- no measurement if interference signals are present
- better raw data quality for the analysis
- fewer false alarms
- reduced scatter leads to improved fault detection
- integration of further signals (temperature, pressure, current) enables integrated signal/system monitoring.

Quality benefits:

- reliable hardware from established industrial suppliers
- mass production with high quality standards