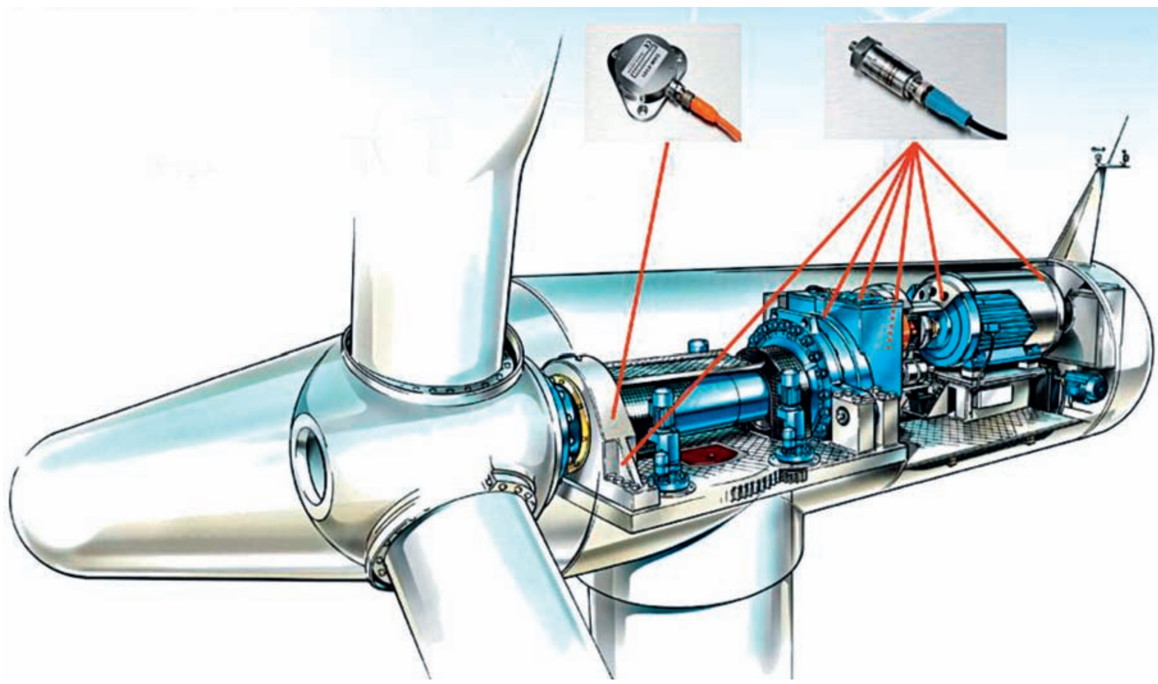
Assessing the future of condition monitoring

Condition monitoring sytems are undoubtedly going to have an increasing part to play in wind-farm operations and maintenance management. But the extent to which it is rolled out across the industry will be largely, as always, dependent on cost. Mark Anderson reports



Under the bonnet
The position of turbine condition monitoring sensors in a Siemens turbine

Few argue against the concept of condition monitoring systems (CMS), which aim to predict and limit turbine breakdowns before they become wildly expensive catastrophic events.

Yet while many experts see an increasing likelihood of CMS coming as standard on new wind farms in coming years, the issue is complicated by differing theories regarding how the technology will roll out en masse and whether it will ever be extensively retrofitted onto thousands of turbines that are out of warranty but expected to last another decade or more.

Central to the debate are questions regarding which CMS methods best suit the wind industry, who should control the ocean of information the systems emit and whether the technology can live up to its potential as a value-enhancing necessity.

But perhaps the biggest immediate question involves who will bear the cost, which can range anywhere from $3,000-20,000 or more for each machine plus a significant fee for collecting, storing and interpreting the daunting blast of round-the-clock data.

The US Department of Energy's National Renewable Energy Laboratory (NREL) is looking at a variety of CMS alternatives as part of an ongoing gearbox reliability collaborative project at its campus in Golden, Colorado. In addition to testing different brands and formats along with the optimum number and placement of sensors, NREL will attempt to determine whether costs can be cut by using the equipment on a selection of a wind farm's turbines.

NREL senior engineer Shawn Sheng says that what is needed is a way to calculate the point at which CMS becomes cost-effective from the owner-operator's point of view. "If we had a tool to establish that point, it would be beneficial to the industry," he says. "But there is still a long way to go."

In other words, the CMS market represents a wide-open playing field where clear answers are slow to emerge. And while most well-established industries including traditional power plants, paper mills and a gamut of factories have long included CMS, the wind

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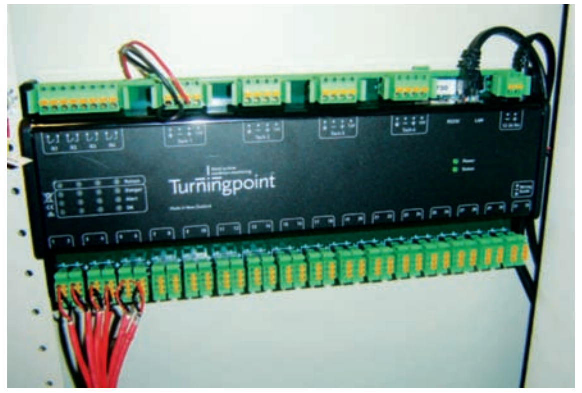

Special equipment Vibration CMS from Turningpoint

industry has dragged its feet for a variety of reasons. These include the complicated nature of wind turbines, the remoteness of their installations and the random nature of the industry's renegade early years.

Applied to turbines, CMS typically takes the form of vibration sensors attached to key locations on major moving parts and a real-time gearbox oil-debris monitor that reports irregularities — or a combination of the two.

The nerve centre

Equipment is typically tied into the computerised supervisory-control and data-acquisition (Scada) systems that accompany all modern wind turbines and provide basic operating information of their own then send comprehensive readouts to remote databases, which apply algorithms that examine the signals and flag potential problems for technicians to interpret.

Ultimately, maintenance workers are deployed for hands-on action as deemed necessary – ideally long before a major failure occurs. The goal is to improve turbine performance and limit outages by confining the majority of repairs to straightforward up-tower fixes, as opposed to costly down-tower emergency surgery requiring extended shutdowns, along with costly crane callouts involving outlays of $50,000-400,000 or more.

Many experts suggest that less than 10% of the US fleet employs CMS. The percentage is thought to be higher in Europe – especially in Germany, where insurance requirements promote more widespread use.

In China and other emerging markets where labour costs are low and equipment represents the bulk of capital costs, CMS has been slow to catch on as turbine prices are low. Owners opt instead to send workers up-tower to provide regular preventative maintenance and retrieve oil samples for laboratory inspection, which is a time-consuming old-school method that can reveal metal debris and foretell impending problems.

Yet all top-tier original equipment manufacturers (OEMs) currently provide some form of modern condition monitoring either as an add-on option or, increasingly, as standard equipment. Gearbox manufacturers and third-party players offer myriad factory and after-market alternatives, some exploring acoustic monitoring instead of vibration. The technology is constantly evolving and the best solution has not yet been found.

Siemens is at the forefront of factory-installed technology and its 2.3MW turbines have included CMS as standard equipment in the Americas for more than half a decade and even longer in other markets. Typically, customers purchase a service agreement of two to eight years, which provides constant monitoring where data readouts for individual turbines can be compared with a pool of stored information referencing thousands of the company's 2.3MW machines installed around the world. After the initial agreement expires, Siemens offers a menu of options for extended monitoring that can cover the expected turbine lifespan of 20-plus years.

Through condition monitoring, Siemens is more than 99% accurate in detecting gearbox failures before they occur, according to Anthony Renda, the company's head of service technologies for the Americas. "Whatever the scenarios are, you've seen them somewhere else on the globe and you can apply your knowledge to preemptively get in front of a problem," he says.

Controlling vibration

Siemens' system includes thousands of alarm codes derived from independent systems networked together. Vibration monitors are applied to the gearbox, generator and main shaft. Although no monitors inhabit the blades, the main shaft's sensor provides enough information to give advance warnings of ice, lightning strikes, cracks and other abnormal blade conditions.

"But it's not just vibration," says Renda. "There are many integrated systems that talk to one another and give a picture that shows perhaps there's something going on. So the customer has a real-time view of the health of his system based on a number of flags, and we're in the background with a much more detailed view."

One Siemens customer, US utility firm Puget Sound Energy (PSE), is about to employ CMS on 149 Siemens 2.3MW machines at its Lower Snake River project in Washington state, expected online next year. PSE has worked primarily with Vestas equipment on past projects, installing turbines without CMS before the technology was in vogue.

"I don't think, if we were going to build a new project, that we would buy equipment without condition monitoring," says Chris Walford, consulting engineer for PSE. "Our philosophy is that we'll own our equipment for a long time and we want to keep it in the best condition possible."

Still, PSE hasn't rushed to retrofit CMS on more than 200 turbines at its prior projects. Instead, it rotates 14 portable condition monitors among the machinery. "We're monitoring a certain percentage of those turbines at a time," Walford said. "We leapfrog the equipment around on the machines as we go and, if it really proves beneficial, then we may decide to deploy it on all of them. But we're starting this way."

Taking precautions Turbines at PSE's Lower Snake wind farm, Washington state, will be installed with CMS

Others report similar caution regarding retrofit CMS, expressing the notion that requesting additional money for existing projects is a tough sell to upper management, which is typically locked into a 20-year balance sheet derived from an upfront power purchase agreement — payback from CMS is not that easy to prove.

Horizon Wind Energy, a US subsidiary of EDP Renewables, has developed more than 3.6GW of North American wind power and expects to see widespread adoption of CMS coming mainly from factory-installed systems. According to Tim Hertel, the company's director of technology, about 15% of Horizon's US fleet is equipped with condition monitoring hardware. "That's primarily machines built in the past two years," he explains. "It's very hard to retrofit existing machines unless you have a turbine platform that has specific and very serious problems that warrant it."

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THE CMS TOOLBOX WHAT CAN BE MEASURED BY CONDITION MONITORING SYSTEMS, BY EIZE DE VRIES

Wind turbine loads

What it can monitor Main components — blades, nacelle, tower, foundations.

How it works Strain gauges or other sensors applied at or integrated into main components; records actual loads, load changes and load patterns; sends real-time data to wind-turbine Scada system and/or control system and off-site computers.

Installation Emerging and likely growing trend for factory installation, following a similar pattern to the automotive industry — both aimed at enabling increasingly advanced monitoring and control strategies.

Advantages Growing need for (real-time) loads data fed into the turbine's control system; can be combined with output control; example load-detection system in Enercon E-101 rotor blades limits output when loads exceed maximum design value; such optimising control measures can enhance turbine operational lifetime as well as optimising its design.

Disadvantages Adds system complexity and thus costs.

Drive system monitoring

What it usually monitors Main bearings, gearboxes, generators

How it works Sensors applied near moving parts detect changes in vibration patterns, sending real-time data to wind-turbine Scada system and off-site computers; temperature and acoustic sensors can provide additional real-time data on actual values, set against historic reference values and changes on a time scale.

Installation Vibration sensors are increasingly factory installed but can also be added after construction by the OEM or independent supplier. For accurate results, it is essential to take a representative initial condition reference measurement, following installation or after a certain running-in period.

Advantages Through early detection, problems can be pinpointed before causing expensive catastrophic failure to a specific bearing, gear or other component.

Disadvantages Risk of overabundant information supply that can easily be misinterpreted if no high-level matching statistical analysis and interpretation capacity is available from OEMs and/or independent service providers.

Gearbox oil condition monitoring

What it usually monitors Oil condition; water saturation; viscosity; temperature; relative dielectricity and particle counting. Normal laser-counting systems to industry standards. Counts metal particles, air and water bubble contamination, which could affect results, conclusions and potential remedying actions.

How it works Periodic time- and/or operating hours-related up-tower oil sampling and analysis; real-time oil condition, particle counting and analysis/processing. It is essential to always take the oil sample from the same standardised location.

Installation Particle counting equipment increasingly factory installed, but can also be added later by OEMs, independent suppliers or service providers.

Advantages Oil sample analysis can be employed for oil-quality monitoring and for determining remaining time until the next oil change; metal particle counting in oil samples is an accepted and useful early-detection method for preventing costly future gearbox failures; supplements CMS. Oil-filter content analysis may be considered as an addition or alternative to oil-particle counting.

Disadvantages Sampling equipment, methods and quality still lack uniformity.

Supervisory Control and Data Acquisition (Scada)

Scada systems are considered a vital wind turbine/farm nerve centre. In wind-farm configurations it connects individual turbines and eventual meteorological masts via servers and a PC to a central OEM control centre. The Scada computer communicates with individual turbines via an optical-fibre based network and Scada systems are usually original OEM equipment. Scada systems accumulate historic and present data of individual turbines and at wind-farm level on a monthly, weekly and daily level.

A computer screen in individual turbines can display a wide variety of individual and processed data, including actual wind speed and power output, corresponding rotor-blade pitch angles, etc. In addition, various actual and historic component or system operating temperatures at individual turbine or wind-farm level can be displayed, as well as detected faults, types of stoppage and linkages between variables such as nacelle temperature versus power output.

Finally, at wind-farm level Scada systems show individual turbine and wind-farm output, turbines in service mode, or energy yield, and availability during the past day, week, month or year.

Other advanced control options include wind-farm output and active wind-farm voltage regulation.

Hertel's casual cost-benefit analysis underscores the overall uncertainty. "A $5,000 system that detects 50% of the failures may actually be a more attractive proposition to us than a $20,000 system that detects 80% of the failures," Hertel said. "Even though it's detecting more failures, the cost of detection is so much higher that maybe it's not worth it."

Cautious approach

He also warns of the need to use caution when assessing expected savings from CMS. "If someone detects shavings in the oil and it ends up they have to replace the gearbox, well, they didn't save $300,000," adds Hertel. "They still had to replace the gearbox. Maybe it can be refurbished and there's some savings there. But you have to be very careful with the way companies are saying how much money they're saving from condition monitoring."

One strong proponent of retrofitting CMS onto ageing turbines is David Clark, director at Bachmann Monitoring, a subdivision of Austria's Bachmann Electronic, a leader in wind-turbine controller systems. Clark points to statistics that suggest 70% of the US fleet's turbines are coming out of warranty within the next two years, meaning repair costs will transfer to owners.

"When they have to start paying for their own repairs and gearboxes, there's going to be a mass implementation of condition monitoring," he says. "These turbines are not going to run better in the next 18 years out of warranty than they did in the two years under warranty."

Clark believes CMS pays for itself and he craves an opportunity to install it on half of anyone's large wind farm to prove the point. "Run them as two independent sites and tell me which one is more profitable," he says. "I would do that for free with the caveat that they'd pay me a percentage of the money they save on the side that has condition monitoring. I could retire."

Clark further contends that factory-installed CMS is not the best answer for the industry because it allows OEMs to control data and hide flawed equipment. But Horizon's Hertel argues that buyers need to negotiate access to data when contracts with OEMs are signed. "We're very careful with our agreements and how we structure the purchase of condition monitoring," he says. "There's no doubt in our contracts that we have full access to the information for our own use, in addition to the analysis that's being done by the OEM."

One area seemingly beyond debate is the offshore market, where extreme costs attached to working on the high seas are ideally suited to CMS. The technology is generally required for certification in European waters – and likely to be commonplace by the time the US begins installing turbines offshore. W