Wind Turbine Control Systems

Exploring the capabilities of the latest systems, and the drivers and challenges for further development.

Written and published by Wind Power Monthly 2014
Sponsored by Mita-Teknik

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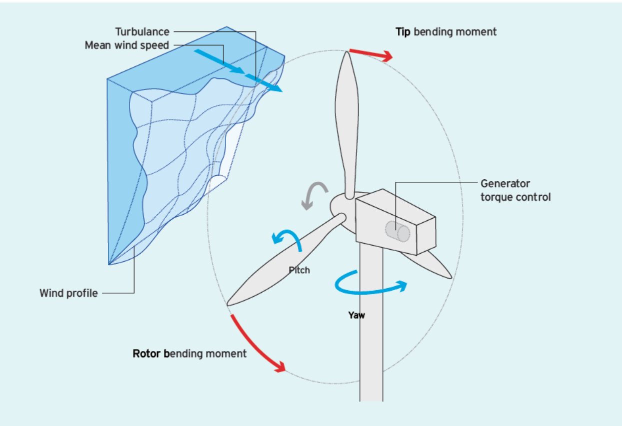
Exploring the innovations, challenges and future potential of the systems that ensure real-time reliable, efficient and safe functioning of wind turbines.

Wind Turbine Control Systems

The first wind turbine control systems were relatively simple. Used on stall-pitch, fixed-speed turbines, little more was required of them than starting the blades, stopping them and turning the nacelle into the wind. Turbines used today for commercial-scale wind farms are variable-speed, variable pitch and are considerably larger than those seen in the industry's early days. The control systems have also grown much more complex as wind turbines themselves have evolved. As a trend towards larger rotors and higher megawatt ratings continues, and pressure to drive down the cost of energy gives no sign of easing, further advances in control systems will be critical.

Control systems are essential for the reliable, efficient and safe functioning of wind turbines. They are fitted with sensors that gather data on wind conditions, power generation, vibration, lubricants, rotor and generator speed and other parameters, which are then sent for analysis to a computer.



Key Forces and Controls
Control system monitor and respond to changing forces, optimizing performance.

Algorithms – which are closely guarded business secrets of the control-system manufacturers and are updated through software upgrades – are used to tell components known as actuators how to respond to that input in real time, perhaps putting in a request to change the pitch angle of a blade or setting off a braking system when the wind is blowing too strongly. Information updates are sent several times a second.

Market Demand

Turbine control systems are seen as an important contributor to lowering the cost of energy, a drive that has been gaining momentum as subsidies are rolled back and higher-cost offshore wind develops. Reducing the cost of energy is partially a function of maximizing power production (and revenue) over the lifetime of a turbine, something that turbine control systems can do by altering the pitch of the blade and maximizing wind capture. It also involves balancing performance with technology investments and other production costs, including the wear and tear on the turbine.

Insight garnered from the turbine control system is critical to understanding whether an individual turbine is performing at its best. Turbine owners are looking for control systems that are easy to use and include diagnostics and troubleshooting characteristics that allow those in the field to understand the reasons for eventual problems and fix them quickly. They are also looking for flexibility. Turbine manufacturer GE is receiving a growing number of requests from customers seeking increased control-system functions that take into account site-specific characteristics or requirements such as wildlife mitigation.

Grid operators are also putting greater demands on turbine control systems to guarantee the grid operates safely and efficiently, ensuring that the power generated from wind farms has the correct frequency and voltage, particularly as wind power begins to represent a significant portion of power production in some countries. These requirements must all be satisfied.

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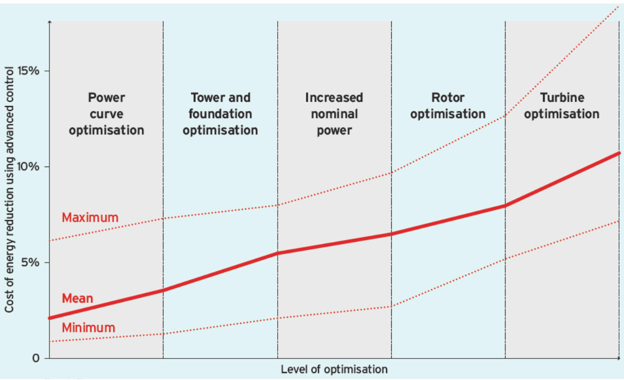
And while ensuring safety has always been a key task of control systems, the fact that turbines installed offshore are immense, and set to get even larger, means that safety will most certainly remain a key driver for market demand.



Cutting the Cost of Energy
Using the control system to increase optimization can cut costs significantly.

Source: Mita-Teknik

Recent Developments

In the last twelve months, the market has focused on wind-turbine optimization possibly more intensely than ever before, with control systems a key part of this process. Competition among control system suppliers has increased, as have the requirements that wind turbines must satisfy. Optimization often involves marrying control-system improvements with other changes to the turbine, according to Mita-Teknik.

When it comes to control systems for individual wind turbines, load control has been the clear focus of engineers' recent efforts. Reducing fatigue loads and mitigating extreme loads can help reduce damage to components and lengthen a turbine's lifetime. Money can be saved by catering for lower load levels on a turbine.

It is therefore increasingly important to use load-analysis data to optimize the design elements of the turbine and the control system.

More recent additions to capabilities, such as individual blade pitch control, are an increasingly common offering by control-system providers. With large blades often encountering substantial wind-speed differences and structural loads from top to bottom positions, individual pitch control is now seen as a key method for better managing and balancing these asymmetries.

The technology for individual pitch control has moved past the first-generation stage, although there are still barriers to their widespread use by turbine manufacturers, who are concerned about strains on actuators, according to Bill Leithead, director of the industrial control centre at the University of Strathclyde in the UK. As turbine sizes continue to increase, however, and the load reduction benefits increase, a tipping point will be reached, at which it will make economic sense for this technology to become a standard offering, Leithead believes.

One development now standard on newer turbines that users cite as beneficial is the ability for individual turbines to de-rate – or operate below nominal rated capacity – when a temperature limit is reached or exceeded inside the turbine. Now, for example, a turbine with 2MW rated capacity may operate at 1MW until the problem is resolved and the machine can resume operating normally. In the past, this situation would have caused the turbine to shut down completely, with a greater loss of power output.

Another area in which progress has been made is in allowing wind turbines to continue operations even in adverse, high-speed winds of around 25 metres a second. This is an improvement on previous systems that would have required the turbine shut down for safety reasons. Enercon, for example, is one manufacturer known for its "storm control" feature, part of the control system.

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Improvements for Older Models

While the most advanced control systems are found on new turbines, there is also robust demand for system upgrades for older machines. Wind farm owner Enel Green Power routinely upgrades software improvements made available by turbine manufacturers. The company has around 4,000 turbines, of which a fair share are older than five years.

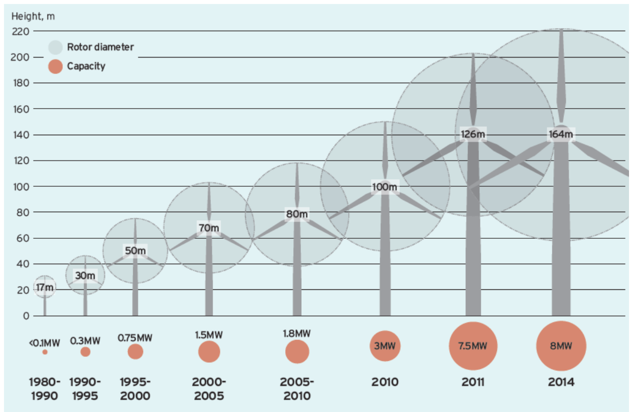
Depending on site conditions, this exercise can result in an annual increase in power output over the lifetime of the turbine in the order of 1% to 5%, according to Santiago Rubira Dominguez, head of operations and maintenance, before any control system or turbine hardware adjustments are made.

The best way to lower the cost of energy, however, is by introducing new algorithm designs and other advanced control features during the turbine design stage. By integrating the design of the control system more closely with the turbine, the cost of energy can be reduced by as much as 10%, according to some control system providers.

Reliability Issues

Given the complexity of turbine control systems and the number of parts involved, it is not surprising that they are not fail proof. Indeed, some industry commentators say that reliability is the biggest challenge facing turbine control systems. This criticism is often followed up with a request for the wind industry to better pool resources to understand the reasons for failures.

Reliable systems are constructed through feedback, they argue.



Turbine Growth
The bigger the turbine, the greater the importance of load reduction.

Availability, one measure of how reliable a turbine is, has improved on an industry-wide basis, and control systems can move this further along again, believes manufacturer GE's engineering leader for electrical and controls, Minesh Shah. Modern control systems can increasingly explore de-rating strategies that allow production of a turbine, and, believes Shah, greater opportunities are available through improvements in the control-systems hardware to reduce failures from electronics and sensors.

In addition to robust hardware, one important component of reliability lies in how a control system is programmed. This may prompt a trend away from commercial operating systems and software applications, which may be more fragile, and towards industrial products.

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Technology Forecast

Going forward, the general consensus is that one key area for the advancement of control systems technology will be in the field of sensors, which feature throughout the turbine, feeding information through to the control system. For example, better sensors are needed to handle the loads that will accompany larger rotors and megawatt ratings and allow wind-farm operators to take a more proactive approach to operating a turbine.

Remote-sensing devices such as lidar (light detection and ranging) and sodar (sound detection and ranging) continue to be costly but, as prices drop, are increasingly seen as becoming viable technologies. With turbine-mounted lidar sensors, for example, it is believed that it can be possible to reduce the load quite radically, by as much as 15-20%.

Researchers are also looking at control-system features that move away from pitch control. One possibility being studied is that of positioning smallish-sized individual flaps, not dissimilar to those found on aircraft wings, on the trailing edge of the blades as a means for load mitigation.

To continue on the path of cost reduction, sensors, algorithms and actuators – which can be seen as the eyes and ears, the brain, and the arms and legs of the turbine's control system – must all evolve. Developments in one area may very well lead to progress in others, believe some industry experts. As new and better information is provided by sensors, that can up opportunities to better manage algorithms. Actuators with a faster response speed can help to better manage the delicate balancing act between performance and load.

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A selection of Control Systems on the Market

Company	Lead Control Product	Key Features
AMSC	wtECS Electrical Control Systems	Control systems feature AMSC's proprietary PowerModule power converters
Bachmann electronic	M1 controller, automation system	Include ColdClimate modules for applications in demanding climactic conditions, grid measuring module that can be integrated into controller system
Beckhoff Automation	Control technology	PC- and EtherCAT-based control technology is characterised by variety of hardware and software interfaces
DEIF Wind Power Technology	AWC500 controller	Software technology relies on opensource Linux, PLC Link feature supports control strategy development
kk-electronic	C System	Modular software allows for differentiation of wind turbine
Mita-Teknik	WP4200 control system platform	Onboard condition monitoring system, grid quality analyser, well-suited for individual pitch control
Moog	Pitch control systems	Features include TÜV-certified Moog Pitch Servo Drive feathering control for blades
SSB Wind Systems	Pitch control systems	Proprietary UniFlex Pitch system, which can be used in roughly 85% of all wind turbines, independent of manufacturer