Retrofit and production solution extends wind turbine (WT) service life

# PC-based control, paired with sensor and wind power expertise, optimizes wind turbines' service life

In a landmark achievement, the global installed capacity for wind energy generation surpassed 650 GW in the middle of 2020. However, operating wind turbines successfully over the longer term involves a significant challenge: During the next five years, more than one-third of turbines installed in Germany, Denmark and Spain will reach the end of their intended service lives. In light of this, solutions capable of optimizing wind turbines and prolonging their useful life – like a retrofit for pitch control systems, complete with rotor blade condition monitoring, co-developed by the companies fos4X and aerodyn – offer an important way forward.

Munich-based fos4X GmbH, founded in 2010, is an established industry player specializing in the use of data-driven approaches, including machine learning, to digitalize and optimize new and existing turbine systems. Its smart solutions, based on robust fiber-optic rotor-blade sensor technology, are deployed in today's best-performing, latest-generation turbine systems. Aerodyn Energiesysteme GmbH, headquartered in Rendsburg, Germany, is an engineering firm that develops wind turbine (WT) systems and rotor blades, provides WT redesign and optimization services, and licenses its turbine designs to third parties. The company's portfolio is based on its modular aeroMaster technology – a three-blade design with electrically powered pitch control and a variable-speed generator/converter system.

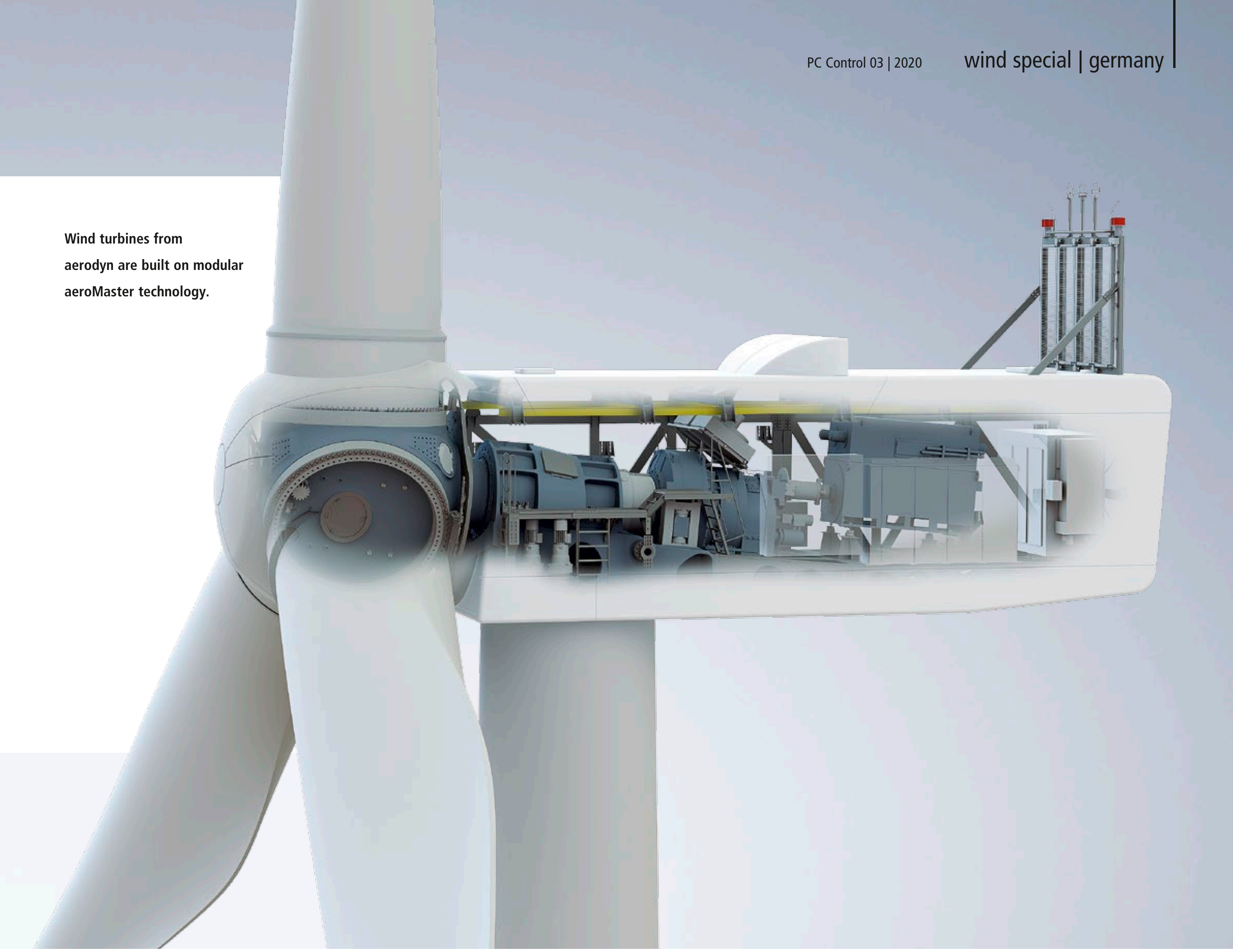
**End-of-life solutions for maximum plant efficiency**

End-of-life solutions are helping to extend wind turbines' service life while at the same time significantly increasing overall energy yields. Particularly at sites where regulatory constraints mean repowering is not an option, prolonging generating units' service life is sometimes the only way to preserve a wind farm. Extending turbines' useful life can also boost the financial appeal of wind power projects as well as bring down energy generation costs. This is underscored by the following figures for repairs and outages, and their financial impacts:

- Rotor blade faults account for around 7% of all wind turbine malfunctions. Repairs can be time-consuming, resulting in outages lasting several weeks.
- Experience in the field has shown that wind turbine components are likely to fail before they reach the end of their projected service life, which means that an appropriate repair budget generally needs to be set aside.
- Over a 10-year period, 2% of wind turbines, on average, needed to have their blades completely replaced. The ability to monitor the structural condition of rotor blades is therefore becoming increasingly important – not least because the blades' acquisition cost accounts for 15% – 20% of the total costs of a turbine system.

Ultimately, the key consideration here is what kind of financial benefit a project to extend a turbine's service life can deliver. One way to prolong the latter beyond a turbine's design life is to reduce the load on the main components, thus extending the relative service life without affecting the yield. For instance, a 10% reduction in damage-equivalent load at the rotor blade root results in a 50% longer service life. So if a system receives a retrofit in its tenth operating year that achieves such a reduction, its service life is extended by five years.

Comprehensive load monitoring gives wind farm operators consistent visibility into the impacts of discrete events on rotor blade service life. The same



Wind turbines from aerodyn are built on modular aeroMaster technology.

indicators can serve as metrics for understanding differences in behavior between individual turbines within one and the same wind farm, enabling operators to identify wake effects (caused by wake currents in slipstreams) in turbines with higher levels of fatigue, as well as damage caused by tracking fluctuations in rotor blades' natural frequencies, and yaw and pitch errors due to uneven rotor loading.

**A solution built on combined expertise**

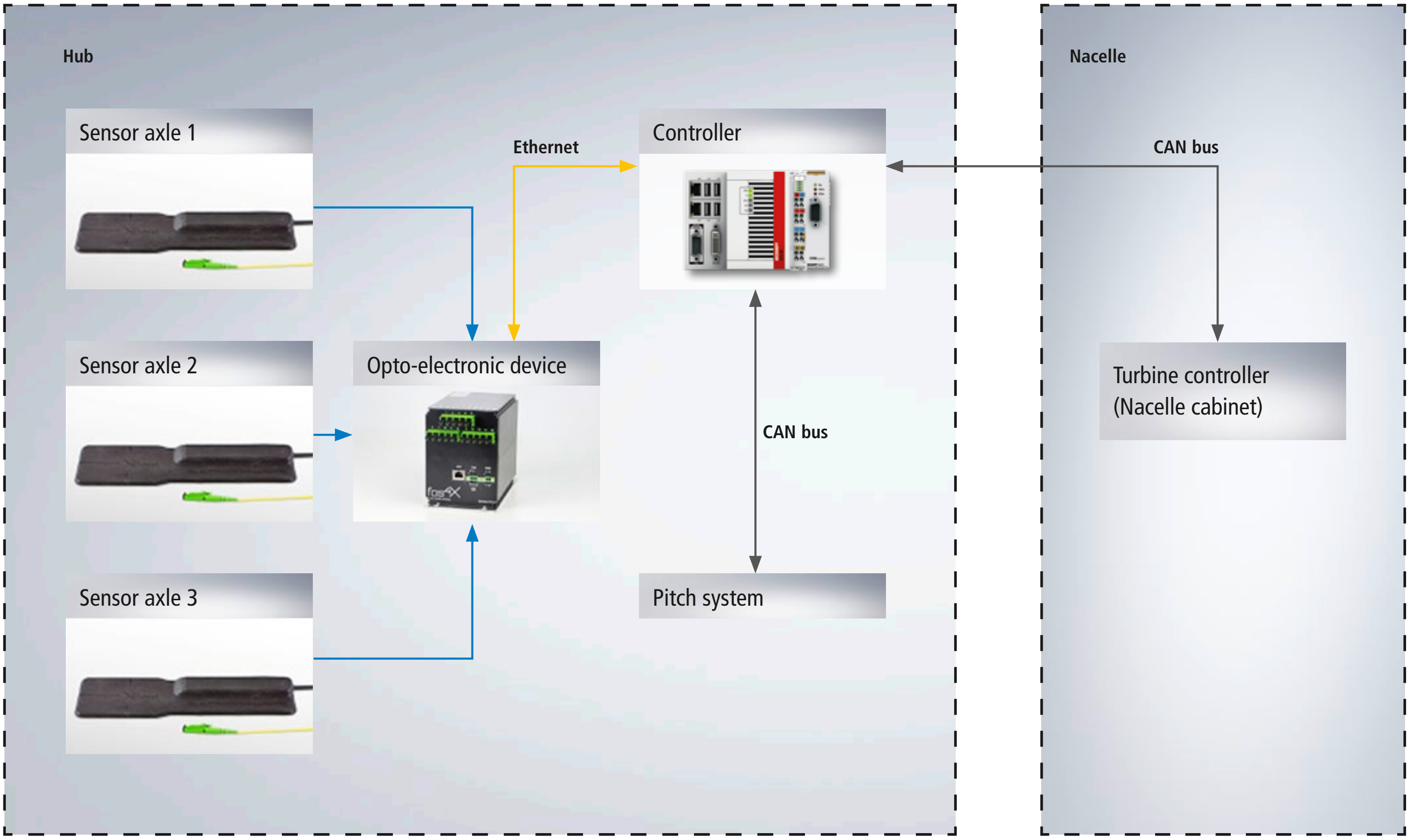
Solutions from fos4X bring down wind turbines' energy production costs by delivering the following:

– higher annual power production
– lower operating costs
– minimized operation risk
– extended service life

The focus of these solutions is on rotor blade sensors and data analytics. Says Bernd Kuhnle, Chief Sales Officer at fos4X: "In our joint solution with aerodyn, we supply the hardware platform and the streaming analytics that serve as a basis for different approaches to optimizing wind turbine operation and extending service life. The wind turbines are fitted with our field-proven sensor system, which is installed inside the rotor blades to protect it from environmental impacts. The sensors reliably deliver valuable data over the entire WT service life."

**For Bernd Kuhnle, Chief Sales Officer at fos4X, the openness of PC-based control technology is key.**

The solution is calibrated autonomously during regular system operation using algorithms developed by fos4X. Much like a digital twin, the fos4X system produces high-quality data needed in subsequent processing. The real-time data captured and generated is read out by aerodyn and used to adjust each rotor blade's angle of attack in a specially developed approach known as individual pitch control.




How the fos4X solution integrates with the turbine control system

But the system has more to offer in terms of value-add besides aerodyn's method of individual pitch control: While the basic version only measures loads, it can be augmented to generate a load history over the system's remaining service life. In addition, fos4X can detect yaw and pitch errors from the load data captured. Correcting these errors leads to a higher energy yield and reduced wear. The solution can also monitor the condition of blades to identify damage or ice build-up. These capabilities make the solution the first in the world to enable comprehensive rotor blade monitoring while at the same time delivering important data for use in digital twins and predictive maintenance.

**Implementing individual pitch control**

A variety of data needs to be captured in order to implement pitch control. This includes forces acting on the wind turbine, which are best measured directly at the rotor blades themselves. To accomplish this, fos4X installs sensors inside the turbine blades – a process that typically takes just a day to complete. Load data can then be captured continuously and fed to aerodyn's pitch control system.

The purpose-designed algorithm in the retrofit system allows each rotor blade to respond individually, in real time, to load fluctuations and to compensate for loads as they arise. This can substantially reduce the effective load borne, which has a beneficial effect on the wear and the durability of the various turbine components. Loads are managed using the aeroBalance method, which continuously computes the required angles of attack according to blade load. Timm Daunke, Load, Tower Design, aerodyn, explains in more detail: "Self-monitoring routines ensure that the loads are always reduced or, at minimum, never exceed the levels they would reach without individual pitch control. This means that the turbine doesn't need to be re-certified. Nor do the wind turbine's control parameters need to be modified. The load management process uses the unsecured bus communication between the turbine controller and the pitch system as this allows the wind turbine to automatically activate bypass modes and continue operating, even if an internal system error occurs."

**Control system with integrated condition monitoring**

For actual access to the wind turbine's control system, though, communication has to be secured. This, says Bernd Kuhnle, is where Beckhoff comes in as a strategic partner – and here, the openness of PC-based control plays a central role. With existing wind generating facilities in particular, which typically use a heterogeneous mix of components from different vendors, being able to integrate with the equipment already deployed is key. As an open platform that supports all common fieldbus standards, including EtherCAT, CANopen, PROFIBUS and PROFINET, PC-based control enables simple and flexible integration with solutions of any kind. The combination of modular hardware with the high-speed communication capabilities and flexible topology of EtherCAT means the system can adapt perfectly to the given requirements.

The solution from fos4X operates as an EtherCAT slave, so it is exceptionally simple to incorporate into a PC-based control system. However, it can integrate just as easily with any other controller, making it suitable both for retrofits to existing turbines and for installation in new turbine systems. If required, the system can also be expanded on a modular basis using Beckhoff EtherCAT Terminals – to capture strain, vibration and temperature information, for instance.

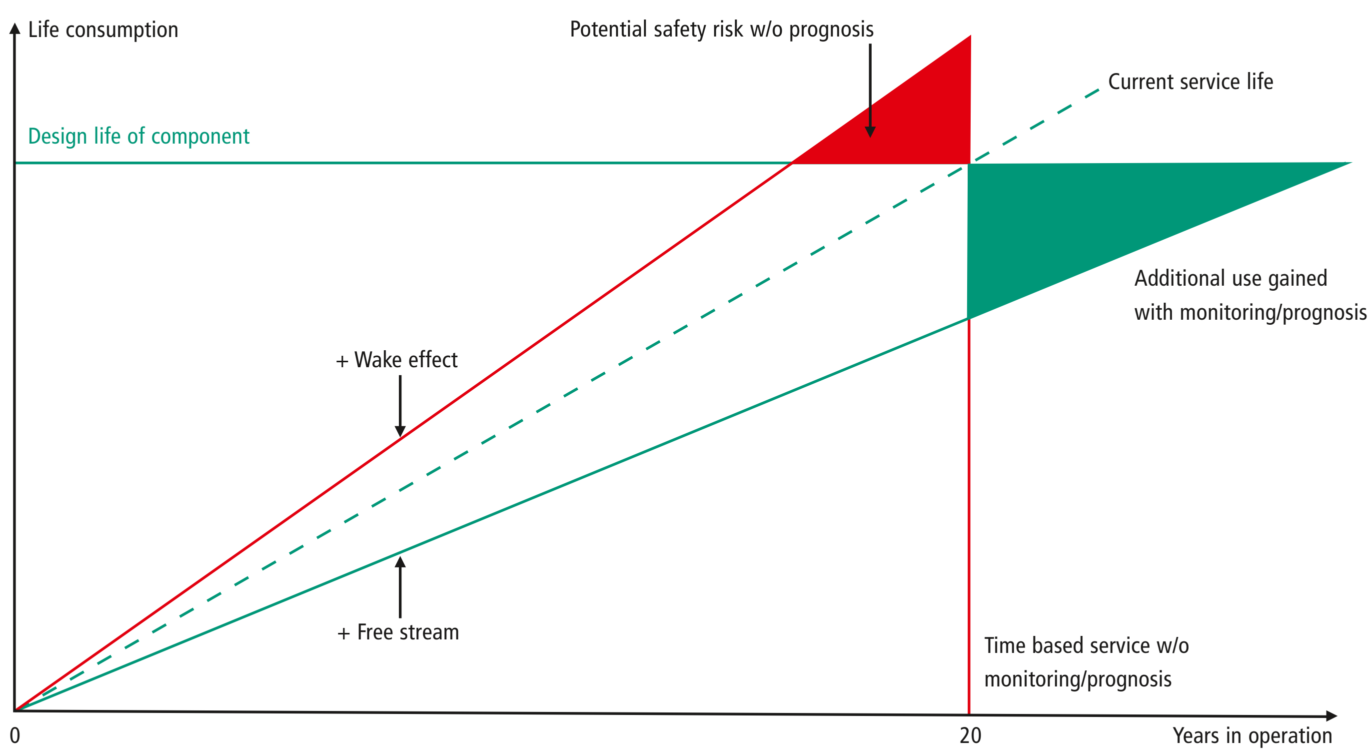
The controller developed by aerodyn is implemented as a TwinCAT TcCOM module, which means it will work on any Embedded or control cabinet PC running TwinCAT 3 software. TwinCAT also makes connecting fos4X sensors simple. Plus, by adding TwinCAT 3 functions for OPC UA, IoT and database connectivity, for instance, integration with existing SCADA systems can be accomplished with little effort.

More information:
www.aerodyn.de
www.fos4x.com/en
www.beckhoff.com/wind

## A modern aerodyn wind turbine design using TwinCAT Wind Framework

Originally implemented in an initial project in 2014, aeroMaster 5.0 from aerodyn is the first wind turbine system to use the TwinCAT 3 generation of software and the new TwinCAT Wind Framework from Beckhoff. Modular control software based on the Wind Framework perfectly matches the turbine's modular hardware, which is designed to allow the sourcing of components such as the pitch controller, converter and generator from different vendors. TwinCAT 3 Wind Framework unites control technology with industry-specific expertise in a set of encapsulated modules and an application template. The modules offer a comprehensive range of services for automating wind turbines, as well as real-time access to a full range of data, plus long-term data retention in a database. The application template provides a modular architecture designed to enable efficient, highly focused engineering and to get users off to a quick and easy start.

More information:
www.beckhoff.com/twincat-wind




**The benefits of continuous monitoring with fos4X rotor blade sensors: differences in linear service life consumption for a component's operating times (dashed line), including the potential safety risk and additional use gained, with or without monitoring.**