

# PC Control

The New Automation Technology Magazine

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Vensys: Wind turbine manufacturer propels alternative energy using Beckhoff control technology

10 | worldwide

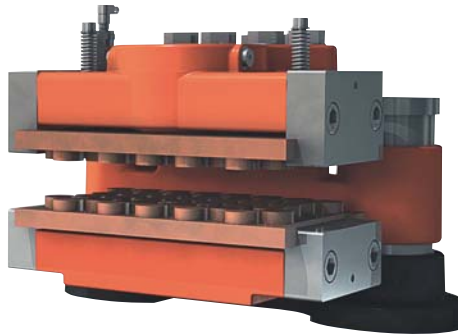
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Winwind: EtherCAT becomes the main communication system in the 3 MW wind turbine



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The New Automation Technology Magazine

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## The wind power industry is booming

**“When the wind of the change blows, some build protective walls, while the others build windmills”\***

The wind power industry has recorded considerable growth this year worldwide – a development that has significant consequences for us as a supplier of controllers to the industry. True to the Chinese proverb quoted above, the wind business has also been pushed at Beckhoff: Beckhoff’s wind power division has been able to more than double its turnover for the fifth year running. Over 6,000 operational management systems and more than 6,000 pitch controllers have been supplied with Beckhoff technology this year alone. We owe this success not least to the massive expansion of wind energy in China. Looking back: about ten years ago, the first customers from the wind power sector became aware of PC-based Control from Beckhoff and our Bus Terminals. The openly designed control architecture, which supports all common fieldbus systems and a large number of signal types, fit the industry’s requirements like a glove. That was our entry

into wind energy. The introduction of our CX series of Embedded PCs gave further lift to the development of the business. With the Ethernet-based fieldbus EtherCAT we have created a standard that more and more customers are using in their plants due to the flexible topology options. Today, nearly all important suppliers of pitch and converter systems are members of the EtherCAT Technology Group (ETG), the EtherCAT user’s organization. The openness of the components additionally permits the integration of all control, measuring and safety-related tasks. The integration of the safety chain with TwinSAFE, power measurement, visualization and data storage as well as remote monitoring are further advantages of the PC-based controller from Beckhoff.

We have realized all of this using standard components that have successfully proven themselves over many years of employment in other branches of industry. Beyond that we have specifically extended the product range: for example, the extended temperature range of our I/O components, the realization of the new IEC 61850 and IEC 61400-25 tele-control protocols for plant communication with wind farms or wind turbines or Condition Monitoring solutions. Together with the international Beckhoff subsidiaries, the ‘Wind Expertise Team’ introduced in Lübeck offers customer support for all areas of wind turbine control. The range of services extends from application-specific software libraries through to control cabinet design and complete application software, i.e. operational management. The customer will find partners at Beckhoff who speak ‘wind’.

Beckhoff will also continue the technological development of its components and solutions. Beyond that we also want to open up new tasks in, or at the edge of automation technology. This booklet is intended to encourage you to discuss your wishes and ideas with us.

\*Chinese proverb

## China provides for fresh wind in the industry

China is playing an increasingly important role in the worldwide growth of the wind power industry, not only as a user of wind power, but also as a manufacturer of wind turbines. The experts from the Global Wind Energy Centre (GWEC) believe that China could be using more wind power than Europe by 2014. China had already doubled its capacities to 25.8 gigawatts in 2009, thereby replacing Germany as the second largest wind power producer. This year the newly installed wind power output in China is expected to be 19 GW. Our customers, the leading wind power plant manufacturers in China, will have a substantial share in this development and the effort is worthwhile, not least in view of the savings on CO<sub>2</sub>. Like hydroelectric power or biomass, virtually no natural limits are imposed upon wind power.

Beckhoff owes a large part of its success in the Chinese wind power industry to its local presence. Founded almost ten years ago, Beckhoff’s Chinese subsidiary has now established a network of sales offices throughout China, so that we can say: Wherever our customers are, so are we! And we have made a name for ourselves on the Chinese market as a reliable partner for PC-based control technology. This year, we expect a further increase in revenue from our wind energy business in China.

New names in the global wind power market make it clear that the balance of power is shifting: whereas wind turbines were brought onto

the market with the aid of European development consultancies at the start of the wind power boom in China, more and more Chinese wind power plant manufacturers are now taking care of the construction and development of their wind power plants themselves. The local supplier industry for large components is also expanding massively: examples of this are subsidiaries of large international suppliers, such as our customers Moog and Convertteam, who maintain production sites in China. However, more and more Chinese companies are also taking the plunge into this industry, e.g. ReEnergy Tianjin.


Beckhoff China is reacting to this development and, as in previous years, is strongly expanding its sites both geographically and in terms of personnel, in order to be able to provide its customers with optimum local support.



Dirk Kordtmeikel,  
Business Manager Wind Energy  
at Beckhoff



Xingkai Ma,  
Business Manager Wind Energy  
at Beckhoff China



Open control solutions provide for lean plant design of wind turbines

## PC Control for wind turbines

In the field of renewable energy, Beckhoff supplies manufacturers of wind turbines and their suppliers, among others, with PC- and EtherCAT-based automation solutions. The integration of PLC, safety technology and condition monitoring as well as lower level bus systems on one control platform simplifies the engineering and reduces space requirements and costs. The plant manufacturer gains high investment security by the employment of open industrial communication standards, such as IEC 61400-25, Ethernet TCP/IP and OPC.

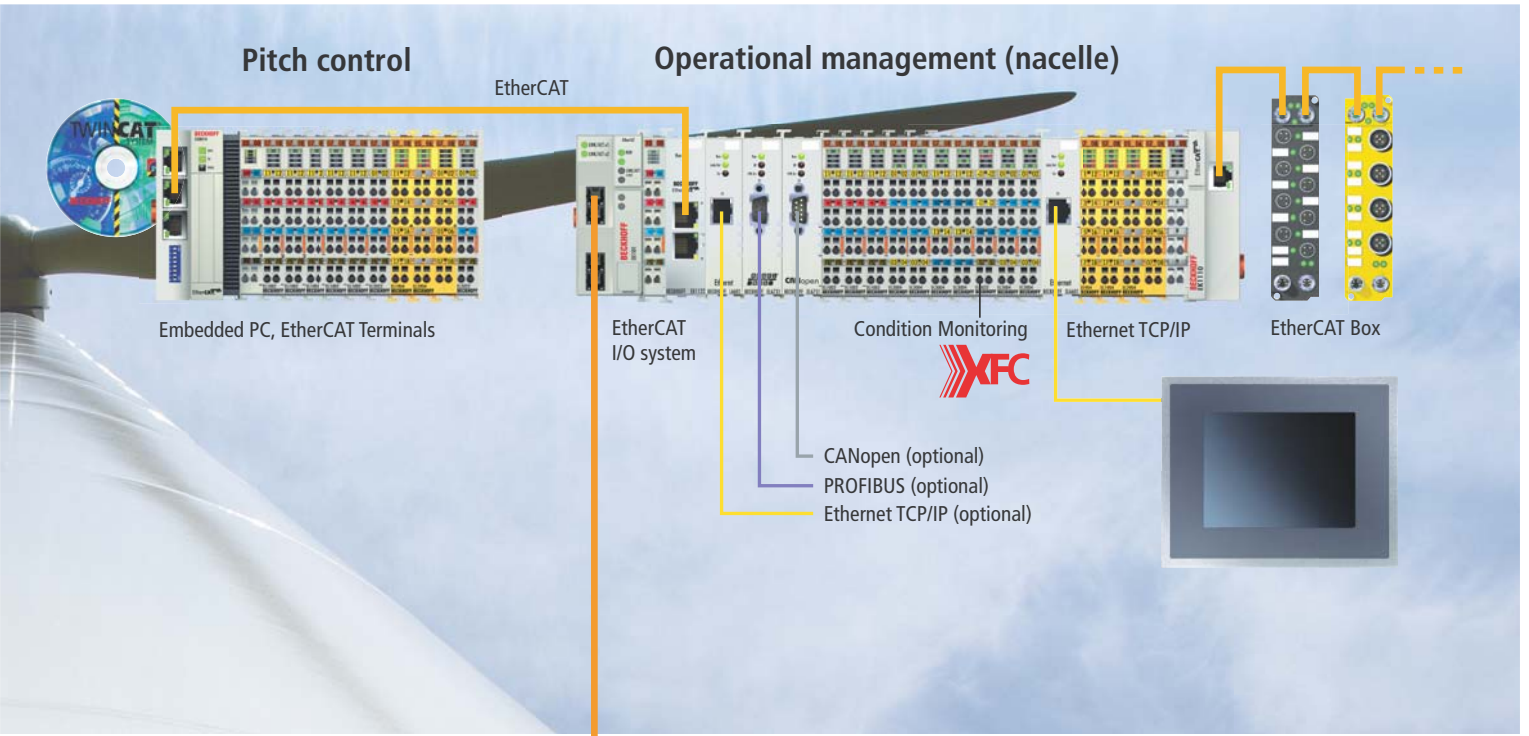
Control technology from Beckhoff has successfully proven itself in use worldwide in wind turbines up to a size of 5 MW. Based on PC and EtherCAT technology, Beckhoff supplies universal control solutions for all areas of application in wind turbines, from pitch control and the operational management of tower and pod through to the farm networking and control room – both onshore and offshore.

In modern wind turbines the EtherCAT real-time Ethernet system is the basis for fast communication in the wind turbine and for wind farm networking. Through the integration of lower level fieldbuses, fieldbus masters can be relocated to the field for the control of subsystems without any additional CPUs being necessary. EtherCAT enables the seamless integration of condition monitoring into the EtherCAT terminal system. TwinSAFE, Beckhoff's safety technology, merges the safety functions into the existing controller application and thus replaces the hard-wired safety chain.

The Beckhoff I/O systems are continuously being supplemented by new terminals or Embedded PCs. The latest developments, the Embedded PCs from the CX5000 and CX8000 series, are fanless, compact and energy-efficient PC-based controllers, which are ideally suited for control tasks in wind turbines.

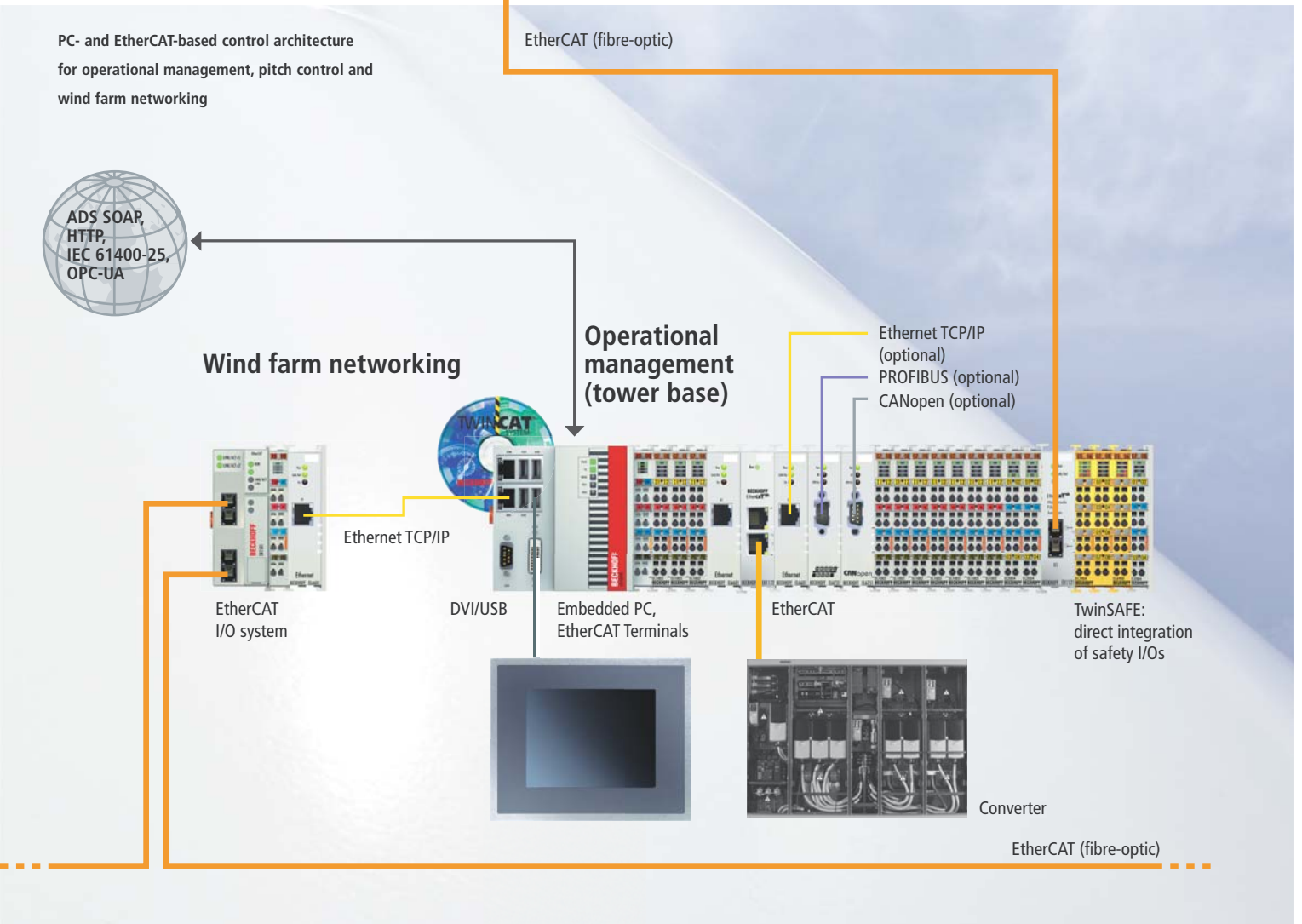
The standard automation world is extended considerably by TwinCAT 3, the new software generation from Beckhoff. In addition to the object-oriented IEC 61131-3 extensions, the languages of the IT world are available in C and C++. Through the integration of Matlab®/Simulink® and Scada into the development environment, TwinCAT 3 offers a convenient tool for designing the control software. The modules are executable in the different languages in a common runtime under hard real-time conditions, using multi-core technology and with 32 or 64-bit operating systems.

PC Control for wind turbines [www.beckhoff.com/wind](http://www.beckhoff.com/wind)



PC- and EtherCAT-based control architecture for operational management, pitch control and wind farm networking

EtherCAT (fibre-optic)



Chinese wind turbine manufacturer Goldwind uses Vensys plant design and PC-based control from Beckhoff

# High-quality, proven control components for Vensys wind turbines



The gearless Vensys wind turbines are characterized by their simplicity and quality. The turbines are proof that a few high-quality and proven components are sufficient for building state of the art wind energy converters. With the 70, 77 and 82 series, Vensys offers advanced wind turbines in the 1.5 MW range with different hub heights and rotor diameters. New 2.5 MW plants will follow near the end of 2010. All Vensys wind turbines use PC-based control technology from Beckhoff. To date, more than 6,200 wind turbines based on the Vensys design with Beckhoff technology have been delivered worldwide.

Vensys Energy AG specializes in gearless wind turbines. In addition to manufacturing facilities at Neunkirchen (Saarland, Germany), the company has manufacturing capacities for more than 2,000 wind energy converters through licensees around the world. At Diepholz, Lower Saxony in Germany, the subsidiary Vensys Elektrotechnik GmbH produces frequency converters, low-voltage distribution boards and pitch systems for the Vensys wind power units.

In addition to the development and manufacturing of wind turbines, Vensys sells expertise in the form of licenses. The licensees have the right to manufacture and sell wind turbines according to Vensys designs. Over recent years the companies Goldwind in China, Eozen in Spain, Regen Powertech in India and Enerwind/IMPISA Wind in Brazil have become the license partner of Vensys. Vensys wind turbines can be found in all major emerging markets around the world.

Vensys originated from the wind energy research team (FGW) at the University of Saarbrücken in Germany, which was established in 1990. The first Vensys 70/77 type 1.5 MW wind energy converters started operating in spring 2007. In September 2009 Vensys presented its newly developed 2.5 MW wind turbine generator. The design is based on established Vensys technology: At the core of the gearless wind energy converter is a synchronous generator with permanent magnet technology that is driven directly by the rotor. The direct drive avoids the need for gearboxes which are maintenance-intensive and susceptible to faults. The characteristic Vensys generator design achieves a high

efficiency. The market introduction of the Vensys series 90 and 100 with 2.5 MW rated power is planned for the end of 2010.

#### **Versatile and robust operations management permits application anywhere and under extreme environmental conditions**

The control systems for all Vensys wind turbines are developed and manufactured in Diepholz by Vensys Elektrotechnik GmbH in close cooperation with Beckhoff. This is where the pilot production for the control cabinets and systems takes place before the licensees and/or their manufacturing partners commence series production. In order to be successful internationally, wind turbine manufacturers need high-performance and flexible control systems: Rapidly changing system states under different, and in some cases extreme climatic and environmental conditions result in complex demands for the control systems. Wind turbines must be suitable for the locational conditions found in Central European lowlands and climatically extreme conditions, as they occur in China, for example: Deserts naturally present different conditions than coastal locations or mountain regions. The control systems must withstand heat, cold, humidity, sand, extreme wind forces, turbulence and other demanding influences and respond reliably. The system must always face the right way relative to the wind; data must be collected and evaluated; state or error messages must be exact and meaningful; grid feed-in must be correct and grid-supportive. All this requires a high-performance and adaptable control system.

The gearless Vensys wind turbines are controlled by a CX1020 Embedded PC. To date more than 6,200 wind turbines based on the Vensys design with Beckhoff control platform have been delivered worldwide.

At the Diepholz, Germany facility Vensys Elektrotechnik GmbH builds the "pilot series" for the control cabinets before the licensees and/or their partners commence series production.





Hans Beckhoff, managing director of Beckhoff Automation, on the Vensys windmill

	Rated power	Rotor diameter
Vensys 70	1.500 kW	70 m (230 ft)
Vensys 77	1.500 kW	77 m (253 ft)
Vensys 82	1.500 kW	82 m (262 ft)
Vensys 90	2.500 kW	90 m (295 ft)
Vensys 100	2.500 kW	100 m (328 ft)

**Lean control architecture integrates standard and safety I/O in a single system**

The Vensys system design, which is based on just a few components, is matched by the “lean” Beckhoff control concept with a single PC (see topology diagram). The master computer is a Beckhoff CX1020 Embedded PC to which two Bus Terminal stations in the tower base, two stations in the nacelle and the pitch controllers in the hub are connected via PROFIBUS. The central Embedded PC collects and processes the operational management and pitch controller data, controls the grid feed-in and communicates with the control room via Ethernet.

Compared with conventional solutions the PC-based control system from Beckhoff has the advantage that only one PC is required for control purposes and data interfaces. The Bus Terminals are attached directly to the Embedded PC, so that PC technology and modular I/O level form a cohesive unit.

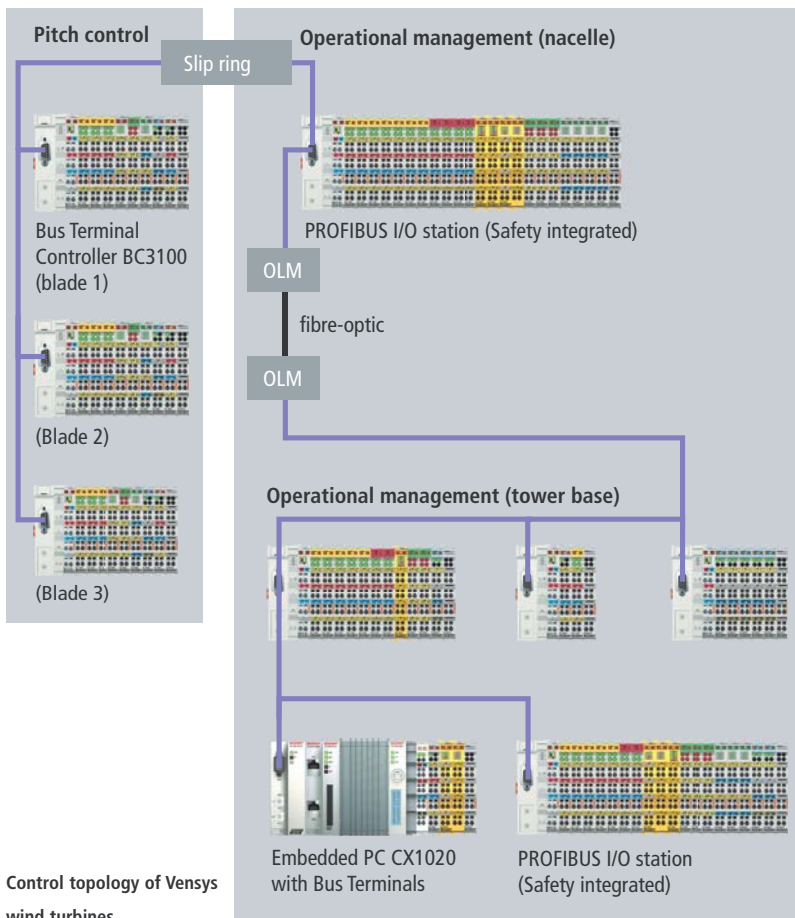
The safety functions are also directly integrated in the Bus Terminal system. TwinSAFE terminals are distributed to the different I/O stations. A central KL6904 TwinSAFE logic terminal serves as the link unit between the safe input and output terminals. The logic terminal integrates safety function blocks which are configured accordingly. In the Vensys wind turbines, the overspeed relay, vibration sensor and the emergency off button are integrated in the safety circuit.

Robert Müller, wind power expert from the Beckhoff branch office in Lübeck, Germany explains the benefits of the integrated safety technology: “The merger of standard and safety I/O into a single streamlined system simplifies project planning, programming, cabling and diagnostics significantly. The TwinSAFE Bus Terminals permit the connection of all common safety sensors and actuators. The TwinSAFE protocol is used for secure communication. This enables safety-related data to be transferred via any media. In the case of Vensys systems, PROFIBUS is used for transferring the safe signals.” The use of TwinSAFE technology makes multi-wire copper cabling between the nacelle and the tower base, which is required for a conventional hard-wired safety chain, unnecessary. The safety chain is integrated in the optical fiber used for system automation.

**Compact pitch controllers and flexible IEC-61131 programming**

The pitch controllers are coupled with PROFIBUS via slip rings. Each rotor blade features a Beckhoff BX3100 Bus Terminal Controller with various Bus Terminals. The pitch box with integrated controller automatically collects and analyzes the ambient data, decides independently and communicates with the other pitch boxes in order to coordinate the initiated actions. At the same time the data are transferred to the Embedded PC in the nacelle. The rotor blades are pitched via external toothed belts – a solution developed in-house at Vensys that developers are quite proud of.

“Crucial factors for choosing the Beckhoff systems were the flexibility of the comprehensive Bus Terminal I/O kit, the small footprint of the controllers and I/O systems, the user-friendly programming via



Control topology of Vensys wind turbines

Dirk Kordtomeikel, Business Manager Wind Energy at Beckhoff, and Nicole Grote, purchasing manager at Vensys Elektrotechnik GmbH, on the windmill



TwinCAT, and ultimately the low system costs,” said Frank Becker, director of control technology at Vensys.

Another argument in the decision for Beckhoff as control equipment supplier was the global positioning of the company in more than 60 countries. Beckhoff has wind power experts in its subsidiary branches in important wind power regions such as China.

## Goldwind relies on German technology

The main licensee of Vensys wind energy converters is the company Goldwind Science and Technology Co Ltd., based in Urumqi in northwest China. Goldwind Windenergy GmbH, a German subsidiary of Goldwind, has been the main shareholder of Vensys Energy AG since April 2008 with 70% of the shares. Goldwind has become the industry leader among Chinese wind turbine manufacturers and is set for further growth.

Goldwind's main activities include the development, manufacturing and sale of wind turbines. Goldwind also offers comprehensive technical and consulting services for the construction and operation of wind turbines for windfarm operators and investors. More than 6,000 Goldwind wind turbine generators are currently in operation in China. Goldwind supplied wind turbines for the Olympic Park near Beijing, which was built for the Summer Olympics in 2008. The company is also successful in the international wind energy market: The first networked 1.5 MW wind turbines at the UILK windfarm in Minnesota (United States) were commissioned in February 2010.

“Goldwind and Beckhoff have had a successful working relationship for many years,” said Dr. Yuwen Bo, deputy director of the Goldwind wind energy technology center. “Beckhoff has extensive expertise in the wind energy industry and is able to supply complete system solutions. In addition, PC Control offers us a high degree of flexibility for programming and facilitates modifications of the control system according to application- or customer-specific requirements.”

The Guanting windfarm near Beijing is located at an elevation of approx. 460 to 479 m (1509 to 1572 ft) and is spread over an area of 6 x 14 km (3.7 x 8.7 mi). It has an installed wind power capacity of 49.5 MW. Guanting II, with a capacity of 50 MW, is currently under construction.

The increasing demands for efficiency and energy yield have resulted in strong growth for high-performance wind turbines: 1.5 MW systems are currently the standard in China. For the 2.5 MW systems, which will commence production towards the end of this year, Goldwind will use EtherCAT as communication system instead of PROFIBUS.

“The control algorithms for the systems are getting more and more complex,” said Dr. Yuwen Bo: “In order to cope with difficult geographic and climatic conditions and varying requirements, the performance of the main controller – which represents the ‘brain’ of the wind turbine – must be able to ‘grow.’” The Embedded PCs from Beckhoff are able to process very complex algorithms, which means all wind turbine control tasks can run on an integrated platform.

Vensys Energy AG

Goldwind Science and Technology Co Ltd.

Goldwind International

[www.vensys.de](http://www.vensys.de)

[www.goldwind.cn](http://www.goldwind.cn)

[www.goldwindglobal.com](http://www.goldwindglobal.com)



Avantis achieves higher efficiency and improved operational reliability with gearless wind turbines

## Innovative technology meets modern design

Wind energy has come of age and is developing rapidly: New concepts, new companies and new success stories are emerging. The Avantis Group, represented in Europe through German-based Avantis Europe GmbH, is among the newcomers in the international wind energy market. The company develops, produces and sells gearless wind turbines with capacities between 2.3 and 3.5 MW featuring cutting-edge technology and appealing aesthetics. Designer Luigi Colani is behind the design of the nacelle for the Avantis windmill. With their PC- and EtherCAT-based control platform, the wind turbines are the ideal products for a high tech industry.

The Avantis Group was founded in 2004 and is active worldwide with subsidiaries in Asia, the United States/Canada, Brazil and Europe. In addition to the development and production of wind turbines, Avantis also acts as a service provider in the areas of maintenance, support planning, site evaluation and investor relations management. In 2004 Avantis started developing its own control system concept. Five years later the first 2.5 MW turbine was commissioned at Beihai in southern China. After a highly successful test phase, series production started in 2010 in China. The Beihai facility is designed for an annual production capacity of 300 to 400 turbines.

### **Water-cooled generators and converters offer improved performance and operational reliability**

Avantis wind turbines are characterized by a specially developed, water-cooled permanent magnet generator with very high efficiency and a water-cooled converter. The innovative concept and the modular design enable system configurations for different climatic and geographic conditions. The AV 928, a windmill with a capacity of 2.5 MW, a rotor diameter



In 2004 Avantis started developing its own system concept. Five years later the first 2.5 MW turbine was commissioned at Beihai in Southern China.



of just over 93 meters and a hub height of 80 meters, is approved for wind speeds according to the IEC IIa standard. Its larger „sister,” the AV 927 with a capacity of 3.5 megawatts, is designed for wind speeds up to typhoon strength according to IEC Ia and is suitable for offshore application. The next generation system from Avantis, the AV 1010 with a slightly modified generator and larger blades (49 m), is a class III turbine with a capacity of 2.3 MW. Avantis is also working on systems in the capacity class between 5 and 6 megawatts. The drive train concept of the AV wind turbine series enables integration of generators with different sizes without resulting in additional mechanical loads on the components. Many components are identical across the whole range, which leads to lower production and stock-keeping costs.

The water cooling system of the converters in the nacelle generates an overpressure that results in hermetic sealing of the system and prevents ingress of dust, contaminants or moisture. This makes the wind turbines suitable for application in extremely arid regions (deserts) as well as in the offshore sector.



The streamlined nacelle designed by industrial designer Luigi Colani perfectly combines aesthetics and function. Yet another new blade design is planned for the future.

AV 928 windmill with a capacity of 2.5 MW, a rotor diameter of just over 93 meters and a hub height of 80 meters



### Higher system availability through gearless system design

Avantis uses state-of-the-art technology and has a wealth of experience. The system design was developed by German Drive Systems (GDS), an Avantis Group company. As in most new system concepts no gearbox is used. The direct drive system with variable rotor speed enables very high efficiency, particularly at part load, under which wind turbines operate most of the time.

The small generator diameter of five meters leads to relatively small system dimensions and simplifies transport and assembly. The water cooling of the generator enables precise temperature control of the permanent magnets. The converter and the control system are positioned at the center of the nacelle. This reduces the vibration stress, resulting in higher availability and lower windmill failure rates.

The tower base only contains the control cabinet with the system communication equipment. Optionally, the power switches and the control cabinet can be positioned on the first platform of the windmill, which may be useful for offshore applications.

### Embedded PC as an integrated control platform

Avantis decided to use Beckhoff as the solution provider for developing the control system. "The hardware and software of the control system come from one source and are optimally adapted to each other," said Klaus Bodenstein, co-founder of Avantis. A Beckhoff CX1020 Embedded PC with TwinCAT automation software forms the "heart" of the automation platform, which, in addition to system control, also integrates monitoring and control of the subsystems such as gearing or cooling and logging of operational data for maintenance and diagnostic purposes. EtherCAT as a high-performance communication system enables integration of subordinate fieldbuses such as CANopen or PROFIBUS.

"The integration of the control system development into the plant design takes place in close cooperation between the development teams of Avantis and Beckhoff," said Klaus Bodenstein. "Through the disclosure of the source code we are able to optimally adapt the control system to the very different, specific ambient conditions and to respond flexibly to the plant system states under normal operating conditions."

"Where other control manufacturers use special hardware, we use stan-



Assembly of the permanent magnet generator at the nacelle



Avantis wind turbines are characterized by a specially developed, water-cooled permanent magnet generator with very high efficiency. The direct drive concept enables high efficiency, particularly at partial load.



## The Avantis Group

The Avantis Group was founded in 2004 and has subsidiaries in China (Hong Kong), Europe (Hamburg) and Brazil. In these respective countries, Avantis Energy aims to produce and market its gearless wind energy turbines with the key components they developed in Germany.

Ralf Breuer, an experienced wind power expert, has been managing director of Avantis Energy Ltd. since 2009 and is pushing the expansion of European market share from the company headquarters in Hamburg. Avantis has big plans for the future and is targeting the potential-filled markets of Asia, the United States and Europe. The young company can boast German system design and that it is internationally organized and works with production and licensed partners in Asia. Usually European industrialists work in the other direction, but Avantis co-founder Klaus Bodenstern, who has been working in Asia for more than 30 years and in the wind energy sector for about 10 years, intends to penetrate North American and European markets from Asia. This enables large production capacities and at the same time secures stable, high sales volume locally. These are ideal conditions for economic success.

Avantis Energy has signed a partnership agreement for the production of wind turbines with the southern Chinese company Yinhe Avantis Wind Power Co. Ltd. and has production capacities for approx. 400 units per year at Beihai. The facility has a new 6000 sqm assembly shop and a 40,000 sqm blade production hall. Avantis currently still receives the rotor blades for its wind turbines from Europe, although the company's own design concept is in preparation.

standard components, resulting in significantly lower costs. The shifting of functionality into software results in transfer of know-how to the wind turbine manufacturer. This represents a further, significant advantage for our customers, who can easily integrate their own functions in TwinCAT," said Dirk Kordtomeikel, industry manager for wind energy at Beckhoff. For the prototype system Beckhoff carried out the factory test for the control systems and the complete commissioning procedure of the plant in the field on behalf of Avantis.

### System design combines aesthetics and function

Avantis managed to pull off an impressive coup with the nacelle design by eminent star designer Luigi Colani. Industrial designer Colani, whose customers include renowned companies such as Ferrari, gave the nacelle of the Avantis windmills a distinctive, streamlined shape. Avantis also worked with Colani on the blade design. Yet another new revolutionary blade design is scheduled to be launched in two years at the latest.

Avantis Europe GmbH [www.avantis-energy.com](http://www.avantis-energy.com)

## pitch

## Pitch system suppliers

Electrical pitch controllers, i.e. electrical blade adjustment systems, can be found in more than 80% of all large wind turbines today. Since the pitch system plays a critical part in the safety infrastructure of a wind turbine, it must operate independently and be failure-proof. In order to ensure this, the system has electrical buffers and its own control system so that it can turn the blades out of the wind in case of emergency. As a consequence, two very interesting systems with different architectures – and with correspondingly different controllers from Beckhoff – are presented.

### Moog

## PC-based control and EtherCAT give a boost to pitch systems for extreme wind energy applications

Moog is a globally-known name in drive and control technology. Founded in 1951, the prominent company now has more than 10,000 employees in 25 countries. Moog's core business is in the development and production of high-performance drive solutions. Moog produces approx. 2,000 pitch systems for wind turbines per year. As one of the company's main suppliers, Beckhoff provides Industrial PCs (IPCs) for control and EtherCAT Terminals for system networking.



The pitch system is controlled by a Beckhoff CX Embedded PC with EtherCAT Terminals.

The harsh operating conditions under which pitch systems are used define their technology. For wind turbines, pitch systems act as controllers and emergency systems at the same time. As wind turbines become more sophisticated, the requirements for pitch systems are becoming increasingly demanding. Also, wind turbine manufacturers continue to explore new territory in terms of wind turbine size. Machine capacity now exceeds 5 MW which is an added technological challenge for the pitch systems.

Moog's latest innovation, the PITCHmaster® II + servo controller, is up to the task. An integrated acceleration sensor supplies measurement readings for rotor speed, rotor position and vibrations, ensuring optimum control. The electrical pitch system is designed for site altitudes of up to 3,000 meters (9,843 ft), which far exceeds the standardized operating elevation range of common electrical systems and, therefore, pitch systems. In addition, Moog pitch systems are tested under extreme climatic conditions between -30 ° and +70 °C (-22 ° and 158 °F) in order to guarantee their remarkable temperature resistance.

Moog offers hydraulic and electrical pitch systems, depending on the wind turbine manufacturer's philosophy and design concept. With either approach, high shock and vibration resistance are guaranteed, as well as safety in case of emergency. In the event of a fault, the independence of the pitch boxes from the main system controller is ensured through an independent power supply provided by the pitch batteries.

Moog uses compact CX9000 or CX1010 Embedded PCs from Beckhoff as the controls centrepiece in its pitch systems. Ultimately, the modularity of the CX system was the key factor for the decision to use Beckhoff as supplier. The devices support all common fieldbus systems, both as a master and as a slave. Also, the fine granularity of the Bus Terminals enables Moog to more easily customize its pitch systems. According to Bernd Franzak, chief designer for Moog Unna GmbH, a special highlight of the system is the power measurement I/O terminal (KL3403/EL3403), which enables cost-effective monitoring of the batteries and the double-layer capacitors.

For some Moog customers, Beckhoff CP6008 Panel PCs with TwinCAT HMI are installed. These offer a high degree of user convenience for commissioning engineers and maintenance personnel that operate the pitch system in the hub.

Moog [www.moog.com/wind](http://www.moog.com/wind)

Atech relies on various Beckhoff Embedded PCs for the control and regulation of the pitch box.

## Atech

# Compact pitch systems with open control technology

Atech Antriebstechnik builds pitch systems for wind turbines. The uncompromising concept is characterized by a reduction of components and high reliability in the operational management. Beckhoff cooperates closely with Atech to maintain these standards.

Pitch systems are exposed to great stresses and, as safety systems, must remain functional at all times. They are used not only to adapt the rotor speed precisely to the prevailing wind; in extreme cases, the pitch systems are also used as emergency brakes. Redundancy, low maintenance and high load capability are therefore central requirements – especially under the extreme environmental conditions under which wind turbines must operate.

Atech uses electrical pitch systems, which is an obvious choice for a manufacturer that also markets drive and battery technologies. In addition, the company has a close and long-standing development partnership with the ZAPI group, which is located in the Emilia-Romagna area of Italy. The Atech concept is based on low-voltage technology. All systems are offered for supply voltages between 45 and 100 V. The systems themselves are designed for wind turbines of output classes between 1 and 6 MW. The pitch systems are optionally offered with maintenance-free, load-cycle-independent capacitors, which supply the pitch adjustment system with the necessary power in the event of a power failure.

Special consideration in the development of the Atech pitch systems is given not only to wind-specific requirements, but also to general requirements for automotive use. Atech systems are characterized by tolerance to extreme temperatures and temperature fluctuations, as well as high resistance to shocks and vibration. Many years of experience are reflected in the quality of the products.

Atech has opted for a compact design. Only three pitch boxes are used per plant – one for each blade – which, additionally are 100% identical. The systems are offered not only as standardized solutions, but also as customer-specific versions designed in close cooperation with the devel-



opers of the wind turbine. This permits specific customer solutions on a modular basis. The solutions developed in this way are then produced by the customers themselves (e.g. Goldwind, Vensys, Guodian United Power or Winwind) with the help of the Atech and Beckhoff components.

Various Beckhoff Embedded PCs are available for the control and regulation of the blade pitch. Common to all is a PROFIBUS slave interface to connect to the main controller. The PROFIBUS cabling is connected to the nacelle by a slip ring. Newer designs are characterized by CANopen communication to the power components and battery chargers employed, and the entire system is even more compact as a result. The CX9000 Embedded PC from Beckhoff offers a particularly simple to operate Web interface for easier commissioning.

Atech [www.atech-antriebstechnik.com](http://www.atech-antriebstechnik.com)

CX9000 system	BX system	BC system
CX9000-0001	BX3100	BC3150
EL5001	KL5001	KL5001
EL9011	KL9010	KL9010
EL6731-0010	KL1809	KL1104
EL6751	KL2809	KL2408
EL3204	KL3204	KL3404
EL1809	KL9010	KL4001
EL2809		KL9010

## brakes

## Brake suppliers

Security is a big topic in wind power systems; precise control of the plant performance in all conceivable situations is considered to be very important. Brake systems have therefore developed in the wind power industry into complex, 'intelligent' subsystems that cooperate with the complete plant and its main controller. Beckhoff offers compact control solutions for brake systems in the form of Embedded PCs or Bus Terminal controllers.

### Svendborg Brakes

## PC Control for SOBO® brake controller helps ensure wind turbine safety

Svendborg Brakes is one of the best-known manufacturers of brake systems for wind turbines and is following the trend towards increasingly powerful and more intelligent systems. Beckhoff supplies the hardware for Svendborg Brakes' SOBO® controller.

The Danish company, which today operates internationally and has a growing global presence, supplies brake systems for azimuth and rotor as well as safety brake systems and rotor lock systems. The supplied systems are used primarily to decelerate the rotor – on the fast or slow shaft depending on the design – and to lock it.

The precise alignment or adjustment of the nacelle to the wind direction and the stabilization of the azimuth system are ensured by the azimuth brakes. The loads that the brake system has to cope with are enormous. However, by the interaction of the aerodynamic brake by means of pitch adjustment and the active mechanical brake, all plant sizes up to the multi-megawatt class can be managed securely.

The control of the brake systems is a crucial factor in addition to suitable brake lining materials and a mechanical design capable of bearing high loads.

To this end Svendborg uses its own controller called SOBO® (Control – Soft Braking Option, also with 'fault-ride-through' function if necessary),

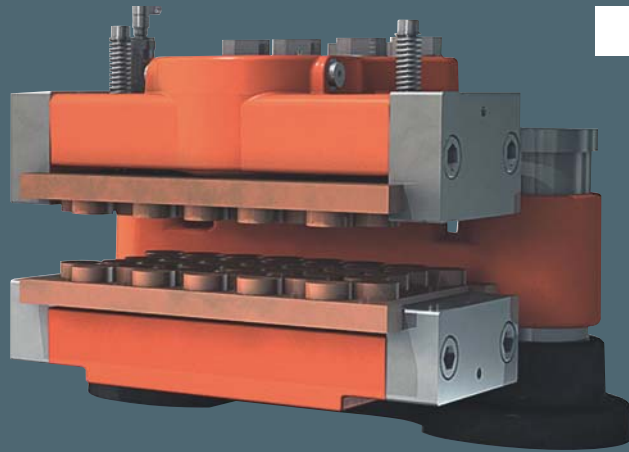
with which the hydraulic unit of the brake systems is controlled. The goal is a controlled, precisely steered and even braking process that is as gentle on the entire plant as it is on the brake system and its mechanical components. The braking behavior of the SOBO® controller can be adapted exactly to the individual type of wind turbine.

Beckhoff supplies the necessary hardware with the flexibility that ensures versatile applicability of the SOBO® controller – which also includes applications outside the wind power industry, e.g. for cranes and conveyor belts. A Bus Terminal Controller from Beckhoff's BX series (BX8000) and various Bus Terminals are used, including an incremental encoder terminal for the detection of the speed of the main shaft. The wide applicability is made possible in particular by the flexible TwinCAT automation solution. In addition, communication with the higher-level automation system is greatly simplified, especially when an automation platform from Beckhoff is also used, as is the case in many wind turbines.

Svendborg Brakes [www.svendborg-brakes.com](http://www.svendborg-brakes.com)

## brakes

The BSAK3000 hydraulic brake system, which is controlled by the SOBO® Control developed by Svendborg, enables a controlled and precisely steered braking process. The system can generate a pressing force of up to 55,000 N.



Precise control of plant performance in all conceivable situations is a big topic in wind power systems. Brake systems have therefore developed into complex, "intelligent" subsystems that cooperate with the complete plant and its main controller.



Maintenance-friendly 3 MW wind turbines based on innovative permanent magnet technology

## Winwind: EtherCAT facilitates flexible and cost-effective wind turbine communication

During the 10 years since it was established, the Finnish company Winwind Ltd has developed into an internationally recognized wind turbine manufacturer and supplier of wind energy solutions. The key to the company's success was the development of an innovative 3 MW wind turbine with permanent magnet technology, which was superior to the conventional technologies that dominated the market until then. For controlling its 3 MW windmills, Winwind utilizes a PC- and EtherCAT-based automation platform from Beckhoff, which enables the integration of control, visualization and data management on a single PC.



Winwind wind turbines are designed for operation under very adverse weather conditions, from arctic frost to arid deserts.



### Winwind Oy

Since it was established in 2000, Winwind Oy, based in Espoo, Finland, has developed from a small start up company to an international wind turbine manufacturer and supplier of complete wind energy solutions.

In 2006, the Siva Group of India acquired a majority stake in Winwind. In 2008, Masdar, an investor in renewable and green technology came on board, giving further impetus for development, growth and international expansion.

In 2009, Winwind commissioned two state-of-the-art production facilities: WWD-1 at Vengal, India, specializes in the production of rotor blades, while the WWD-3 assembly plant at Hamina, Finland, is designed for an annual production of 500 MW.

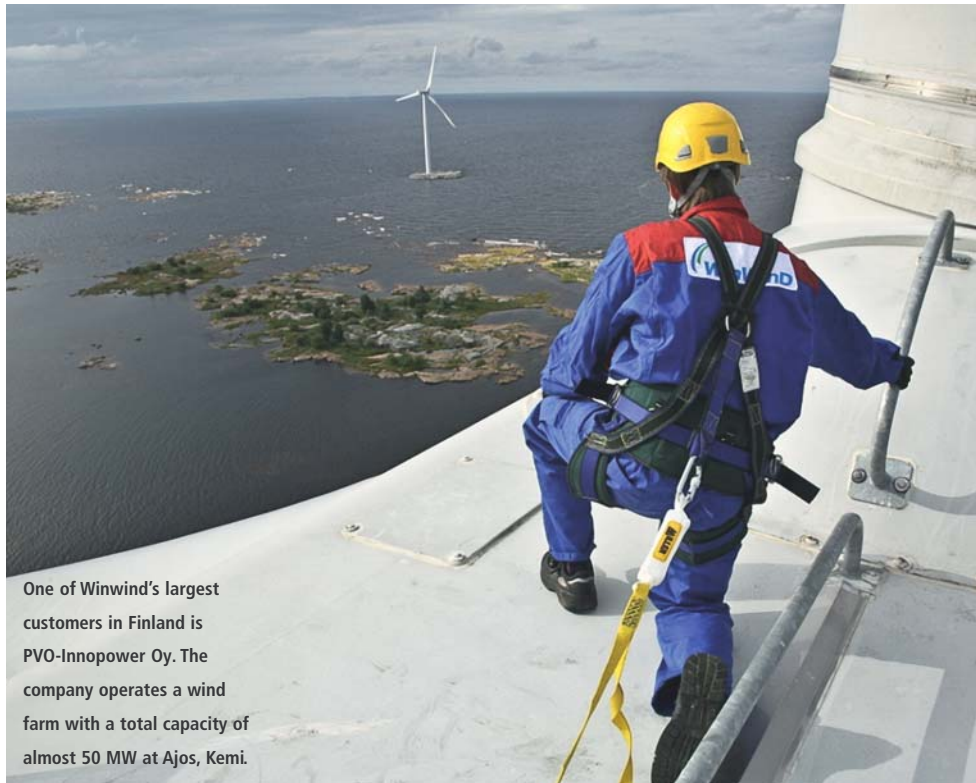
The Finnish wind turbine manufacturer currently has 800 staff, of which 495 work outside Finland in India and in offices in Estonia, Portugal, and Sweden.

In the development of its wind turbines Winwind combines long-standing wind energy expertise with extensive competence in component manufacturing. Over its 10-year company history Winwind has achieved its ambitious goal to develop efficient, reliable and maintenance-friendly wind turbines with a long service life and high returns over the whole life cycle. Winwind 1 and 3 MW wind turbines are used in numerous wind farms in Europe and India. The long-lasting turbines are designed for a minimum service life of 20 years.

#### From pilot wind turbine to series production

The first wind turbine built by Winwind had a capacity of 1 MW, even though it was already clear at this stage that larger wind turbines would be required in the future. In 2004, the company started developing the 3 MW version based on a Beckhoff automation platform. Series production of this Winwind turbine started in 2006.

In its 3 MW wind turbines Winwind uses Multibrid-based technology in which the stator of the permanent magnet synchronous generator



One of Winwind's largest customers in Finland is PVO-Innopower Oy. The company operates a wind farm with a total capacity of almost 50 MW at Ajos, Kemi.

Meanwhile, Winwind has also become the market leader for wind power in Estonia with a total capacity of more than 100 MW across four wind farms. The first wind farm was Viru-Nigula Tuulepark consisting of eight 3 MW turbines which were supplied as a turnkey solution, i.e. Winwind not only supplied the wind turbines, but also dealt with all structural and electrical works. With its 13 3 MW wind turbines, Aulepa is the largest wind farm in the Baltic countries. Once the second stage is completed, it will have a total capacity of 48 MW with an annual output of 123 GWh. This is enough power to cover the annual electricity demand of 43,000 households and reduces annual CO<sub>2</sub> emissions by around 120,000 tons.

is installed directly into the gearbox, forming an integrated unit, where the gearbox casing is part of the load-carrying structure. The rotor is mounted on the output shaft of the planetary gear unit and, as a result, less rotating parts are required than in a conventional geared-type wind turbine drive train. This technology combines the reliability of a direct drive with the compactness of a traditional high-speed gear unit. Low speed in conjunction with optimum mechanical load control ensures low maintenance costs, high reliability and high availability. All these factors play an important role for wind farms which are often located in remote regions. The turbine starts up at low wind speeds or short gusts. Full-load frequency converters and high-quality pitch control guarantee grid-friendly electricity, very advanced FRT capabilities and extensive reactive power production.

### 270 MW installed wind capacity worldwide

Meanwhile, Winwind windmills are used in wind farms in the Czech Republic, Estonia, Finland, France, India, Portugal, and Sweden. One of the largest Finnish customers is PVO-Innopower Oy. The company operates a wind farm with a total capacity of almost 50 MW at Ajos, Kemi. The 1 and 3 MW windmills are built on land and on artificially created islands. The windmills reliably produce electricity despite very adverse weather conditions with temperatures down to around 25 °C below zero (-13 °F). A solution developed by Winwind prevents the icing up of the windmills and guarantees consistent operation, even under arctic conditions.

### Innovative system design meets PC Control

The 3 MW wind turbine is controlled by a Beckhoff CX1020 Embedded PC with Windows XP Embedded operating system and TwinCAT PLC automation software. A user-friendly human-machine interface (HMI), which provides the user with an overview of the system state, is integrated into the control platform. Kimmo Kaappola, Automation and Electrification Manager at Winwind explains the reasons why the company decided to use the Beckhoff Embedded PC as the basis for the control system: „For us, the decisive argument was the fact that the same control platform not only deals with supervisory control and dynamic control of the wind turbines, but can also be used as HMI and for data logging,” he said. “And thanks to the versatile and highly efficient TwinCAT ADS communication, it is possible to use the same HMI interface within the wind farm to link



all the wind turbines with the park control system. Moreover, the use of ADS communication substantially simplifies logging of the data from the different wind turbines within a wind farm."

#### **EtherCAT cost-effectively networks tower base to nacelle**

Winwind uses EtherCAT as the primary communication system for its wind turbines. In addition to its high performance, the fast bus system offers a high degree of flexibility. The EK1501 EtherCAT coupler and the EK1521 junction terminal for the Beckhoff EtherCAT Terminal system permit flexible topologies based on glass fiber technology and cost-effective communication between the tower base and the nacelle. "The option of integrating other bus systems such as CANopen into the EtherCAT I/O system via convenient gateway terminals was another key factor in our decision to use the Beckhoff control platform," said Kimmo Kaappola. "In addition, EtherCAT is also very suitable for diagnostic purposes, unlike traditional bus systems. Since more and more manufacturers offer EtherCAT interfaces for wind turbines, we are possibly en route to a single bus solution for the industry. This makes wind turbine control simpler and more robust." One of the latest developments at Winwind was the integration of ABB converters with the EtherCAT fieldbus.

## ABB converter systems with EtherCAT interfacing

ABB's full-power converters for wind turbines offer system manufacturers a high-performance, reliable solution that meets the requirements of long service life and simple maintenance. Due to their modularity the ABB converters are suitable for installation in the nacelle or the tower and can be operated in conjunction with all common generators. The converter system not only supplies the required current frequency and voltage, it also supports weak grids by feeding in or absorbing reactive power. In this way wind turbines can operate at their optimum duty point and feed energy into the grid with high efficiency.

Winwind uses ABB low-voltage converters for its 1 MW turbines and medium-voltage converters for its 3 MW turbines. Winwind recently successfully tested interfacing of the converter via EtherCAT in a 1 MW prototype system, thereby replacing the previous Canopen fieldbus solution. EtherCAT interfacing offers clear benefits for system manufacturers: Sub-bus systems and associated master connections are no longer required, and the system is faster and the control architecture leaner.

Optional converter cooling with air or liquid enables optimum adaptation of the wind turbines to different locational and climatic conditions. The liquid-cooled converters with fully encapsulated control cabinets are designed for operation under extreme conditions, such as offshore or in the desert. Liquid cooling offers additional benefits: In view of the ever increasing wind turbine generator outputs it enables more power to be produced within the same cabinet volume. It eliminates heat losses from the converter and therefore prevents the surrounding equipment and electronics from heating up.

Wind turbines are generally equipped with a built-in monitoring unit. The converter can provide additional data for analysing error states or the turbine output. ABB offers a remote monitoring system that offers the windfarm operators direct access to the converter and parameters such as DC and AC voltage, output, reactive power, temperature and speed.

## converter

# Converter system suppliers

While great for promoting green energy and reducing reliance on fossil fuels, the constantly growing percentage of electricity generated by wind power places are increasing certain demands on electrical grids. Whereas in times gone by the electricity utilities disconnected the wind turbines from the grid when there were grid problems, the turbines nowadays truly have to support the grid. As a result, converters play a crucial role today. The manufacturers of converter systems master the task of supporting wind turbine-enabled grids with the help of fast and flexible Beckhoff technology.

## The Switch

### Switch Drive™ fullpower converter guarantees reliable operation

The Switch Drive generator and converter package was developed by the Finnish wind turbine parts supplier The Switch. In addition to increased reliability and availability, the Switch Drive™ offers high efficiency in the partial load range, leading to a higher energy yield. The converter is controlled by a Beckhoff Embedded PC. Both the internal converter communication and the external communication are based on EtherCAT.

“The Switch” arose in December 2006 from the fusion of three enterprises, Rotatek Finland, Verteco and Youtilty; over 25 years of expert know-how flowed together among the three companies. Apart from the company headquarters in Vantaa and the production sites in Lappeenranta and Vaasa in Finland, The Switch also manufactures in Hudson, New Hampshire in the United States and in China. In 2009 the company brought solutions onto the market for 2.5 MW high-speed turbines, for medium-speed 1.25 MW generators and for a 1.5 MW direct drive solution. The annual production capacity for generator and converter systems currently amounts to 5.5 GW.

The Switch offers a large selection of standard and customer-specific gearless drive systems, consisting of a permanent magnet generator (PMG) and a full-power converter (FPC). They represent a direct drive solution in which the rotor of the wind turbine is connected directly to the generator, thus making a gearbox unnecessary. The payoff is improved reliability and availability as well as simplified maintenance over the entire turbine life cycle. The technology also guarantees compliance with future grid compatibility requirements by providing grid-supporting functions.

#### **EtherCAT promotes communication freedom**

In supplying its customers with generator and converter packages, The Switch found itself confronted with different customer needs regarding the transmission of data between the Switch Drive™ and the plant

controller. With the use of the EtherCAT Terminal system, however, the company can offer its customers any desired communication interface: PROFIBUS, CANopen, DeviceNet, RS485, etc. The communication master that matches the specific project is simply selected from the modular EtherCAT Terminal system and implemented. If the Beckhoff CX9000 or CX1010 Embedded PCs are used, Modbus TCP can also be utilized directly as the gateway to higher-level systems, without the use of a separate communication master. This greatly simplifies communication between the converter unit and the turbine controller, while at the same time reducing the number of components required for communication. If, as in many cases, the turbine controller is also from Beckhoff, then the operational management can also be connected via real-time EtherCAT or real-time Ethernet.

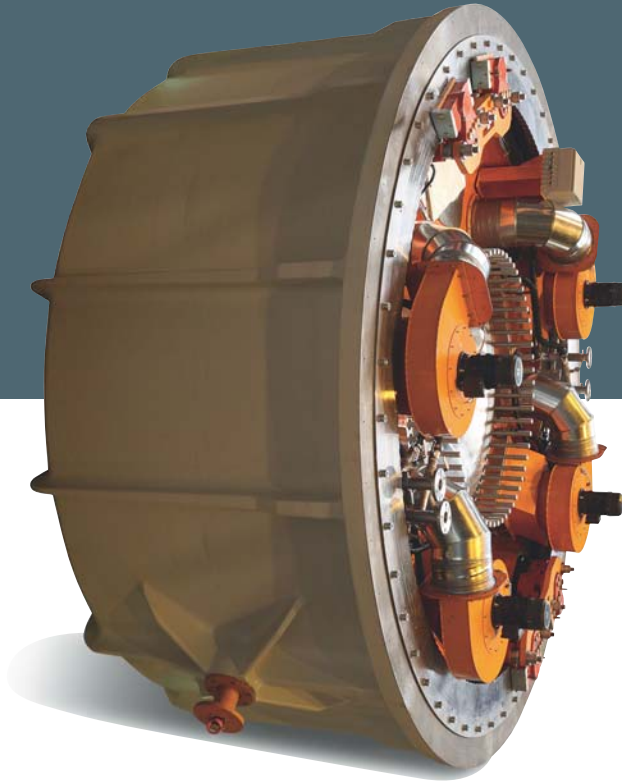
#### **Integrated data recording**

Apart from their function as communication interfaces, Embedded PCs also serve to log all necessary process data. The system can also monitor and log the temperature via analog EtherCAT Terminals. An almost unlimited storage capacity is available for data logging via the USB interface of the Embedded PC.

The Switch  
Beckhoff Finland

[www.theswitch.com](http://www.theswitch.com)  
[www.beckhoff.fi](http://www.beckhoff.fi)

## converter



The permanent magnet generators (PMGs) from The Switch cover all wind power applications. Each PMG is designed with special magnet shapes and arrangements to match specific wind conditions for smooth operation and maximum efficiency. The directly driven, low-speed PMGs work without a gearbox, which results in an unequalled overall efficiency of the drive train.

The sturdy full-power converters from The Switch, which are designed for the highest performance demands in wind power generation, are virtually immune to disturbances or changes in the grid and enable adaptation to changing operating conditions due to the flexible design of the controller.



## converter



The Xiangyang wind farm, in Jilin province, produces 150 MW of power with a hundred 1.5 MW wind turbines.

In the main controllers, Renegy Electric employs Embedded PCs from the CX1020 and CX9001 series, standard digital and analog Bus Terminals, temperature measuring terminals and special terminals, e.g. for the measurement of power and voltage or for the measurement of all other relevant supply network data, as well as communication terminals.



## Renegy Electric

## Renegy Electric: PC-based controllers and converters for wind turbines from 1.5 to 5 MW

In recent years China has recorded strong growth in the field of wind energy, which is attracting an ever increasing number of investors. Unsurprisingly, this is accompanied with tough competition by technology providers. Renegy Electric Tianjin Ltd (REE), a newcomer to the Chinese market as a supplier of control systems, converters and pitch systems for wind turbines, has positioned itself successfully through the implementation of advanced PC-based control technology from Beckhoff.

Renegy Electric Tianjin Ltd (REE), with headquarters in Tianjin, China, has made a name for itself with complete solutions for the control of wind turbines. "Control solutions and components from REE are now used successfully in wind turbine designs by Aerodyn, the Shenyang University of Technology, DeWind and GH Garrad Hassan. More than 700 control systems, 500 pitch controllers and 100 converters from REE are now in use," explains Dr. Lijun Hou, CEO of Renegy Electric. "Although our company is still quite young, we have undergone aggressive development and we hope to develop our position on the international wind energy market as well within the next three to five years."

### Everything under control with innovative solutions

Close cooperation with controller suppliers from North America and Europe, such as Beckhoff from Germany and MLS from the United States, is crucial for the success of REE's high-end products. "Expertise and market experience in high voltage converters were built into the establishment of Renegy Electric and form the second column of our success story," states the CEO. "We began with research and development work even before founding the company in 2008," Dr. Lijun Hou explains. "The main controllers went into series production in May 2008, followed by the converters in January 2009." In the meantime, REE's product portfolio also expanded to include the pitch controller and a SCADA remote monitoring system for wind farms. The controllers can handle wind turbines with outputs ranging from 1.5 MW to 5 MW.

### Close cooperation leads to positive synergy

Cooperation with Beckhoff began as early as 2007. Dr. Lijun Hou, CEO of REE, states the reasons: "Due to the impressive price-to-performance ratio, versatile range of functions and high scalability and modularity, Beckhoff's PC-based control technology is ideally suited to fulfill our customers' requirements." In the main controllers, REE presently utilizes Embedded PCs from the CX1020 and CX9001 series, standard digital and analog Bus Terminals, temperature measuring terminals and special terminals, e.g. for the measurement of power and voltage or for the measurement of all other relevant supply network data, as well as communication terminals. The Beckhoff Embedded PCs are also used in the converters. REE uses a robust Beckhoff Control Panel with touchscreen for the control display.

The developers from Renegy especially appreciate the programming functionality of the Embedded PC systems. "As a lower-level computer, the converter must upload a large amount of data to the central computer, which is not a problem with the Embedded PCs. A further advantage is the Beckhoff Bus Terminal system's broad fieldbus support, e.g. for CANopen, EtherCAT and PROFIBUS, which ensures compatibility with different peripherals. On top of that, Beckhoff has accumulated extensive know-how through its many years of experience in the wind energy industry and is not only an expert partner with respect to general control questions, but also offers technical support for specific problems in the field of wind energy," says Lingling Zhou, development manager at Renegy Electric. "That is one of the main reasons why we decided in favor of Beckhoff technology. However, the service, the technical support and close cooperation with Beckhoff in the development of application-specific solutions represent considerable competitive advantages for us."

Renegy Electric Tianjin Ltd [www.relectric.cn/en](http://www.relectric.cn/en)  
Beckhoff China [www.beckhoff.com.cn](http://www.beckhoff.com.cn)

# Fuzzy controller revolutionizes power control in wind turbines

Simply put, modern wind turbines control the amount of power extracted from the wind by changing the rotor blade angle. The wind generates a lift force at the rotor blades which results in a rotary movement of the rotor. At wind speeds above around 12 m/s, the power at the rotor would exceed the rated output of the wind turbine and therefore has to be limited. To this end, the inflow angle of the wind is modified by adjusting the rotor blades, thereby reducing the rotor output. Robert Müller, Beckhoff Wind Team, gives an overview and an outlook of the technology.

Rotor blade angle modification		Acceleration						
		1	2	3	4	5	6	7
Rotor speed	7	3	5	5	6	6	7	7
	6	3	3	5	5	6	6	7
	5	3	3	4	5	5	6	6
	4	2	3	3	4	5	5	6
	3	2	2	3	3	4	5	5
	2	1	2	2	3	3	5	5
	1	1	1	2	2	3	3	5

Controlling the rotor blade angle system

The associated control loop is highly non-linear, primarily as a result of the aerodynamic behavior of the rotor blades. In modern wind turbines traditional PID controller are therefore supplemented with filters and additional functions.

## State-of-the-art controller parameter configuration

The critical parameters for the mechanical design of a wind turbine are the (wind) loads acting on the system. They form a spectrum of extreme loads and fatigue loads. The former can be reduced through intelligent operational management, the latter through careful parameterization of the speed controller.

The controller parameters are pre-configured as part of the load calculations for the wind turbine. A turbine computer model is subjected to standardized wind profiles in simulation runs. Competing optimization criteria have to be taken into account in the controller design. The optimization process can be complex and protracted, since several iteration loops are required before the optimum can be determined. The ideal that is determined in this way is still only a best possible compromise.

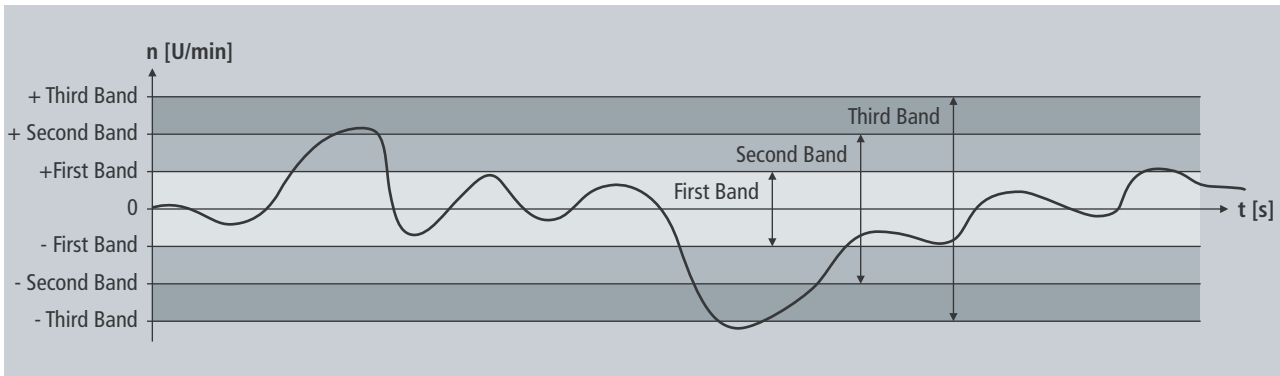
In addition to this pre-configuration, it is usually necessary to optimize the parameters determined in the simulation during the commissioning of the turbine. This process can also be rather complex, since the required wind speeds are not available ‚on tap‘ and only occur for a limited period of time, depending on the site.

## Anyone for a small revolution?

In contrast to the PID controllers that are still mainly used for wind turbines today, a basic characteristic of “fuzzy controllers” is that they are non-linear state controllers with a reputation for robustness. Using fuzzy controllers in wind turbines can have several benefits:

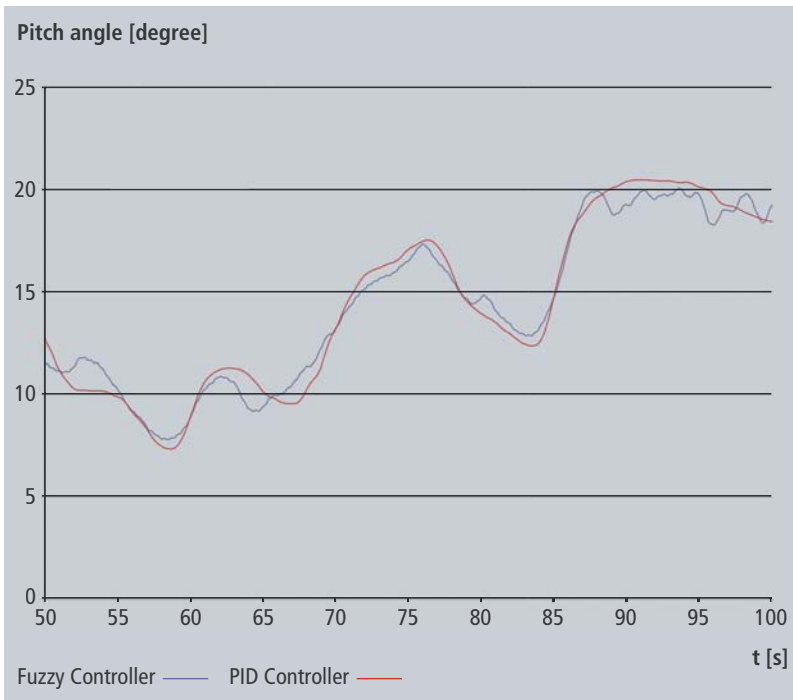
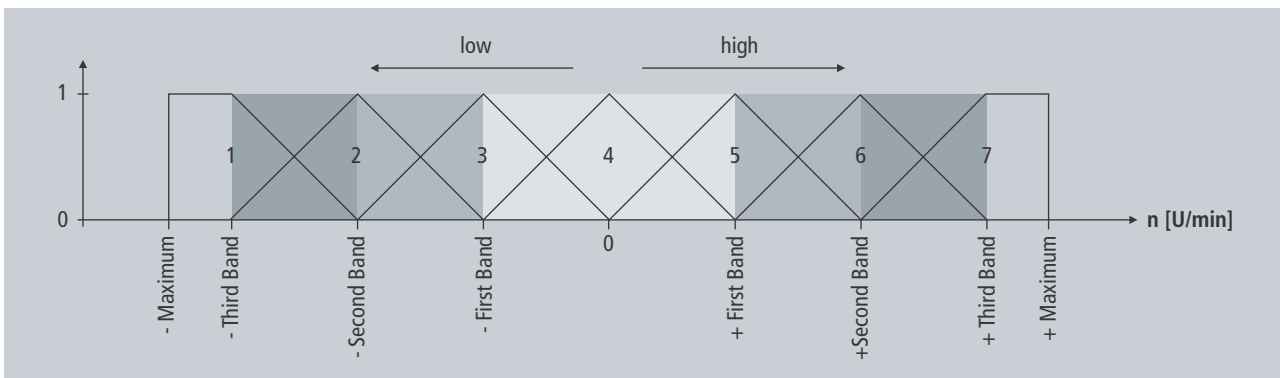
- | Reduced load calculation effort
- | Minimum effort for pre-configuration of the controller
- | No or minimum optimization effort in the field
- | Single controller for different turbine types (e.g. different rotor diameters or tower heights)
- | Increased energy yield in the transition range between part load and rated load
- | In a “best-case” scenario, a basic controller, once configured, can be transferred to other systems without further adaptation.

In practice, however, these benefits only become relevant if they don't result in increased system loads. If, on the other hand, a fuzzy controller was even able to reduce the loads as a kind of side effect, it would represent a small revolution in the control of wind turbines.



Speed ranges

Fuzzy sets for the speed deviation

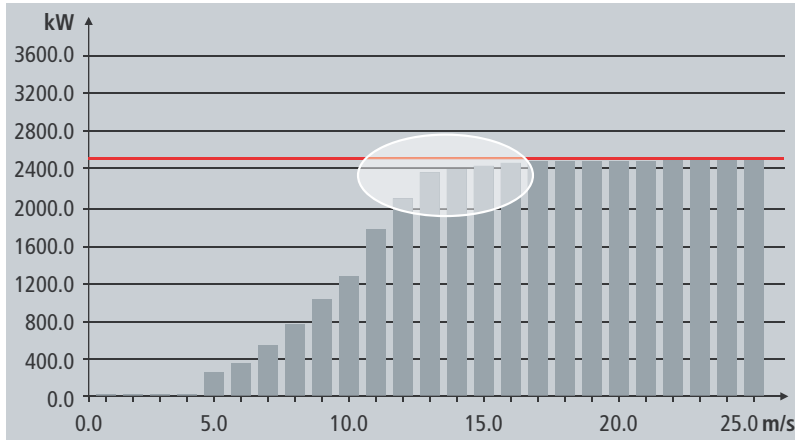


Set value specification for the rotor blade angle, comparison of a fuzzy controller and a PID controller

**TwinCAT integrates "fuzzy" solution**

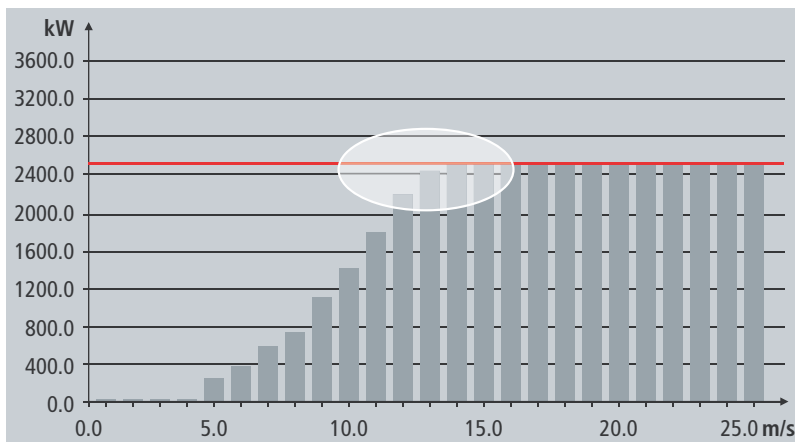
Based on the TwinCAT development tool, Beckhoff developed a fuzzy controller and implemented it into the operational management program of a wind turbine. The turbine is 2.5 MW direct-drive model, for which Beckhoff had already developed the operational management and control software (see also Avantis article on page 10). The programming language is Structured Text according to IEC 61131-3. The fuzzy controller is subdivided into the actual fuzzy algorithm consisting of the "fuzzifier," the decision logic and the "defuzzifier," and the rule base, which is defined and parameterized via structures. For parameterization of the input variables three ranges are specified for the rotor speed and the rotor acceleration. The output parameters are set via three ranges for the blade adjustment speed. The corresponding program code was encapsulated in a library.

Before the fuzzy controller was used in the actual turbine, the functionality and its effect on the loads were examined in detail. This examination was carried out by WINDnovation Engineering Solutions GmbH using the BLADED software tool from GL Garrad-Hassan. Using the same tool, WINDnovation had already undertaken the full load calculation and the pre-configuration of the conventional PID controller for the



Robert Müller, wind energy expert,  
Beckhoff, Germany

Performance curve comparison of a PID controller (above)  
and a fuzzy controller (below)



2.5 MW turbine. The results for the two controller types are therefore fully comparable.

#### Optimized load design, improved energy yield

The analysis showed that the fuzzy controller largely provided comparable results, in some cases even better results, although in some cases it led to significantly higher adaptation activity of the pitch system. Above the rated wind speed, the deviations of rotor speed and the generator output (i.e. the key control variables) from their specified set values were significantly lower, resulting in higher energy yield of the turbine (with comparable pitch adaptation activity).

Fuzzy controllers also lead to significant improvements in terms of the loads (for all load cases and system components). In some cases the fatigue loads were also significantly lower, with the exception of the tower. In terms of extreme loads, the differences between the fuzzy controller and conventional controller were small.

As part of the studies, no optimization of the fuzzy controller was

carried out, which would no doubt lead to further improvement. The fuzzy controller also demonstrated its robustness in trials involving significant 'provocative' modifications of the controller parameters.

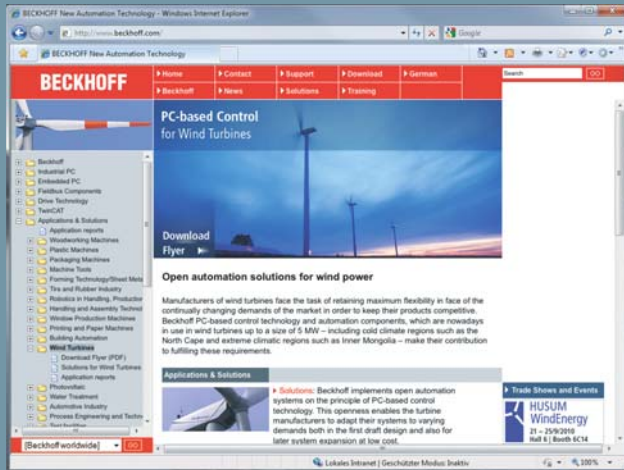
In summary, it can be noted that this controller types meets the above-mentioned expectations (even based on merely a pre-configuration of its parameters) and is clearly the ideal controller for wind turbines.

#### Outlook

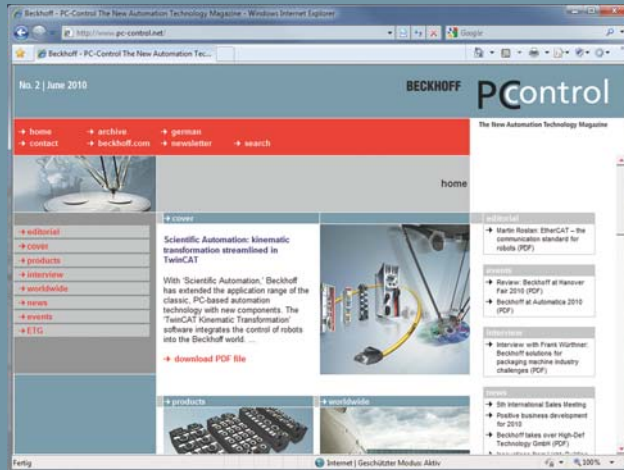
Future extensions of the fuzzy controller could include additional inputs for further improvement of the characteristics. For example, the wind speeds could be analyzed to determine a trend and enable anticipatory responses. Additional outputs could be used to enhance the functionality of the controller and enable greater intervention in the process. For example, the resisting moment of the generator could be used in a targeted manner to influence the speed. In addition, it is conceivable to combine the controller with a neural network, also referred to as a neuro-fuzzy system, for automatic optimization of the parameters.

# PControl

The New Automation Technology Magazine



www.beckhoff.com/wind



www.pc-control.net