PC-based Control for Wind 4.0
With PC- and EtherCAT-based control technology, Beckhoff implements system solutions that have been tried and tested worldwide: more than 45,000 wind turbines all over the world have been automated using Beckhoff technology, each providing up to 8 MW capacity. An Embedded PC with line-connected I/O modules, EtherCAT as universal communication system and TwinCAT automation software functions serve as the central control system. Robust hardware components and compliance with industrial communication standards provide optimum protection for your investment.

PC-based control: universal control platform for wind turbines

- Integrated control platform for operational management, pitch control, wind farm networking
- Flexibility in control system design
- Scalable performance
- Modular expandability
- Reduced hardware and engineering costs
- Increased efficiency and profitability
With a wealth of industry experience, the Beckhoff wind energy experts will provide support from control cabinet design to system commissioning.

All functions are run on a central CPU, from operational management, pitch control, visualisation and safety technology through to Condition Monitoring, remote access functions and wind farm networking. With outstanding flexibility in control system design, high scalability in terms of performance and a superior level of integration, PC-based control makes wind turbines more efficient and profitable. The modularity of the hardware and software portfolio enables users to configure a controller that exactly matches the performance requirements of their system and allows subsequent extensions and modifications, for example a retrofit of Condition Monitoring functions, without great expense. In the new TwinCAT 3 Wind Framework, Beckhoff created a software tool that transfers the concept of Industrie 4.0 to the wind energy industry and provides system manufacturers with optimum assistance in system programming.

The Beckhoff range of services is supplemented by control cabinet design, ranging from the creation of circuit diagrams to the manufacture of prototypes or series production.
One system solution for all control functions

An Embedded PC installed in the tower base acquires and processes all data, monitors the grid feed-in and communicates with the central control room. Safety and measurement technology as well as Condition Monitoring are seamlessly integrated into the controller via appropriate I/O modules. The converter in the base of the tower, the I/O system for operational management in the nacelle and the pitch controller in the hub are connected to the master controller via EtherCAT. Lower-level fieldbuses such as CANopen, PROFIBUS, and Ethernet TCP/IP can be relocated to the field via fieldbus master or slave terminals for the control of subsystems. The universal use of EtherCAT accelerates communication, and at the same time simplifies the project planning, programming and cabling of the wind turbine. Open hardware and software interfaces enable integrated communication from sensors to cloud systems.

**Pitch control**
Beckhoff offers a complete control solution for pitch systems: The DIN-rail-mountable Beckhoff Embedded PCs with line-connected EtherCAT I/O Terminals or IP 67-rated Box modules, are ideally suited to the collective or individual adjustment of the rotor blades. Encoder terminals for all types of blade pitch sensors are available as standard. Intelligent control routines reduce the loads acting on the system components resulting in a prolonged lifetime.

**Operational management**
For operational management in tower base and nacelle, a complete hardware and software solution programmed with TwinCAT 3 in IEC 61131, C/C++ and/or MATLAB®/Simulink® is available. Interfacing with higher-level control systems is based on internationally standardised telecontrol protocols. Servers that allow remote access to the control system are integrated into the Embedded PC. TwinSAFE enables the integration of the conventionally hard-wired, higher-level safety chain into the automation system. Communication between tower base and nacelle is implemented inexpensively and flexibly over fibre-optic cables using EtherCAT.
Safety input

Safety output

EtherCAT Box modules

Control Panel

Safety input

EtherCAT (fibre-optic cable)

Operational management (nacelle)

EtherCAT Terminal

DVI/USB

Control Panel

Operational management (tower base)

Converter

EtherCAT

EtherCAT (fibre-optic cable)

Wind farm networking

Big Data

EtherCAT (fibre-optic cable)

ADS, OPC-UA, IEC 61400-25, IEC 61850, IEC 60870-5-104, Modbus TCP

We reserve the right to make technical changes.
Producers of renewable energies are faced with the challenge to support grids in the event of voltage drops (Low Voltage Ride Through or LVRT). Wind farm networking with EtherCAT sets new benchmarks due to its high speed: in case of an LVRT, the setpoint values can be specified for all wind turbines in the entire farm network in less than 1 ms and the control of current, voltage, and frequency can be adapted efficiently. The existing fibre-optic-based EtherCAT fibre-optic cable (100BASE-FX) up to 2,000 m (multimode) or 20,000 m (singlemode)

Ultra-fast wind farm networking: with EtherCAT

- Ultra-fast wind farm networking
- Response times under 1 ms
- Current and voltage measurement with 10,000 samples/s
- Optimum protection against voltage drops
- Monitoring of heterogeneous wind farm environments through standardised communication protocols
Ethernet infrastructure can be used for this purpose up to distances of 20 km without a loss of speed. Even the synchronisation of the IGBTs of converters within a wind farm can be realised with this technology.

Wind farm networking with EtherCAT is not only faster compared to conventional Ethernet solutions, but also offers substantial cost benefits by eliminating the need for costly switches or hubs. With the EtherCAT power measurement terminal EL3783 integrated into the automation system, momentary current and voltage values can be measured at high frequencies with up to 10,000 samples/s. With EtherCAT “Distributed Clock” functionality, the measured values of all wind turbines and the measurement at the feed-in point of a farm can be synchronised to a timeframe smaller than 1 μs. TwinCAT supports the standardised IEC 61400-25 communication protocol for wind turbines, which simplifies the monitoring and control of heterogeneous wind farm system environments, including the connection to electric utilities.
The operation and maintenance of modern wind turbines incurs considerable costs. To maintain competitiveness, failure risks must be minimised, maintenance costs lowered and the availability and energy efficiency of the system increased. This is where Condition Monitoring enters the game: monitoring of gear units and generators is generally recommended, not just for offshore wind turbines or systems in remote regions.

System-integrated Condition Monitoring

- Time-synchronous data logging in << 1 μs
- Reliable data analysis
- Enhanced diagnostics
- Increased system availability
- Longer service life of wind turbines
- Reduced maintenance costs
- Reduced system costs
- Enhanced competitiveness
Beckhoff marries the powerful processors of modern PC technology together with EtherCAT as fast communication system, integrating Condition Monitoring functionality seamlessly into the controller. The vibrations of bearings or electrical machines are picked up by standard measurement terminals from Beckhoff and transmitted to the controller via EtherCAT. Configuration, programming and diagnostics are carried out within one system using TwinCAT.

With improved error detection and holistic system analysis capabilities, the control system-integrated Condition Monitoring from Beckhoff is superior to conventional hardware-based Condition Monitoring solutions. Through integration of further signals from operational management, including temperatures, pressures and current, among others, false alarms can be prevented and error detection is improved. Integration of Condition Monitoring into the central PC-based controller is advantageous, in particular where large amounts of data from different devices need to be analysed or if damage frequencies need to be evaluated in relation to the rotary speed. The controller acquires and processes the signals in the microsecond range.

However, cost reductions with regard to system, installation and maintenance also highlight the merits of system-integrated Condition Monitoring. Existing systems can be retrofitted simply and inexpensively.
Reliable Condition Monitoring: easily integrated in three steps

**Step 1**
Existing turbine control system

**Step 2**

High-frequency data acquisition via EtherCAT Terminals

For grid voltage monitoring, two EtherCAT Terminals are available from Beckhoff: the EL3783 power measurement terminal with oversampling function for status monitoring in a 3-phase AC network, and the EL1252 2-channel digital input terminal with timestamp function for the chronologically precise detection of binary control signals.

The retrofit of a wind turbine with Condition Monitoring can be realised by simply adding a terminal block with the corresponding EtherCAT measurement terminals to the turbine controller. A multi-functional input for analog measurement technology is avail-
Condition Monitoring hardware

EL3632: 2-channel analog input terminal for Condition Monitoring (IEPE)

Condition Monitoring software

Step 3

able in the EL3751 EtherCAT Terminal. The EL3632 enables the direct connection of various acceleration sensors via an IEPE (Integrated Electronics Piezo-Electric) interface and performs high-precision vibration measurement. Strain gauges (SG) can be evaluated via the EL3356-0010. The raw data are recorded synchronously (<< 1 µs) with other system data, such as power and speed, which increases the reliability of the data and reduces the number of false alarms.

A modular tool kit of mathematical algorithms for the analysis of measured values is available in the TwinCAT Conditioning Monitoring library. The library provides all essential functions for analysis, statistics and classification. In addition to spectral analysis via FFT, or using, for instance, an envelope spectrum, it is possible to calculate key statistical values such as the kurtosis or the crest factor. Combining these algorithms with limit value monitoring is for instance, ideally suited to monitoring roller bearings.

Alternatively, status data can be analysed with user-specific Condition Monitoring software or that of a third-party vendor, which can be integrated into the Beckhoff control platform via an open interface such as OPC. If component-related threshold values are exceeded, the Condition Monitoring system triggers alarms to inform the system operator about wear, imbalances or impermissible operating states. These alarms can be reported for further processing directly to the system controller or other operator systems. In addition, the continuous machine monitoring can be carried out online. Trends in the characteristic values are analysed and translated into recommendations for action, for example in the planning of maintenance intervals.
The TwinCAT 3 Wind Framework bundles the industry expertise that Beckhoff gained in the automation of more than 45,000 wind turbines and makes Industrie 4.0 concepts available to the wind energy industry. The modular software package includes all necessary functions and tools for the modern and efficient engineering of wind turbines. All basic functions are encapsulated as TwinCAT modules in simple to use function blocks in TwinCAT 3 and provide a modular range of components for the programmer to choose from, simplifying the development of the application software. Apart from basic
functions for operational management and state machine, there are software function blocks for event management, parameter configuration, user management, data connection, power and Condition Monitoring and simulation. The integrated “Big Data” database link enables the comprehensive acquisition, evaluation and provision of data from operational management, Condition Monitoring and power management in real-time. All data are continuously recorded, summarised in the central controller and analysed in detail. This way, for example, signs of wear in individual components of the wind turbine that could lead to operational failure are detected at an early stage, thus increasing the availability of the system.

The ready-made software modules and application templates are tried and tested and offer high quality and future security. In the same way as modifications to the hardware, individual software modules can be added or removed. This makes engineering as simple as possible and the developer can focus on the actual system functions. The development process is also optimised by distribution across the team: development and tests on customer-specific modules can be carried out in parallel, thus further reducing the time-to-market.

The consistent use of the TwinCAT modules and the uniform architecture of the subsystems create an application standard. This standardisation enables programmers to quickly familiarise themselves with the application and the source code, even if it was implemented by another programmer.
Maximised flexibility: modular engineering for modular wind turbines

The TwinCAT 3 Wind Framework is facilitated by a library and an application template. The library provides all functions of the Wind Framework as PLC function blocks. The application template provides a modular architecture for the operational management software for wind turbines in the form of a PLC project, in which all required functionality of TwinCAT modules and functions is implemented.

Each subsystem of the wind turbine (such as pitch, gear unit, generator, converter, etc.) is represented by a self-contained object. In this way the subsystems can be developed, used and tested independently. As a result, the subsystem software modules are interchangeable, as is already common practice in the mechanical modularisation of systems. This increases the quality, flexibility and reusability of the software, while at the same time reducing development time and costs.

The different operating modes for starting, stopping and the higher-level state machine of the system are consolidated in the application template as Supervisory Control...
and implemented in simplified form as PLC function blocks. This results in higher-level set values for operating the system, which are used for control purposes.

General control functions of the wind turbine, such as pitch and torque control, are prepared in the software as Operational Control. For general control purposes, the integration of further modules is possible, for example to integrate algorithms for load calculation. These options include the automatic generation of a TwinCAT module from MATLAB®/Simulink® or the integration of control algorithms via C/C++. Thus, the same controller that was used for load calculation can also be used for general control purposes. The controller does not have to be translated beforehand into a second programming language, eliminating the need for error-prone implementation of the algorithms.

On top of that, an adaptive simulation of the wind turbine is integrated into the application. This enables testing of the entire operational management within the development environment. The model can be adapted and configured to match the individual system. The system simulation is provided as a TwinCAT module, although just like the control application itself, it is ready to be replaced by a specific model from MATLAB®/Simulink® or C/C++, as required.

The simulations integrated in the application can be used to map, analyse and verify the processes of the whole system, the operating modes and also individual subsystems. Each subsystem can be operated separately and independently, by switching between the simulation and the actual hardware. In this way, it is possible to activate nacelle components, for example, on the factory floor for testing. In addition, test benches can be configured for software-in-the-loop or hardware-in-the-loop simulations and even for training sessions using the original application software. Real-time simulations enable rapid control prototyping and virtual commissioning with a single version of the software, enabled by simple parameter modifications.

The application template provides a complete operational management software.

The uniform architecture for the integration of subsystems creates a standard in the application and enables quick familiarisation by programmers.
Big Data

Optimised processing, availability and evaluation of all relevant data in real-time for wind turbine operators and manufacturers

- Data acquisition and Data Warehousing
- Data analysis and Data Mining
- Power and Condition Monitoring

Communication

Secure vertical and horizontal communication

- Support for all common bus systems (EtherCAT, Ethernet, PROFIBUS, etc.)
- Comprehensive messaging/connectivity (ADS, OPC UA, live diagnostics, etc.)

Engineering

Universal and integrated engineering throughout the wind turbine life cycle

- IEC 61131-3, C/C++, MATLAB®/Simulink®
- Object orientation, modularisation
- Data exchange between engineering tools
- Automated engineering

TwinCAT 3 Wind Framework

Covering all functions: generic TwinCAT modules for higher-level services
Operational Control is implemented as a stand-alone TwinCAT module, and the subsystems are implemented as independent objects.

The generic TwinCAT modules provide higher-level services. Each module is ready for use and only needs to be integrated in TwinCAT 3 as a TcCOM module. The modules can be used separately and independently of each other or in combination, in order to facilitate interaction and data exchange.

The Status module supports the monitoring of all components and enables error detection, event management, error handling and reporting. Status objects are created that represent an event and are used to display messages, warnings or errors. A system stop can optionally be configured as a response to specific events, and also event-triggered high-resolution logging of system data or sending of notifications. Events are evaluated by the Status module and the corresponding reactions are generated. In addition, each event is logged in the database and provided with a timestamp; this enables the frequency and duration of the occurrence of each event to be determined and conclusions to be drawn about the operation or level of availability of the system.

The Parameter and Command modules provide services for configuration and interaction with the application. A Parameter object can assume any value of any data type. For example, temperature monitoring limits can be implemented in the form of two Parameter objects, whose values indicate the minimum and maximum temperature or are used for switching the heating on or off. In this way, the entire wind turbine configuration can be mapped and modified, saved and reloaded via parameters. Command objects can be used to trigger or activate actions in the application. Each interaction, for example via a switch at the control cabinet door or a button from the visualisation, can be implemented via a Command object.

Signal logging and a statistical analysis is provided by the Capture and Mean modules. Raw data are flexibly recorded via Capture objects. Initial evaluations for subsequent diagnostics are carried out in real-time. In this way, it is possible, for example, to monitor a unit and its behaviour and to read out the switching frequency and operating time.

The integrated user management tests and logs all interactions by the user. In this way it is possible to specify during the programming phase which rights are required to use each function. These user rights are checked in the application. Thus, the operational management automatically ensures correct user access, independent of an external user management.
Optimises reliability and prolongs the lifetime of wind turbines: Big Data

All information from the various TwinCAT modules is continuously transmitted in real-time to the database module. It is then saved in the database, or retrieved from it, via SQL procedures. The TwinCAT 3 Database Server manages the data in the database.

Interfacing with the SQL database through the database module and the TwinCAT 3 Database Server enables efficient and compact data management based on a uniform, familiar format. Logging of all events and signals, and storing and loading the entire configuration of all objects enables detailed analysis. Any pre-processing required is carried out by the TwinCAT modules in real-time. For instance, the Mean module calculates mean values consistently in each application cycle, and each value from each cycle is used for average calculations. The Capture module evaluates the scanning of values and integrations in each cycle, in order to make calculation as accurate as possible. Logging and pre-processing of all data in real-time, followed by a reliable transfer to the database, enables evaluation on demand and outside of the operational management. Based on this historic data, it is possible to detect state changes and the causes of faults, create detailed statistics and ultimately optimise the system.

The database is organised in such a way that the data from individual or multiple systems can be collected and managed within a single database. In this way, the data can simply be merged using predefined procedures in order to prepare for higher-level analyses and comparisons. If the data from all systems are consolidated on a central company server or in the cloud to form a Data Warehouse, it is possible to store the data permanently over the complete lifetime of the systems. Such huge data volumes from any number of systems, which are generated in real-time and are accumulated on central servers, can generally be referred to as “Big Data”. Big Data applications are a further building block towards Industrie 4.0, supported by the option to integrate additional data from wind farm management or from monitoring and measuring systems. Uniformly accessible, these data facilitate extensive and automated evaluation. They can be used to detect faults or irregularities, create statistics and optimise the operational management, and also for condition-based monitoring and predictive system maintenance. Data Mining can be used to gain new insights into system operation. For example, it may be possible to determine relationships between component wear and their switching frequency and operating cycles, allowing components to be replaced before a costly failure occurs.

Data from all TwinCAT modules are provided in a SQL database by the TwinCAT 3 Database Server.

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During important events, critical signals are recorded in a high-resolution trace.

All system data can be consolidated on central servers for higher-level analysis.

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Xinjiang Goldwind Science & Technology Co., Ltd., Urumqi, China

PC-based control of 1.5, 2.5 and 3 MW wind turbines without gearboxes

Industrial PC: Embedded PC CX1020
I/O system: EtherCAT/PROFIBUS
  PROFIBUS Bus Coupler BK3150
  PROFIBUS Bus Terminal Controller BC3150, BX3100
  Bus Terminals
  EtherCAT Terminals

Software: TwinCAT PLC

www.goldwind.com.cn

Guandong Mingyang Wind Power Technology Co. Ltd, China

PC- and EtherCAT-based control platform for 1.5 and 2 MW wind turbines

Industrial PC: Embedded PC CX1020
  built-in Control Panel CP6901
I/O system: EtherCAT Terminals
  Bus Terminals
  TwinSAFE Terminals

Software: TwinCAT PLC

www.mywind.com.cn/English

Zhejiang Windey Co. Ltd., Hangzhou, Zhejiang, China

PC- and EtherCAT-based control platform for 5 MW aeroMaster

Industrial PC: Control cabinet PC C6930
  Embedded PC CX2030
  15-inch-multi-touch built-in Control Panel CP2915
I/O system: EtherCAT Terminals
  TwinSAFE Terminals

Software: TwinCAT 3
  TwinCAT 3 Wind Framework

www.chinawindey.com/en/about.aspx
www.aerodyn.de/company

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Areva Wind GmbH, Bremerhaven, Germany

PC- and EtherCAT-based control platform of the M5000 5 MW wind turbine and wind farm networking for the first German offshore wind farm (Alpha Ventus)

Industrial PC: Control cabinet PC C6515
Embedded PC CX9020
built-in Control Panel CP6832
I/O system: EtherCAT Bus Coupler
Bus Terminals
Software: TwinCAT PLC

www.areva-wind.com

Further references

- Guodian United Power Technology Co., Ltd, Jiangsu Province, China
- DeWind Europe GmbH, Lübeck, Germany
- Vensys Energy AG, Neunkirchen, Germany
- Alstom Group, Levallois-Perret Cedex, France
- LEITWIND AG/SPA, Sterzing, Italy
- Renewtech LLC, Elbow Lake, MN, USA

Pitch
- Atech Antriebstechnik GmbH, Mehring, Germany
- Dongfang Electric Corporation (DEW), Chengdu, China

Brakes
- Svendborg Brakes A/S, Vejstrup, Denmark

Converters
- TheSwitch, Vantaa, Finland
- Vensys Elektrik, Diepholz, Germany

Obstacle light
- Enertrag AG, Dauerthal, Germany

Condition Monitoring
- 8.2 Monitoring GmbH, Hamburg, Germany
- KONČAR Electrical Engineering Institute, Inc., Zagreb, Croatia
- GfM Gesellschaft für Maschinendiagnose mbH, Berlin, Germany
- Zensor, Brussels, Belgium

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Beckhoff – New Automation Technology

Beckhoff implements open automation systems using PC-based control technology. “New Automation Technology” from Beckhoff stands for innovative and industry-independent control and automation solutions that are used in a wide variety of applications worldwide, ranging from CNC-controlled machine tools to intelligent building control and to wind turbines. Continuous technological development, economic growth, high-level vertical integration, and extensive production capacities ensure the industrial strength of our components, long-term availability and delivery reliability that our customers value.

Beckhoff at a glance

- Headquarters: Verl, Germany
- Sales 2015: 620 million € (+22 %)
- Staff worldwide: 3,000
- Branch Offices Germany: 14
- Subsidiaries/Branch Offices worldwide: 34
- Distributors worldwide: in more than 75 countries

(As of 4/2016)

www.beckhoff.com
Worldwide presence on all continents

The worldwide presence of Beckhoff in more than 70 countries ensures fast service and support for globally-operating customers in their local language. Moreover, geographical proximity helps us develop an in-depth understanding of the technical challenges our customers are faced with around the world.

Further information

The web pages “PC-based Control for Wind Turbines” offer further information, e.g. application reports or industry-specific solutions. ► www.beckhoff.com/wind

The Beckhoff catalogs and flyers are available for download on the Internet. ► www.beckhoff.com/media

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