From prototype to series production: Multibrid M5000 for offshore applications

PC Control for an offshore wind farm

Multibrid GmbH never bothered with onshore wind farms: the 5 MW M5000 turbine was designed for offshore wind energy applications from the outset. Multibrid revised the control scheme in close cooperation with Beckhoff and based it on an integrated platform for the mass production of these turbines.

M5000 specifications

Rated capacity:	5 MW
Rotor diameter:	116 m
Rotor speed:	4.5 – 14.8 rpm
Maximum blade speed:	90 m/s
Offshore hub height:	90 m (prototype 102 m)
Head weight/swept area:	< 30 kg/m^2

Multibrid developed the first prototype of its wind turbine back in 2004, although it took another three years before it was ready for series production. Assembly of the Multibrid M5000 with a rotor diameter of 116 meters and a hub height of 90 meters started in mid-2007 at Multibrid's own production facility at Bremerhaven, Germany.

When project manager Bernd Zickert joined the company in 2005, he found a typical technical situation: The control and automation systems for the turbine were not based on an integrated platform. The hardware components came from four different manufacturers, which meant that the Multibrid engineers had to familiarize themselves with diverse systems. Coordination of the components and data acquisition were also problematic.

For Multibrid's prototype this internal diversity made sense, because it was intended to demonstrate resilience of the design and form a basis for the final decision on series production. To this end, the company had to test various options. The first field test for the M5000 took place two years earlier. This test showed that the approach basically passed. The next challenge for Multibrid was to prepare for series production and offshore operation.

The prototype was tested through detailed simulation of the complex environmental influences affecting a wind turbine, including a wide range of possible fault and malfunction scenarios (hardware-in-the-loop). "For the simulation we created an exact model of all system interfaces," said Bernd Zickert. "We were able to implement further developments for improving system performance." The focus was on system feasibility in terms of production, installation, operation and service. In 2008 Multibrid intends to build up to 13 systems, six of which are scheduled for the Alpha Ventus offshore wind farm (see page 39). Alpha Ventus is the first German offshore wind farm on the high seas. It is a pioneering joint project in which E.ON Climate & Renewables, EWE and Vattenfall Europe New Energy are all involved.

Low-wear technology minimizes system failures

The Multibrid design is ambitious. Unlike most other wind turbine manufacturers, Multibrid uses permanent magnet synchronous generators. While most electricity suppliers use synchronous generators, the wind industry tends to prefer asynchronous (induction) generators. Multibrid's decision to use a multi-pole synchronous generator with a ring design means it is based on proven technology and has the additional advantage of significantly less wear. This provides major benefits, particularly for offshore operations where service, maintenance and repairs are much more difficult than onshore, especially during periods of poor weather. Any equipment or feature that is less prone to faults and failures helps make the turbines more reliable.

Less weight facilitates construction and installation

To facilitate transport and ensure safe and fast installation, a key design requirement for the M5000 was minimized weight of the nacelle and the rotor. Multibrid placed a single-stage gear unit between the rotor and the generator, which reduced the speed variance of the rotor by a factor of almost 10 : 1. The generator

The production facility at Bremerhaven, Germany has direct access to a port for transport by ship.

is linked to the grid via a four-quadrant inverter, which enables variable-speed operation. At the same time it meets the requirements stipulated by grid operators for advanced wind turbines. With this design Multibrid reduced the total weight of the rotor, hub and nacelle to around 310 t.

Despite the high rated capacity, Multibrid turbines are very compact: The two-level nacelle is only 7 meters high and 10 meters long, making the system significantly smaller and lighter than comparable units. This has several advantages: The tubular steel tower, which rests on tripod foundations, can be dimensioned differently. The nacelle can be pre-assembled on land and installed at sea as a complete unit.

A key requirement for offshore operation is hermetic sealing of the nacelle: an air treatment system separates salt and water particles from the ambient air and generates a positive pressure in the nacelle, which keeps out the aggressive sea atmosphere and protects the sensitive control elements from corrosion.

Integrated control platform simplifies system management

The revision of the control and automation system carried out by Bernd Zickert and his team simplified the system. The number of controllers was reduced from five to two. In addition to the main computer in the tower, there is a hub computer that provides redundancy and prevents data loss during transfer via the slip ring coupling.

The complete hardware platform was converted to Beckhoff components, creating an integrated control system that offered coordinated and simpler handling, interfaces and data flows. The system processes no less than 500 digital and analog signals. This is particularly beneficial when it comes to service and maintenance: the service technicians only have to familiarize themselves with one operator guidance system, which drastically reduces the training and commissioning effort.

Multibrid

Multibrid was established in 2000. The company develops and builds the Multibrid M5000 offshore wind turbine. In collaboration with suppliers, a team of specialists for all key system components continuously develops and enhances the Multibrid technology. Through the affiliation of the Prokon Nord Group, Multibrid technology can draw upon long-standing experience with wind farm implementations.

The project design company Prokon Nord ventured into the offshore sector at an early stage and designed three wind farms in the North Sea and off the coast of Normandy, the latter featuring 181 turbines with a capacity of 5 MW each. Prokon's involvement was very useful: backed by large demand, the new development was economically viable. The involvement of the French energy company Areva, which acquired 51 percent of the Multibrid shares in September 2007, provided a secure financial basis for Multibrid. The company was able to turn a good idea into good business. Meanwhile, Multibrid production is up and running.

M5000 control architecture

Control system

- Main computer: CX1020 Embedded PC with Windows XP
- Hub computer: CX9000 Embedded PC with Windows CE
- Automation software: TwinCAT PLC

HMI

- Built-in Control Panel CP6832

I/O

- Bus system: EtherCAT (PROFIBUS with EtherCAT Terminals)
- I/O systems: Bus Terminals/EtherCAT Terminals
- I/O terminals:
  - Various digital/analog I/Os
  - Power measurement terminal
  - Relay terminal
  - SSI angular measurement terminal
  - Incremental encoder interface
  - Serial interface

The M5000 test stand is used primarily for reducing the time for function tests and commissioning and for optimizing the operating procedures and control processes.

Open system philosophy facilitates further development

In order to minimize the effects of possible component failures, the sensors, actuators and auxiliary systems are also designed for redundancy. This particularly applies to the air treatment, oil supply and hydraulic systems, the battery chargers for the hub and the cooling system.

PC-based control technology ensures openness of the system. Multibrid engineer Zickert regards this as a particularly significant feature, because it offers scope for further development of the control and automation system: "After all, we operate in a highly dynamic sector that is constantly changing." Third-party equipment can easily be integrated via the available interfaces. The openness of the system also enables integration of I/O terminals with new functionalities.

The fact that the TwinCAT control software from Beckhoff is based on the Windows standard simplifies operator guidance and ensures compatibility with conventional user interfaces. This also has positive effects on the visualization of the data streams and information provided via a SCADA system. The control system offers secure access on site and in the control center by multiple users. Parameters can be modified and adapted to specific requirements. The error analysis capability of the system is improved. The system is monitored in real-time via the Internet Protocol over an optical fiber cable.

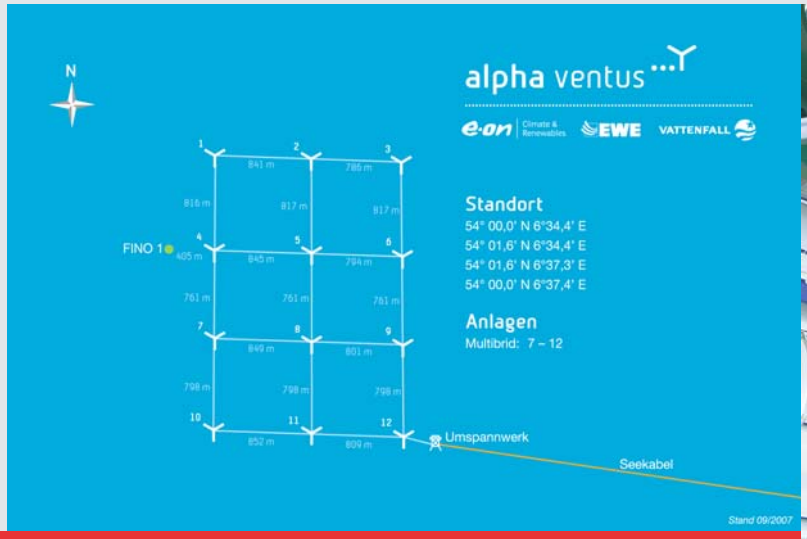
An integrated ORACLE database system can store data offline for up to 50 days (in the event of system communication malfunctions, for example) before forwarding them to the control center. The storage capacity depends on the size of the flash card used. The system stores all data that are relevant for managing the wind farm, including operational data (10-minute mean values, trace, counters), error log analysis, power curve, production, reactive power, internal consumption and mode.

Comprehensive and complex simulation ensures quality

Of particular significance is the quality of the simulation software developed by the Multibrid team in close cooperation with ISET (Institut für Solare Energieversorgungstechnik, University of Kassel, Germany). It enables real-time simulation of the system states and data exchange via TwinCAT. Beckhoff supplied the associated hardware and was involved in the development of the SCADA system.

The test stand is used for initial plausibility checks for theoretical assumptions and concepts as well as staff and customer training. In addition, Multibrid developed it into an efficient and effective quality assurance tool: All system control components are mapped on the test stand. The system is able to simulate all actuators and sensors, as well as the communication with the turbine control equipment. In this way, the functionality of the control system and other systems can be fully tested in advance of installation. Rather than having to install components with unproven functionality under difficult conditions at sea, the quality of the components and subsystems can be ensured before delivery. This is also beneficial for the installation of updates and retrofit measures, which no longer have to be field-tested as beta versions, but can be installed with extensive function tests included.

→ Multibrid GmbH **www.multibrid.com**



Alpha Ventus: first German wind farm in high seas

The Alpha Ventus offshore wind farm is a pioneering joint project in which E.ON Climate & Renewables, EWE and Vattenfall Europe New Energy are involved. It is located on the North Sea, around 45 kilometers (28 miles) north of the island of Borkum, at a water depth of 30 meters (98.4 feet). Alpha Ventus is the first German wind farm to be built on the high seas under real offshore conditions. The design, construction, operation and grid integration of the Alpha Ventus research project will provide highly valuable insights for the future commercial utilization of offshore wind farms.

The 2008 project schedule includes construction of the southern half of the wind farm with six Multibrid M5000 turbines and the offshore substation. The wind farm is expected to be connected to the grid in autumn 2008. Construction of the northern half of the wind farm with six further turbines of a different type is scheduled for summer 2009.

The wind turbines are prefabricated on land as individual components. The nacelle, rotor blades, tower segments and foundation structures are assembled at sea into a complete wind turbine.

The 12 turbines will be spread over an area of 4 square kilometers (1.5 square miles). They will be positioned in the form of a rectangle, with four parallel rows (from north to south) of three turbines each. Within this grid-like formation, the turbines are spaced with a distance of around 800 meters (approx 0.5 miles) from each other.

The Multibrid M5000 turbines are anchored to the seabed with tripod-type foundations. The water depth at this location is around 30 meters (98.4 feet). To reach around the triangular 255 m² footprint of a tripod would require 56 men. The 1,000-ton weight of a turbine is equivalent to around 200 fully grown elephants or 22 railway wagons. The area swept by the rotor is around one and a half times the size of a soccer field. At the maximum rotational speed of the rotor, the blade tips cut through the air with around 300 km per hour (186 mph).

The average wind speed at the location is 10 meters per second (m/s), which corresponds to a 5 on the Beaufort scale of wind force (19 – 24 mph or 30 – 39 km/h). The designers expect the farm to operate at full capacity for around 3,800 hours per year. For comparison: good onshore locations offer around 5 m/s and 2,200 to 2,500 full-capacity hours.

Alpha Ventus key data

- No. of turbines: 12
- Total capacity: 60 MW
- Expected energy yield/year: approx. 220 GWh (= annual consumption of approx. 50,000 3-person households)

→ **www.alpha-ventus.de**