# ENERCON technology & service

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**Introduction**

ENERCON has been among the top producers of wind energy converters for nearly 30 years now. Two of the key contributing factors to the company’s success are innovation and quality. Both highly developed vertical integration and a comprehensive quality management system play a significant role in securing ENERCON’s high quality standards.

Through constant product enhancement and sophistication of the turbine components, ENERCON’s main objective is to provide its customers with state-of-the-art products. A tight-knit team of engineers specialised in various fields is constantly working on setting technological benchmarks in terms of new turbine generations in to consolidate ENERCON’s leading position in the German market.

An efficient development organisation provides the basis for developing successful new products. ENERCON uses the latest research methods and tools for the strategic process of developing innovative and profitable technologies. At ENERCON, developing new products is an essential factor of the business, however much emphasis is placed on further enhancing and refining existing serial machines. The objective is to develop and build on the company’s expertise as well as to continue expanding its core competencies.

Elaborate simulation and test stations at ENERCON’s research centre allow precise advanced testing on new turbine components, providing customers with a reliable product which fulfils the highest of quality standards.

The production of cast parts is an excellent example of how well tuned the development and production of ENERCON wind energy turbines is. Constant further development of the individual cast parts is performed with 3D CAD systems which assist the developers in verifying overstress and critical areas by means of the finite element method. Production processes are not launched until comprehensive quality tests have been completed – a strategy which has been successfully adopted by ENERCON’s exclusive production plants since 2009. The company is therefore distinguished by outstanding quality and a high degree of vertical integration.

Thanks to its technological innovations, ENERCON maintains a cutting edge in a wide range of disciplines. An example of this is the ENERCON grid management system. By means of an intelligent control system. ENERCON wind energy converters already contribute highly to maintaining and improving grid stability and can be easily integrated in any grid structure worldwide.

Not only can ENERCON turbines be conveniently integrated in various grid configurations, they can also be efficiently adapted to meet extreme climatic conditions. With modified components and a sophisticated rotor blade de-icing system, the development of wind turbine installations at both hot and cold sites can be advanced without fears of operations being limited by the weather.

Finally, ENERCON also transfers its know-how in terms of energy efficiency to other applications. New solutions and further developments within ENERCON’s own research network are the dynamic impetus of the company’s innovative strength.
ENERCON
turbine technology

[Aurich]
ENERCON turbine technology

The performance and reliability of the gearless drive system combined with an efficiently streamlined rotor blade design provide for optimal returns on investment.

Rotor blades

When it comes to yield, noise emission and stress minimisation, ENERCON’s rotor blade concept has set new standards in the wind energy sector. Due to their modified shape, the blades now not only draw energy from the outer edges of the swept area but also make more efficient use of the inner radius – considerably increasing power output. The new rotor blades are also less susceptible to turbulence and provide an even flow of air along the entire length of the blade profile.

In addition to the new design, the blade tips have also been improved to reduce noise emission and increase power output. Turbulence at the blade tips caused by over and underpressure is effectively eliminated in the rotor plane. The entire length of the blade is therefore utilised without energy loss resulting from turbulence. In order to withstand extreme wind loads during the entire lifespan of the machine, ENERCON rotor blades are engineered with a large flange root. The double-row bolt connection specially developed by ENERCON for large wind turbines also provides additional strength by creating even load distribution. The safety of turbines with longer rotor blades is further enhanced by sensors at the blade root, enabling the turbine to react to extreme loads. These are important factors, particularly in locations with extreme wind and considerable load fluctuations.

ENERCON rotor blades are manufactured using a vacuum infusion system and the so-called sandwich technique. In a final step, the rotor blades are finished with a special coating in order to efficiently protect their surface from weathering.

Advantages of ENERCON rotor blades
- High efficiency and little sound emission due to an efficient blade shape incl. tips
- Longer service life due to reduced loads
- More convenient transport for streamlined blade profiles and divided blade variants

Direct drive

The drive system of ENERCON wind energy converters is based on a basic principle:

Fewer rotating parts reduce mechanical stress and increase the machine’s lifespan. Wind turbine maintenance and service costs are reduced (fewer wearing parts, no gear oil change, etc.) and operating expenses lowered. The rotor hub and the rotor of the annular generator are directly interconnected to form one consolidated unit. The rotor unit is mounted on a fixed axis, the so-called axle pin. Unlike conventional geared systems with a large number of bearing points in a moving drive train, ENERCON’s drive system only requires two slow-moving rolling-element bearings; the reason being its low direct drive speed.
Annular generator technology

Amongst other features, the annular generator is a key component in ENERCON’s gearless wind generator design. Combined with the rotor hub, it provides an almost frictionless flow of energy, while a smaller number of moving components ensure minimum material wear.

Unlike conventional fast-running generators, ENERCON’s annular generator is subjected to little mechanical wear, making it ideal for particularly heavy loads and guaranteeing a long service life. It is a low-speed synchronous generator with no direct grid coupling. Output voltage and frequency vary with the speed and are converted for output to the grid via a DC link and inverter which allow for high speed variability.

Stator and rotor

According to ENERCON’s service life requirements, the copper winding in the stator (the stationary part of the annular generator) is produced in insulation class F (155 °C). Because this resembles basket weaving, it is also called closed, single-layer basket weaving. It consists of individual varnish-insulated round wires gathered together in bundles. At ENERCON, the copper winding is exclusively done by hand. In spite of increasing automation in other manufacturing areas, there is a good reason for relying on manual labour in this instance.

It ensures that all materials are thoroughly inspected. Furthermore, a special work process allows continuous windings to be produced. Each individual wire strand is continuous from start to end.

ENERCON wind energy converters are based on a gearless turbine design that uses an annular generator with separate excitation. The magnetic fields required to generate electrical power are created electrically, so permanent magnets containing the controversial rare earth element neodymium can be dispensed with.

The magnetic field of the stator winding is excited by means of the so-called pole shoes. These are on the rotor - the rotating part of ENERCON’s annular generator. Since the shape and position of the pole shoes have a decisive influence on the generator’s noise emission, ENERCON’s Research & Development department has devoted particular attention to this aspect. Because the pole shoes are precisely adapted to the slow rotation of ENERCON’s annular generator, there is virtually no tonal noise.

Quality assurance

In order to ensure ENERCON’s high quality, all annular generators are manufactured in the company’s own production facilities. Superior-quality materials are always used. Close collaboration with suppliers has proven to be the most reliable way of providing top material quality. For example, the varnished copper wires are subjected to more testing than is specified in the standard. Samples of these are archived, while surge voltage tests are performed on the pole shoes and chokes and then documented in the computer system.

Temperature behaviour

ENERCON’s annular generator features optimised temperature control. The hottest areas in the generator are constantly monitored by numerous temperature sensors. The sensors’ activation temperature is considerably lower than the temperature resistance of the insulating materials used in the generator. This prevents overheating.

Advantages of ENERCON’s annular generator

- Gearless
- Little wear due to slow machine rotation
- Little mechanical stress due to high level of speed variability
- Yield-optimised control
- High power quality
- No use of permanent magnets with rare earth metals
- Continuous winding

Copper pole shoe windings for the rotor

- Enamelled copper wire [200 °C]
- Impregnating resin [180 °C]
- Insulation class F [155 °C]
- Copper conductor
- Impregnating resin
- Superficial insulation
- Winding surface

Temperature

Limit temperature
Actual temperature
Tower construction

The load-dynamic design of the materials and structure used in ENERCON towers provides the best conditions for transport, installation and use. Over and above the binding national and international norms (e.g. DIN and Eurocode), ENERCON sets its own standards which raise the bar in terms of quality and safety.

Virtual 3D models of the tower designs are produced during the development phase using the finite element method (FEM). All possible stress factors on the wind turbine are simulated on the model. This means that accurate predictions concerning tower stability and service life are not left to chance before building a prototype.

ENERCON continuously evaluates additional measurements on existing turbines for further verification of the calculated data. ENERCON’s calculations are verified through results produced by specially commissioned certification bodies, research institutes and engineering firms.

Aesthetic considerations are also a decisive factor during tower development, and are obvious in the finished product. The streamlined, gradually tapered design offers a visibly sophisticated concept which has next to nothing in common with the huge and bulky conventional cylindrical structures.

Precast concrete towers

ENERCON concrete towers are not manufactured as a monolithic construction. The towers are made up of individual precast concrete segments, with a steel section positioned at the top of the assembled tower. Concrete segments with large diameters are produced in two or three shells so that they can also be transported to locations otherwise difficult to reach.

After all segments and sections have been assembled, the bottom steel section, the concrete segments and the foundation are joined together and tensioned during prestressing tendons to form one solid unit.

Produced in accordance with strict quality control requirements, the plane parallel precast concrete segments are manufactured at an ENERCON production plant nearest the installation site. The high quality of the individual concrete segments is guaranteed through the use of unique steel moulds with extremely minimal tolerances. Detailed procedures and work instructions are provided for each manufacturing area. This ensures that each individual manufacturing stage as well as the materials used can be completely retraced. To guarantee optimum quality, the properties of the high-strength concrete are also tested by specialised material testing authorities.

Heavy-duty trucks deliver the segments to the construction site. At the site, the divided segments are bolted together and set directly on the tower. The precisely pre-fabricated horizontal system joint allows the tower to be erected in virtually all weathers.

Advantage of precast concrete segments

- Produced at production plant without having to take weather conditions into account
- Consistently high quality
- Quick installation largely independent of weather conditions
- Excellent rigidity even with high towers
The foundation is the link between the tower and the subsoil and bears all the static and dynamic loads of the wind turbine.

ENERCON foundations are always circular. Covering the foundation with backfill soil is not only calculated as a load but also taken into account when calculating the weight required to reduce buoyancy caused by ground or strata water.

Since the ground (depending on the site) can only absorb a certain amount of load, ENERCON has a range of standard flat or deep foundations to choose from. This way, appropriate solutions can be provided for a multitude of construction projects in the near term. If required, further measures such as soil improvement can be combined with the standard solutions. It is thus possible to start construction shortly after the building permit has been approved.

Advantages of circular foundations

- The stress is the same from all wind directions
- Significant reduction of the required amount of concrete and reinforcing steel
- Smaller formwork area and optimised cubic content
ENERCON WEC control system
ENERCON WEC control system

ENERCON wind turbines are equipped with state-of-the-art microelectronic control technology developed in-house.

Sensor system

The MPU (main processing unit), the central element of the control system, is in constant contact with peripheral control elements such as the yaw control and active pitch systems. A large number of sensors continuously monitor the current status of the wind energy converter as well as all the relevant ambient parameters.

The control system analyses the signals and regulates the wind energy converters so that the wind energy available at any given time is always optimally exploited and operating safety ensured. Thanks to an integrated lightning and fire protection system, the turbine electronics are protected against lightning strikes and overheating.

Advantages of the control system

- Adaptive nacelle yaw control through constant evaluation of measurement data from wind sensors
- Variable speed for maximum wind turbine efficiency at all wind speeds, and elimination of undesirable output peaks and high operating loads
- Maximum output as well as load reduction due to active pitch system
- ENERCON brake system for maximum turbine reliability by means of three independently operated pitch mechanisms with backup power supply (capacitors) in the event of a power failure
- Tower monitoring using of vibration and acceleration sensors to check tower oscillation

ENERCON ice detection system

All ENERCON serial-produced wind energy converters are standardly equipped with an ice detection system which works on a specially developed power curve analysis method. Various key operating values such as rotor or wind speeds are analysed during operation. The collected data is then plotted on an operating map. Ice build-up on the machine changes the aerodynamic properties which change the operating map. When certain criteria are fulfilled, the WEC is brought to a halt and the de-icing procedure is initiated. ENERCON’s ice detection feature stands out by its remarkable dependability confirmed by well-known independent institutes including MetoTest.

At sites more susceptible to ice build-up, ENERCON installs sensors of the company Labiotec on the nacelle in addition to the power curve method.

Rotor blade de-icing system

Once ice build-up has been detected and the turbine has been stopped, the optional ENERCON rotor blade de-icing system, which operates with hot air circulation, speeds up the thawing process. A fan heater installed at the root of the rotor blade circulates a stream of hot air all the way to the blade tip. The temperature of the blade surface warms up to above 0°C and the ice build-up melts off.

The thawing time is determined by the outside temperature. Once thawing has been completed, the turbine is restarted. If required by the particular site, it is possible to deactivate automatic restart. The operator or service technician in charge restarts the machine manually after having carried out a visual inspection.

At sites with minimal risk factors, it is also possible to automatically activate the rotor blade de-icing system while the wind turbine is still running thanks to the sophisticated ice detection technology. Thin layers of ice are thawed off at an early stage thus reducing downtime. Should ice however continue to build up on the rotor blades during extreme weather conditions, even though the de-icing system is functioning, the wind turbine is stopped.

The outstanding efficiency of ENERCON’s rotor blade de-icing system has been proven by an independent technical validation agency, Deutsche Windguard Consulting GmbH. Over a period of five winter months, ENERCON E-82 wind energy converters with and without the rotor blade de-icing system were observed at sites with a risk of icing. In that time, significant output differences of up to 870 MWh were recorded.

ENERCON storm control

ENERCON wind energy converters run with a special storm control feature. This slows the wind turbine down so that it can continue to operate even at high wind speeds. Numerous shutdowns which lead to considerable losses in power output can thus be avoided.

When storm control is activated, the rated speed is linearly reduced starting at a predetermined wind speed for each turbine type. Beginning at another turbine-specific wind speed, the limitation of the turbine’s rated speed also reduces active power. The turbine only shuts down at a wind speed of more than 34 m/s (10-minute average).

In comparison: When storm control is deactivated, the wind turbine stops if the wind speed reaches 25 m/s in the three minute average or 33 m/s in the 15 second average.

Fig. 1

Wind turbine shuts down at preset maximum wind speed (V3).

V1 = Cut-in wind speed
V2 = Rated wind speed
V4 = Cut-in wind speed after deactivated storm control
V3 = Cut-out wind speed with deactivated storm control

Fig. 2

Wind turbine reduces output starting at a determined wind speed (V3). A shutdown does not occur until a predetermined maximum wind speed (V4) is reached.

V1 = Cut-in wind speed
V2 = Rated wind speed
V3 = Beginning of power reduction
V4 = Cut-out wind speed with activated storm control.
ENERCON grid integration and wind farm management
ENERCON grid integration and wind farm management

ENERCON wind energy converters are equipped with intelligent grid management technology. Fulfilling international grid code requirements, ENERCON WECs guarantee reliable power feed in any networks worldwide.

Optimum grid integration

ENERCON’s grid management system is made up of a rectifier, DC link and modular inverter system. To ensure that the generated power is properly fed into the grid, voltage, current and frequency are constantly recorded at the point of reference and transmitted to the WEC control system. The reference point is located on the low-voltage side of the WEC transformer.

The key task of ENERCON’s grid management system is to feed the generated power into the grid in accordance with grid code requirements. It allows reliable and continuous turbine operation in grids with heavily fluctuating voltage or frequency.

Depending on the grid, the grid management system can be flexibly parameterised for 50 Hz or 60 Hz-rated grid frequencies. The voltage and frequency ranges of ENERCON wind turbines comply with international standards which specify the operating range for normal operation.

Due to its intelligent controls, ENERCON’s inverter system possesses FACTS properties. These enable ENERCON wind energy converters to contribute to maintaining and improving grid stability and meet specific international grid code requirements (incl. fault ride-through). Therefore, ENERCON WECs can be integrated into various grid systems worldwide.

ENERCON grid management system

- Contributes to maintaining grid voltage and frequency
- Optimum power quality through an adapted control system and operating mode in accordance with IEC standards and FGW (Federation of German Windpower) regulations
- The idea behind the grid management system is to control and regulate power feed without power peaks
- FACTS properties enable the turbines to provide system services similar to those provided by conventional power plants or beyond
- ENERCON is the first manufacturer worldwide to have received certification confirming these power plant properties
In order to achieve stable and efficient operation of transmission and distribution networks, reactive power control is essential to maintain voltage and utilise reactive power to compensate operating equipment. With an operating point between 20% and 100% of rated active power, an ENERCON wind turbine provides a wide range of reactive power which is available to the grid as a highly dynamic system service.

If desired, the reactive power range can be extended by means of the Q+ option, with which high grid connection requirements can largely be met.

If required, ENERCON wind turbines can also be equipped with a STATCOM option. Due to the extension of the reactive power range, it is also possible to provide the electrical power network with reactive power if no active power is being fed into the grid (standstill).

ENERCON wind turbines can contribute to stabilising frequency.

**Power-frequency control**

**Power-frequency control at overfrequency**

If temporary overfrequency occurs as a result of a grid fault, ENERCON WECs can reduce their power feed based on current active power or the rated power in accordance with the grid operator’s specifications.

**Power-frequency control at underfrequency**

If underfrequency occurs, the amount of active power being fed into the grid by ENERCON WECs can be limited to stabilise the frequency. This available power can then be provided in the event of underfrequency. The characteristics of this control system can be easily adapted to different specifications.
In order to secure grid stability, riding through momentary grid faults is a crucial factor in maintaining grid operation. The wind turbines’ fault ride-through option (FRT) enables them to ride through various grid faults (undervoltage, overvoltage, automatic reclosing, etc.) and remain connected to the grid.

Despite the decoupling, ENERCON offers the possibility of making backup energy available to the transmission system by means of the rotor’s inertia – so-called spinning reserve – with its “Inertia Emulation” option.

Should a significant drop in grid frequency be detected at the WEC’s point of reference, the active power feed is temporarily increased by using the stored rotational energy.

**Inertia Emulation**

Example: Active power curve of an ENERCON WEC (with Inertia Emulation) during a grid frequency collapse

**Fault ride-through - option**

In order to secure grid stability, riding through momentary grid faults is a crucial factor in maintaining grid operation. The wind turbines’ fault ride-through option (FRT) enables them to ride through various grid faults (undervoltage, overvoltage, automatic reclosing, etc.) and remain connected to the grid for up to five seconds during these faults.

Flexible parameter settings offer maximum performance according to the respective grid operators’ specifications or the respective project’s framework conditions. When a fault is detected, the WEC’s control system activates the fault ride-through feature which allows the turbine to remain connected to the grid.

Once the fault has been cleared and grid voltage returns to within the tolerance range for normal operation, the wind turbine immediately starts feeding the available power into the grid. After a grid fault, there are various strategies available to re-establish normal power feed-in.


ENERCON FRT option

- Various control process settings available
- Certified according to the specific requirements of independent institutes
- Allows the WEC to remain in operation during a grid fault

**Example:** Active power curve of an ENERCON WEC (with Inertia Emulation) depending on grid frequency
Generation management system – power regulation for maximum yield

If the cumulative (rated) output of the turbines in a wind farm is greater than the grid connection capacity at the point of common coupling, ENERCON wind farm power regulation ensures that the available grid connection capacity is used to the fullest.

Should one turbine in the wind farm be generating less power, the other turbines are individually adjusted to run at a higher capacity. If power is being fed without generation management, the feed-in limit is the cumulated rated power.

Optimal coordination of turbines within a wind farm with varying operating loads is achieved fully automatically by generation management in the ENERCON SCADA RTU/ENERCON FCU systems.

Bottleneck management – maximum output during bottlenecks

With ENERCON bottleneck management, it becomes feasible to connect wind farms in regions where the grid does not have sufficient available transmission capacity.

Constant online data exchange between the wind farm and the grid operator ensures that the highest possible amount of wind farm output is adapted to the transmission capacity. By achieving maximum output during bottlenecks, drops in profit for wind farm owner-operators are minimised.

During bottlenecks, the bottleneck management feature automatically adjusts the wind farm’s power output to the best possible setting.

ENERCON SCADA RTU

The ENERCON SCADA remote terminal unit (RTU) is a superordinate closed-loop wind farm control system. In combination with the setpoints, which may be specified by e.g. the grid operator, the RTU provides the wind farm with the control values transmitted by the wind farm server. This establishes closed-loop control.

The RTU is a modular system. Depending on the required functionality, the RTU is equipped with various hardware and control options. In its basic version, the RTU functions as a data interface.

As an option, the RTU can be equipped with digital and/or analogue I/O modules to exchange signals with the utility company/operator-owner. For this purpose, there are a number of interfaces available.

Wind farm control (closed-loop control) based on real-time parameters at the point of reference is possible by means of the RTU. Control variables could be the active power, reactive power or the power factor.

ENERCON FCU

The ENERCON farm control unit (FCU) offers a platform for exact and rapid wind farm control. A number of tasks and regulations are stipulated in the grid code requirements for wind farms – including efficient centralised voltage control.

To meet these demands and assume the tasks, various interfaces are available for signal exchange between the utility and operator-owner.

Depending on the stipulated connection requirements, the ENERCON FCU offers a solution for quick control purposes, with a response time down to less than 1 s – an efficient, cost-effective connection in relatively weak networks. Through the use of an ENERCON FCU, various control concepts for active and reactive power, voltage and the wind farm’s power factor are possible.
ENERCON remote monitoring
ENERCON remote monitoring

The ENERCON-developed system for data acquisition, remote monitoring, and open and closed-loop control can be used for individual turbines as well as for complete wind farms.

ENERCON SCADA system

For remote wind farm control and monitoring, the ENERCON SCADA system (Supervisory Control and Data Acquisition) has been a proven solution for many years and is also an important element of ENERCON’s service and maintenance programme. It offers a number of optional functions and communication interfaces to connect ENERCON wind farms to the grid while meeting technical grid connection regulations.

ENERCON SCADA is a modular system. The applications shown here can be easily and conveniently adapted to customer-specific requirements or extended wherever needed. Due to optimal adaptability to the respective technical and commercial conditions of wind farm projects, the ENERCON SCADA System ensures maximum yield.

ENERCON SCADA wind farm server

The ENERCON wind farm server is part of the ENERCON programme package and the key component of each ENERCON server system. It is connected to the turbines via the wind farm's internal fibre-optic cable data bus system. The ENERCON SCADA wind farm server is responsible for a number of wind farm communication, open-loop control and closed-loop control functions. It is the central storage system for the current and archived operating data of the WEC and SCADA components.

ENERCON SCADA interfaces

Operators of wind energy converters (WECs) and grid operators are increasingly interested in the online analysis of wind farm data and the transmission of control values to wind farms without using the ENERCON SCADA Remote software. For this purpose, ENERCON offers interfaces based on OPC XML-DA and IEC 61400-25-104 protocols.

ENERCON SCADA PDI-OPC

ENERCON SCADA PDI-OPC provides an interface that enables online access to wind farm data without using the ENERCON SCADA Remote software. The shortest data update interval in ENERCON SCADA PDI-OPC is one second. Furthermore, set points can be transmitted via ENERCON SCADA PDI-OPC (to influence reactive power generation by the wind farm, for instance).
The ENERCON Service Info Portal (SIP) offers functionality and transparency in terms of relevant turbine data. In addition to ENERCON SCADA data, customers can obtain quick and simple access to any desired service information via the Internet without having to call up additional software. A personal password and encrypted transmission ensure double data protection in line with the latest security standards.

A user-friendly menu allows easy access to all monthly, weekly and daily analyses of the WECs. Customers can also obtain a yield or availability overview, or consult maintenance and service reports within seconds via SIP. The interface draws on data entered in the internal system by ENERCON Service directly on site, thus making it easy to directly follow any maintenance and repair work.

With those more efficient options, the SIP interface allows an improved flow of information while increasing customer satisfaction.
ENERCON PartnerKonzept
ENERCON PartnerKonzept

ENERCON PartnerKonzept (ENERCON Partner Concept; EPK) gives customers the assurance of consistently high wind turbine availability for up to 15 years of operation at calculable operating costs.

EN 5. ENERCON PartnerKonzept

Guaranteed availability
ENERCON guarantees its customers a technical availability of up to 97% per year incl. a clearly defined maintenance factor. We offer this high availability for a service life of 15 years - a unique service on the wind market. Our aim is to support the customer during the wind turbine’s entire service life and enable the highest possible yield. If technical availability is lower than 97%, ENERCON issues the customer with a credit for the income lost due to lack of availability.

Local service
Local presence plays a key role in providing prompt service. Our local service employees stay in close contact with the wind farm operators and are familiar with the site and local conditions. Through remote connection, they also have access to all WEC-specific documents and technical databases at any time. Furthermore, with the ENERCON SCADA system, the service employees have remote access to all turbines. Fault messages are transmitted to the Service office, where an automatic dispatch system identifies the Service team nearest to the relevant wind energy converter.

Spare parts management
Alongside to reliable technology, the most important factor for guaranteeing high availability is a well-functioning spare parts management system. For quick and reliable material supply at all service points, ENERCON not only carries sufficient stock of compatible components but also appropriate quantities of standard materials. The costs of production, transport and installation for all spare parts are already included in the EPK fee. It even covers the costs for core components and crane hire.

Yield-oriented price structure
The fees under the ENERCON PartnerKonzept contract are based on the annual wind turbine yield. Depending on the type of turbine, the customer pays a minimum fee based on the previous annual yield. In years with good wind and excellent yield, the fee is higher. However, in years with poor wind conditions and less yield, customers pay less. Therefore, the EPK’s yield-based price structure offers applicants significant liquidity benefits.

Calculation formula:
Fee = produced kWh x price per kWh
[SCADA system]

The costs of the EPK contract are based on the generated yield.

ENERCON wind turbines with EPK worldwide

Number of

2000
2001

7,000
6,000
5,000
4,000
3,000
2,000
1,000
0

5. ENERCON PartnerKonzept

Partnership – point by point

Guaranteed technical availability
• Guaranteed technical availability
• Up to 97% p.a. at nearly all sites worldwide
• Reimbursement of yield loss if guaranteed availability is not attained
• Steady yield provides planning and financing security

Above-average contract periods
• Terms ranging from 10 to 15 years
• EPK follow-up package available for operating years 15–20

Repair and spare parts guarantee
• No additional payment for spare parts or core components (with a standard machinery breakdown/down time insurance covering general remaining risks)
• No need to make financial provisions for major repairs
• Complete coverage against unforeseeable events with ENERCON’s additional or conventional insurance

Maintenance
Central monitoring of WECs
• Constant 24/7 SCADA (Supervisory System Control and Data Acquisition)

Contact on site
• Prompt reaction due to a decentralised service network

Performance-oriented payment
• Calculable costs based on yield
### ENERCON product overview

The product portfolio comprises wind energy converters in the sub- to multi-megawatt classes.

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<th>WEC</th>
<th>Rated power</th>
<th>Rotor diameter</th>
<th>Swept area</th>
<th>Hub height</th>
<th>Rotational speed</th>
<th>Cut-out wind speed</th>
<th>Wind zone (DIBt)</th>
<th>Wind class (IEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENERCON E-44</strong></td>
<td>900 kW</td>
<td>44 m</td>
<td>1,521 m²</td>
<td>45 / 55 m</td>
<td>variable, 16 - 34.5 rpm</td>
<td>28 - 34 m/s</td>
<td>-</td>
<td>IEC/EN IA</td>
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<td><strong>ENERCON E-48</strong></td>
<td>800 kW</td>
<td>48 m</td>
<td>1,810 m²</td>
<td>50 / 60 / 65 / 76 m</td>
<td>variable, 16 - 31.5 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
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<tr>
<td><strong>ENERCON E-53</strong></td>
<td>800 kW</td>
<td>52.9 m</td>
<td>2,198 m²</td>
<td>50 / 60 / 73 m</td>
<td>variable, 11 - 29.5 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ II exp</td>
<td>IEC/NVN Class S</td>
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<td><strong>ENERCON E-70</strong></td>
<td>2,300 kW</td>
<td>71 m</td>
<td>3,959 m²</td>
<td>57 / 64 / 75 / 85 / 98 / 114 m</td>
<td>variable, 6 - 21 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IA and IEC/EN IIA</td>
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<tr>
<td><strong>ENERCON E-82 E2</strong></td>
<td>2,000 kW</td>
<td>82 m</td>
<td>5,281 m²</td>
<td>78 / 84 / 85 / 98 / 108 / 138 m</td>
<td>variable, 6 - 18 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-82 E2</strong></td>
<td>2,300 kW</td>
<td>82 m</td>
<td>5,281 m²</td>
<td>78 / 84 / 85 / 98 / 108 / 138 m</td>
<td>variable, 6 - 18 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-82 E4</strong></td>
<td>2,350 kW</td>
<td>82 m</td>
<td>5,281 m²</td>
<td>59 / 69 / 78 / 84 m</td>
<td>variable, 6 - 18 rpm</td>
<td>28 - 34 m/s</td>
<td>-</td>
<td>IEC/EN IA and IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-82 E4</strong></td>
<td>3,000 kW</td>
<td>82 m</td>
<td>5,281 m²</td>
<td>69 / 78 / 84 m</td>
<td>variable, 6 - 18 rpm</td>
<td>28 - 34 m/s</td>
<td>-</td>
<td>IEC/EN IA and IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-92</strong></td>
<td>2,350 kW</td>
<td>92 m</td>
<td>6,648 m²</td>
<td>78 / 84 / 85 / 98 / 104 / 108 / 138 m</td>
<td>variable, 5 - 16 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-101</strong></td>
<td>3,050 kW</td>
<td>101 m</td>
<td>8,012 m³</td>
<td>99 / 124 / 135 / 149 m</td>
<td>variable, 4 - 14.5 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-101 E2</strong></td>
<td>3,500 kW</td>
<td>101 m</td>
<td>8,012 m³</td>
<td>74 m</td>
<td>variable, 4 - 14.5 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ IV</td>
<td>IEC/EN IA</td>
</tr>
<tr>
<td><strong>ENERCON E-115</strong></td>
<td>3,000 kW</td>
<td>115.7 m</td>
<td>10,515.5 m³</td>
<td>92 / 122 / 135 / 149 m</td>
<td>variable, 4 - 12.8 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-126 EP4</strong></td>
<td>4,200 kW</td>
<td>127 m</td>
<td>12,668 m³</td>
<td>135 m</td>
<td>variable, 3 - 11.6 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
<tr>
<td><strong>ENERCON E-126</strong></td>
<td>7,580 kW</td>
<td>127 m</td>
<td>12,668 m³</td>
<td>135 m</td>
<td>variable, 5 - 12.1 rpm</td>
<td>28 - 34 m/s</td>
<td>WZ III</td>
<td>IEC/EN IIA</td>
</tr>
</tbody>
</table>