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ENERCON began its road to economical/ecological success when graduate engineer Aloys Wobben founded the company in 1984. A small team of engineers developed the first E-15/16 wind turbine with a rated power of 55 kW. To start with, ENERCON systems still featured gearboxes. However in 1992, the changeover to gearless technology came about with the first ENERCON E-40/500 kW. This innovative drive system with few rotating components ensures nearly friction-free energy flow providing outstanding performance and reliability. Mechanical stress, operating and maintenance costs are reduced, and the systems’ service life is increased.

Today, all ENERCON wind energy converters are based on the company’s tried and tested turbine concept. Over the past years, new system generations have evolved through constant sophistication of existing components, providing customers with state-of-the-art products. One example of the latest technological innovation is the new rotor blade geometry introduced in 2004. It significantly increases revenue, minimises noise emission while considerably reducing load impact on the wind energy converter.

All ENERCON systems feature a grid connection system which fulfils current grid connection requirements and can thus be easily integrated in any supply and distribution structure. ENERCON’s concept not only offers solutions for normal operation such as reactive power management and voltage control but also for critical situations resulting from network short-circuits or bottlenecks.

ENERCON has been setting new standards for technological design for over 20 years. As one of the world’s leading companies in the wind energy sector and the longstanding leader in the German market, ENERCON directly and indirectly employs over 8,000 people worldwide.

With more than 12,000 wind turbines installed in over 30 countries, ENERCON is also recognized as one of the leading manufacturers at the international level. Research and development, as well as production and sales are constantly expanding. The company’s objective for 2008/2009 is an export share of more than 60%, gradually increasing over the years to come.
DRIVE SYSTEM
ENERCON’s rotor blade concept sets new standards with regard to yield, noise emission and load minimisation. The new rotor blades are also less susceptible to turbulence and provide an even flow 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 due to overpressure and underpressure is effectively eliminated in the rotor plane. The entire length of the blade is therefore utilised without any loss of energy caused by turbulence.

The blades’ high efficiency is reflected in power curves taken on all ENERCON wind turbines where power coefficients (Cp) of more than 0.5 are achieved.

**ADVANTAGES OF ENERCON ROTOR BLADES**
- Higher efficiency due to modified blade design
- Less noise emission due to optimised blade tips
- Longer service life due to reduced load impact
- Easier transport due to streamlined blade design

ENERCON rotor blades are manufactured with a vacuum infusion process using the so-called sandwich technique. Glass fibre mats placed in the mould are vacuum-impregnated with resin using a pump and a hose system. This method eliminates air pockets in the laminate.
In order to efficiently protect the rotor blade surface against weather elements such as wind and water, UV radiation, as well as erosion and bending loads, the rotor blades’ protective finish is composed of gel coat, filler, edge protection and top coat using only solvent-free two component polyurethane compounds in the entire system.

To efficiently withstand wind loads over the entire usage period, ENERCON rotor blades have an extremely large flange diameter. The double-row bolt connection specially developed by ENERCON for large wind turbines also provides additional strength by creating even load distribution. This is an important factor, particularly in extreme wind locations with considerable stress fluctuations.

The drive system for ENERCON wind energy converters is based on a simple principle: fewer rotating components reduce mechanical stress while at the same time increasing the equipment’s technical service life. Wind turbine maintenance and service costs are reduced (fewer wearing parts, no gear oil change, etc.) and operating expenses lowered.

The rotor hub and annular generator are directly interconnected to form one gearless unit. This rotor unit is then mounted on a fixed axle, the so-called axle pin. Compared to conventional geared systems with a large number of bearing points in a moving drive train, ENERCON’s drive system only requires two slow-moving roller bearings due to its low direct drive speed.
A few years ago only the rotor hub was made of cast steel. However, today, with the use of modern spheroidal graphite cast iron, it is possible to manufacture other major components such as blade adapters, axle pins and main carriers with this process.

ENERCON carries out advanced development of its cast components in close collaboration with the foundries. All cast components are drawn with a 3D CAD system and calculated using the finite element method to check for strain increases at critical points. During the entire prototype phase, the designer tests and optimises performance. In order to guarantee the identification and traceability of each cast component when the goods are received at ENERCON, each part is given its own specific barcode from which the serial number can be obtained in the event of quality issues for example. Cast components are only released to the next stages in ENERCON’s manufacturing process once comprehensive quality testing has taken place, thus guaranteeing high ENERCON quality standards in the cast component supply sector.

**ENERCON’S QUALITY TESTING PROCEDURES FOR CAST COMPONENTS**

- Structural inspection on component
- Ultrasonic testing
- X-ray test

**Checking strain on cast components using the finite element method**

**Checking fit on axle pin**
In order to guarantee ENERCON's high quality, the annular generators are all manufactured in the company's own production facilities.

ANNULAR GENERATOR
Amongst other features, the annular generator is a key component in ENERCON's gearless wind generator concept. Combined with the rotor hub, it provides an almost frictionless flow of energy, while fewer smooth running components assure minimal material wear. Unlike conventional fast-running generators, ENERCON’s annular generator is hardly subjected to mechanical wear, making it ideal for particularly heavy loads and a long service life.

ENERCON's annular generator 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 an inverter which allow for high speed variability.

ADVANTAGES OF ENERCON'S ANNULAR GENERATOR
~ No gear
~ Low wear due to slow machine rotation
~ Low machine stress due to high level of speed variability
~ Yield-optimised control
~ High power quality

STATOR AND ROTOR
According to ENERCON’s service life requirements, the copper winding in the stator (the stationary part of the annular generator) known as closed, single-layer basket winding is produced in insulation class F (155°C). It consists of individual round wires gathered in bundles and varnish insulated. At ENERCON, the copper winding is exclusively done manually. In spite of increasing automation in other manufacturing areas, in this case preference has been given to manual labour for good reason. It ensures that all materials used are fully inspected. Furthermore, a special work process allows continuous windings to be produced. Each wire strand is continuous from start to end.

ADVANTAGES OF CONTINUOUS WINDING
~ Eliminates errors when making electrical connections
~ Maintains high-quality copper wire insulating system
~ No contact resistance
~ No weak points susceptible to corrosion or material fatigue

Stator (stationary part) of an ENERCON E-33 annular generator
The magnetic field of the stator winding is excited via so-called pole shoes. These are located on the rotor, the mobile part of the ENERCON 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. The result: The pole shoes are ideally adapted to the slow rotation of ENERCON’s annular generator making it completely silent.

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 temperature overload.

QUALITY ASSURANCE
In order to guarantee 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 supplier companies has proven to be the most reliable way of providing maximum material quality. For example, the varnished copper wires are subjected to more testing than is specified in the standard and samples are archived, while surge voltage tests are performed on the pole shoes and chokes and then documented in the computer system.
CONTROL SYSTEM
ENERCON wind turbines are equipped with state-of-the-art micro-electronic control technology developed in-house. The MPU (main processing unit), the central element of ENERCON’s control system, constantly registers information from the peripheral control elements, such as the yaw control and active pitch control systems. Its function is to adjust the individual system parameters to ensure that ENERCON wind turbines achieve maximum output under all weather conditions.

**ENERCON CONTROL SYSTEM**

- Constant evaluation of measurement data from wind sensor to adapt nacelle yaw control
- Variable speed for maximum wind turbine efficiency at all wind speeds, and elimination of undesirable output peaks and high operating load
- Active pitch control system to obtain ideal angle of flow on the rotor blades ensures maximum output and stress reduction on the entire wind turbine
- ENERCON brake system for maximum turbine reliability by means of three independently operated pitch mechanisms with standby power supply (batteries) in case of a mains failure
- Tower and generator monitoring by means of vibration and acceleration sensors to check tower oscillation
- Temperature and air gap sensors between rotor and stator ensure dependable annular generator operation
**MONITORING GRID CONNECTION**

Ensuring proper power feed from ENERCON wind turbines into the grid requires grid connection monitoring. Grid parameters such as voltage, current and frequency are measured on the low-voltage side between the ENERCON inverter and the system transformer. The measured values are continuously transmitted to the control system, enabling the turbine to react immediately to changes in grid voltage or frequency. If the defined limit values for system or grid protection are exceeded, the wind turbine is safely shut down and the service teams are informed. As soon as voltage and frequency return within the permissible tolerance range, the turbine is automatically started up again. Prolonged downtimes are thus avoided.

**ENERCON STORM CONTROL**

ENERCON wind turbines run with a special storm control feature. Storm control enables reduced wind turbine operation in the event of extremely high wind speeds, and prevents usual shutdowns which cause considerable yield losses.

The diagram shows that the wind turbine stops at a defined shutdown speed \( V_3 \). The reason is that a specified maximum wind speed has been exceeded. In wind turbines without storm control, this occurs, for example, at a wind speed of 25 m/s within the 20 second mean. The wind turbine only starts up again when the average wind speed drops below the shutdown speed or an even lower restart speed \( V_4 \) in the diagram; so-called strong wind hysteresis). In gusty wind conditions there may be a longer delay, which means that considerable yield losses are incurred.

At high wind speeds, ENERCON wind turbines work on a different principle. They are equipped with special storm control software which prevents unnecessary abrupt shutdowns.

The power curve diagram showing operation with ENERCON Storm Control demonstrates clearly that the wind turbine does not shut down automatically when a certain wind speed \( V_{\text{storm}} \) is exceeded, but merely reduces power output by slowing down the rotational speed. This is achieved by slightly pitching the rotor blades out of the wind. Once the wind speed drops, the blades turn back into the wind and the turbine immediately resumes operation at full power. This avoids yield-reducing shutdown and start-up procedures.

ENERCON’s Storm Control feature also offers the grid substantial security benefits. At extremely high wind speeds there is no risk of major disturbances caused by longer feed-in interruptions which could have the same effect as a simultaneous shutdown of several conventional power plants.

**Output loss of an ENERCON E-70 due to two stormy days/year**

\[ 2 \text{ days} \times 2,300 \text{ kW} = 110,400 \text{ kWh} \]

2–4% of yearly income
GRID INTEGRATION AND WIND FARM MANAGEMENT
PREFACE

Today, global energy supply without wind energy would be difficult to imagine. Given the ongoing rise in electricity demand, it is more than ever our responsibility to guarantee secure power supply. Wind energy has come of age and in the years ahead the development of wind energy will play a major role in the race to satisfy demand. To accomplish this, one of the vital factors will be the capability of wind technology to be integrated into existing power systems. Stringent regulations imposed by grid operators require wind turbines and wind farms to fulfil power plant properties which necessitate highly sophisticated and flexible technology. In cooperation with German and international utilities, ENERCON has already made major advancements in developing practical grid connection solutions for our wind turbines and wind farms to offer the desired system services to the grid. Also in the future, ENERCON will always be a pioneer in grid integration of wind turbines, guaranteeing a stable, profitable and highly qualitative supply of wind energy.

ENERCON ANNULAR GENERATOR AND GRID MANAGEMENT SYSTEM

Amongst other features, the annular generator is a key component in ENERCON’s gearless wind generator design. This low-speed synchronous generator is directly connected to the rotor. Generator output voltage and frequency vary with the speed and are converted via the ENERCON Grid Management System to be fed into the grid. This allows rotational speed control to be optimised; the annular generator is coupled in a flexible way to the grid. By adjusting or ‘pitching’ the blades and through electrical excitation via the turbine control system, rotational speed and power output are constantly checked and optimised. The electrical power produced by the annular generator passes into the ENERCON Grid Management System which comprises a rectifier, the so-called DC Link and a modular inverter system. The inverter system defines the essential performance characteristics for output to the grid and ensures that the power output corresponds to grid specifications. Here in the inverter system, voltage, frequency and power are converted accordingly. Via the transformer, inverter voltage (400 V) is stepped up to the appropriate medium voltage required by the grid or the wind farm network.

ENERCON wind turbines are equipped with a Grid Management System designed to meet the latest grid connection requirements. This facilitates integration in any transmission and distribution network. The Grid Management System offers numerous performance features e.g. reactive power management and optimum contribution to maintaining voltage levels. Due to excellent control dynamics, the system also supports the grid in critical situations such as short circuits or bottlenecks and this way improves power system stability and security. Essentially, ENERCON wind farms behave very much like power stations or in some aspects even exceed their performance. ENERCON is the first manufacturer worldwide to have received certification confirming these power plant properties.
ELECTRICAL GRID COMPATIBILITY

Due to their control and operating mode, our wind turbines offer maximum power quality. Certificates from independent institutes confirm these qualities according to IEC Standards and FGW guidelines. The idea behind the Grid Management System is to control and regulate power feed without power peaks. During normal operation, the wind turbine actually requires no reactive power. Flickers and harmonic oscillations are negligible. Due to the Grid Management System’s power electronics there is no inrush current.

WIDE VOLTAGE AND FREQUENCY RANGES

ENERCON’s Grid Management System allows the wind turbine to have a very wide operating range. Depending on the grid, the Grid Management System can be flexibly parameterised for 50 Hz or 60 Hz nominal grid frequency. In grid systems with heavily fluctuating voltage or frequency, the Grid Management System’s stability provides for reliable and continuous operation, even at full rated power.

COORDINATED GRID FEED IN NETWORK

In order to provide reliable economical grid operation, power feed-in timing has to be regulated. To ensure that this takes place, variable setpoint values for maximum permitted power gradients can be specified for the ENERCON Grid Management System. For example, when the wind turbine or wind farm is started up, power feed can be controlled according to grid operator requirements. This allows the grid operator to optimise load flow and grid voltage stability as well as to enhance the interaction between utilities and consumers.

POWER FREQUENCY CONTROL

Grid frequency control is essential to ensure reliable and stable grid operation as well as to attain vital power supply quality. ENERCON wind turbines can contribute to the stabilisation of the grid by adapting power feed-in according to the present grid frequency. If a grid fault leads to temporary overfrequency in the grid, ENERCON WECs reduce their output according to the grid operator’s specifications. As soon as grid frequency has been stabilised, ENERCON WECs continue normal power feed-in. The characteristics of this control system can be easily adapted to different specifications.

REACTIVE POWER MANAGEMENT

In order to maintain reliable and efficient transmission and distribution grids, reactive power regulation is indispensable. This feature is not only necessary to compensate transmission equipment such as cables and transformers but also to maintain voltage stability. ENERCON wind turbines have a vast operating range for reactive power exchange which can be provided to the grid as a highly flexible system service. Since turbine configuration is flexible, wind farm projects can be optimised to suit the particular requirements. In many regions around the world, conventional power plants alone do not suffice to meet highly complex requirements for stable grid operation. In these cases, dynamic reactive power sources such as SVC or STATCOM (Static Compensator) must be integrated into the grid to guarantee adequate power supply quality to the consumer. As an option, ENERCON wind turbines are able to provide the grid performance properties of a STATCOM. With the STATCOM option, an ENERCON wind turbine combines power plant properties with STATCOM properties. Irrespective of the active power feed-in, the entire reactive power range is at the disposal of the grid operator even if active power is not being fed into the grid. These STATCOM properties are essential to provide the grid with an efficient means of connecting weak and heavily loaded networks operating at the limit of stability.
STAYING CONNECTED WHEN GRID PROBLEMS OCCUR

Most transmission networks and even more distribution grids require wind energy converters to remain connected to the grid in the event of grid short circuits. Like conventional power plants, wind turbines are not allowed to rapidly disconnect from the grid during voltage dips or over-voltage caused by grid problems. ENERCON wind turbines with the optional ENERCON UVRT feature have this capacity. No matter what type of short circuit occurs, ENERCON wind turbines can ‘ride through’ faults for several seconds, even if they were operating at rated power before the fault. This is also possible if the wind turbine voltage completely breaks down as a result of the power system failure. These outstanding power plant properties have been certified by independent institutes during actual grid fault testing. Flexible setting options offer maximum performance according to the respective grid operator’s specifications or to the project’s framework conditions. Depending on the selected parameters, the wind turbine can feed in either mainly active or reactive power to maintain grid voltage. Even voltage-dependent reactive current, which may be maximally as high as the rated current, can be fed into the grid if required. Upon request, fault ride-through without any power feed-in is also possible. The ENERCON wind turbine remains in operation during the fault. After the grid problem has been remedied and grid voltage has been restored, the wind turbine can immediately resume power feed-in. Thus the ENERCON Undervoltage Ride-Through feature facilitates adaptable settings in order to meet grid standards and to maximise the amount of installable wind farm power.

ENERCON SCADA

For remote wind farm control and monitoring, ENERCON SCADA has been a proven system for many years and is also an important element of ENERCON’s service and maintenance program. It offers a number of optional functions and communication interfaces to connect ENERCON wind farms to the grid while meeting demanding grid connection regulations. Due to its modular design ENERCON SCADA is flexible and can be easily adapted or expanded to customer-specific applications. The ENERCON SCADA REMOTE software is the usual wind farm operator tool for remote control and monitoring.

POWER GENERATION MANAGEMENT – POWER REGULATION FOR MAXIMUM YIELD

If the cumulative (rated) output of a wind farm is greater than the grid connection capacity at the point of common coupling, ENERCON wind farm power regulation ensures that the capacity is used to the fullest at all times. If one turbine in the wind farm generates less power, the other turbines are adjusted accordingly to run at a higher capacity. Optional generation management in the ENERCON SCADA system handles this automatically.

BOTTLENECK MANAGEMENT – MAXIMUM OUTPUT DURING BOTTLENECKS

Not all regions have sufficient transmission capacity available to manage each low-load and strong wind situation. However, with ENERCON’s bottleneck management it is possible to connect wind farms to this type of grid. 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. Yield loss, along with complicated re-dispatches for load distribution within the wind farm is minimised.
**ENERCON PDI**
**PROCESS DATA INTERFACE**

Today, integration into grid control systems and a connection to network control stations is a standard requirement for wind farms in many countries. ENERCON SCADA offers different optional PDI modules which act as communication interfaces between the various systems. This enables ENERCON’s SCADA system to communicate via analogue or digital interfaces depending on requirements. Certain wind farm target values can be set and status messages or wind farm measurement values can be transmitted to the grid operator. If desired, ENERCON METEO even offers the possibility of integrating wind measurement masts in wind farms into the ENERCON SCADA system and thus also data transfer into external systems.

**ENERCON FARM CONTROL UNIT (FCU)**
**FOR WIND FARMS**

ENERCON wind farms are able to perform a large quantity of complex and dynamical closed-loop and open-loop control processes for electrical key values at the point of interconnection to the grid. These controls become necessary because of the applicable grid codes at the point of common coupling and because of the economical optimisation of a wind farm project. To meet the requirements for such control processes, ENERCON offers its Farm Control Unit (FCU) as an optional feature for the ENERCON SCADA system. It combines active power and reactive power controls in a wind farm and enables closed-loop control of the grid voltage. With the ENERCON FCU the wind farms’ contribution to voltage stability at a given reference point can be managed from a central location. In many countries, utilities require this feature in order to integrate large wind farms into relatively weak grids. The ENERCON FCU uses the reactive power range of ENERCON wind turbines to regulate voltage, typically in respect of the wind farm’s point of common coupling. Grid operators can either control voltage according to a set value or also via additional interfaces. Requirements for wind farm voltage control vary greatly. If a wind farm is for example connected to a substation, available tap changers can be integrated into the control system. In large wind farms with respective cable lengths, a control system can be used to improve reactive power demand for the contractually agreed point of common coupling with centralised compensation facilities and decentralised wind turbines. ENERCON offers a number of cost-effective solutions for the respective connection conditions.

**WIND FARMS WITH SUBSTATIONS**

More and more wind farms feed power into the grid via substations specially constructed for this purpose. Remote monitoring and control of these substations are often required in order to receive continuous information from switchgear units and, as the case may be, carry out switching operations. ENERCON’s SCADA system features special optional modules providing remote monitoring and control of switchgear assemblies and substations for the wind farm operator. Data transmission and operations are carried using the tried and tested ENERCON SCADA REMOTE software. In addition, ENERCON offers complete substation management as an optional service.
Grid connection of ENERCON wind power plants (combination of several wind farms)

**ENERCON MAIN CONTROL UNIT (MCU) FOR WIND POWER PLANTS**

Individual ENERCON wind farms functioning similar to conventional power plants have successfully been in operation and integrated in existing grid structures for many years. It is more and more common to find several wind farms connected to a common central point of connection to form bigger wind power plants. Since installed power output is high, these plants usually feed power into high-performance transmission grids. ENERCON’s MCU assumes centralised open-loop and closed-loop control of a wind power plant. It takes over typical communication and data transfer tasks to grid control systems and load dispatching centres fulfilling complex technical grid connection regulations for wind power plants. ENERCON’s MCU comes as a module. Each application is customised with features best suited to the project. Depending on requirements ENERCON’s MCU has different interfaces to connect to the grid control systems. Bottleneck management for wind power plants is yet another feature in addition to reactive power management, or the integration of switchgear assemblies or entire substations into the wind power plant.

**REQUIREMENTS FOR WIND POWER PLANTS IN TRANSMISSION NETWORKS**

- Wind turbines have to be able to remain in operation without reducing performance and without time limits even with considerable voltage and frequency fluctuations.
- If voltage dips occur due to grid problems, wind turbines have to remain connected to the grid for a defined period of time.
- Short-circuit current power feed-in may be requested during a grid fault. Depending on the grid, the turbine has to be able to feed in primarily active or reactive power to the grid.
- Abrupt grid frequency changes should not cause the wind turbine to shut down.
- During a failure and while a grid fault is being cleared, reactive power absorption is restricted or not permissible at all.
- After a fault has been remedied, a wind farm should resume power feed as quickly as possible within a specified maximum time range.
- Wind farms should be able to operate with reduced power output with no time restrictions.
- For coordinated load distribution in the grid, the increase in power output (power gradient), for example when the wind farm is starting, should be able to be restricted in accordance with the grid operator’s specifications.
- Wind farms have to be able to contribute reserve energy within the grid. If grid frequency increases, the power output of a wind farm should be reduced.
- If necessary, wind farms should be able to contribute to maintaining voltage stability in the grid by supplying or absorbing reactive power with no time restrictions. Dynamic criteria to maintain grid stability must be met.
- Wind farms must be able to be integrated into the grid control system for remote monitoring and control of all components in the grid.
TOWER AND FOUNDATION
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 surpass quality and safety norms.

Virtual 3D models of the tower designs are produced during the development phase using the finite element method (FEM). All possible stress on the wind turbine is then 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 providing further verification of the calculated data. ENERCON’s calculations are confirmed by results produced by specially commissioned certification bodies, research institutes and engineering firms.

The aesthetic aspect is also a decisive factor during tower development, which is 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.

TUBULAR STEEL TOWER
ENERCON tubular steel towers are manufactured in several individual tower sections, connected using stress-reducing L-flanges. Unlike conventional flange connections (such as those used in steel chimney construction), the welding seam of the L-flange is outside the stress zone.

OTHER ADVANTAGES OF THIS CONNECTING TECHNOLOGY:
- Complicated and costly welding work on site is not necessary
- Quick, reliable assembly meeting the highest quality standards
- Full corrosion protection, applied under best production engineering conditions
Due to their relatively small circumference, shorter ENERCON tubular steel towers are mounted on the foundations using a so-called foundation basket, which consists of a double rowed circular array of threaded steel bolts. A retainer ring, fitted to the tower flange dimensions, is used to hold the individual bolts in position. When the foundation is completed, the lower tower section is placed on the bolts protruding out of the concrete surface and then bolted with nuts and washers.

A specially developed foundation connection system is used for taller ENERCON steel towers. A cylindrical structural element is set on the blinding layer and precisely aligned with adjusting bolts. Once the foundation is completed, the tower is flanged together with the foundation section.

Like all other components, tubular steel towers are subject to strict ENERCON quality standards. Quality assurance already begins in the design development stages to ensure that the prototype meets all requirements before going into serial production.

**PRECAST CONCRETE TOWER**

ENERCON precast concrete towers are made using specially developed prestressed steel reinforcement. The individual tower sections and foundation are assembled to form an inseparable unit with prestressing tendons running through jacket tubes in the core of the concrete tower wall. The tower sections themselves are manufactured entirely at the precasting plant. Specially constructed steel moulds assure manufacturing precision for each individual concrete section. This manufacturing process minimises dimensional tolerances which assures a high degree of fitting accuracy. Here again, ENERCON’s Quality Assurance department carries out strict inspections. Detailed procedures and work instructions are available for each manufacturing area. This ensures that each individual manufacturing stage as well as the materials used can be completely retraced.
The foundation transmits any load on the wind turbine into the ground. ENERCON foundations have an optimised circular form.

**ADVANTAGES OF ENERCON CIRCULAR FOUNDATIONS**

- Forces are equal in all wind directions, whereas foundation pressure causing relatively high ground strain is possible on the corners of cross-shaped or polygonal foundations.
- The circular design has proven to reduce the size of the formwork area and the amount of reinforcement and concrete required.
- Backfilling the foundation with soil from the excavation pit is included in the structural analysis as a load. This means that less reinforced concrete is needed for foundation stability.
- ENERCON foundations are designed to ensure optimum stability and prevent the foundation from tilting.

Different foundation types can be chosen as, depending on the site, the ground can only absorb a certain amount of compressive strain. ENERCON’s circular foundations are based on this elementary realisation and as a rule are installed as shallow foundations. If necessary (in soil with low load-bearing capacity, for example), a special deep foundation distributes the load down to deeper load-bearing soil strata. Specially optimised pile installation plans are developed for the individual tower types with deep foundations.

ENERCON foundations are type-tested so that construction can start immediately after the building permit has been granted.
SERVICE MANAGEMENT
SERVICE MANAGEMENT

The aim of ENERCON’s Service Department is to ensure and maintain operational readiness for all ENERCON wind turbines. In accordance with the company’s commitment to “speedy service through local presence”, more than 2,500 employees worldwide provide fast turn-around for wind turbine maintenance and servicing. This means shorter distances for service technicians and ensures a high degree of technical availability (average in the last years more than 98.5%).

A well-coordinated dispatch team is another important factor for efficient field service organisation. ENERCON has more than 100 employees coordinating global service operations, from both a technical and commercial point of view. Each customer has a designated point of contact in their service centre. Operators can be confident that the technician knows the site but also has detailed knowledge of the local conditions surrounding the wind turbines.

ENERCON SERVICE PERFORMANCE PROFILE

- Servicing and maintenance of all wind turbines installed by ENERCON
- Wind turbine monitoring via remote data transmission
- Maintaining technical availability of wind turbines serviced by ENERCON
- Customer care in all technical and commercial matters
- Operator training

Every ENERCON wind turbine has a modem link to the remote data monitoring facility. If the wind turbine signals a malfunction, the service centre and the service branch in charge are notified via the SCADA remote monitoring system. The message is automatically transferred to the ENERCON deployment planning software and displayed on the dispatchers’ screen. With the aid of a specially developed locating system (GIS – Geoinformation System), the deployment planning system automatically locates the service team that is closest to the wind turbine. Service teams are able to access all turbine-specific documents and data using so-called pentops (robust, portable computers with a link to the service centre) ensuring that all maintenance is dealt with as quickly and efficiently as possible. A new standard in service management.
SERVICE INFO PORTAL
The Service Info Portal (SIP) offers ENERCON customers the possibility of easily accessing all the information concerning their own wind energy converters over the internet – at any time and from anywhere in the world. The only requirement is a computer with a Web browser (e.g. Microsoft Internet Explorer) and an Internet connection. A changing PIN code, personal password and encrypted transmission routes ensure triple data protection security.

SIP’s easy-to-use menus provide customers with quick and easy access to all wind turbine data. Work processes, such as producing wind turbine analyses, checking maintenance logs or producing up-to-date yield overviews, which normally take hours, can be done in a matter of minutes using SIP. An efficiency boost which not only increases customer satisfaction but also improves the flow of information (between partners in a wind farm, for example).

The Service Info Portal is available for ENERCON customers as basic, standard and premium versions. The basic package is included for all wind turbine owners without ENERCON PartnerKonzept (EPK: ENERCON Partner Concept). Customers with EPK can use the standard version free of charge. The premium package is provided to EPK customers for a fee and offers the possibility of performing more extensive technical and commercial evaluations.

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Easy access to all wind turbine data such as service reports, maintenance data and availability evaluations.
ENERCON
PARTNERKONZEPT
ENERCON PARTNERKONZEPT (EPK)

ENERCON’s PartnerKonzept (EPK; ENERCON Partner Concept) gives customers the assurance of consistently high wind turbine availability for the first twelve years of operation with calculable operating costs. From servicing to safety inspections, maintenance and repairs, all eventualities are covered by one single contract. Guaranteeing a high value-for-money and comprehensive service, the EPK has long since become an acknowledged ENERCON quality feature. More than 85% of national and international customers have signed an EPK agreement.

Damage caused by unforeseeable events such as acts of nature and vandalism can be covered by a specially developed additional EPK insurance policy. Significantly cheaper than conventional machine failure insurance, the additional EPK insurance policy is now available through all well-known insurance companies.

YIELD-ORIENTED COST STRUCTURE

The costs for the ENERCON PartnerKonzept contract are based on the annual wind turbine output. The customer pays a minimum fee depending on the respective wind turbine type and a yield-oriented surcharge. This means that the customer pays more in good wind years with good yield and less in bad wind years with less yield thus stabilising annual wind turbine profit.

In order to keep customer charges as low as possible, ENERCON assumes half of the EPK fee during the first five-year operational period. The customer is then obliged to assume the entire fee starting from the sixth year of operation. This is a definite advantage for the owner.

Calculation formula

Fee = produced kWh x price per kWh
(SCADA system)

1) The fee is calculated separately for each individual wind turbine/year
2) The fee is calculated according to the annual kWh produced during the elapsed operating year
Spare part delivery depends on the wind turbine location. ENERCON offers two EPK variants: In Europe (EPK I) ENERCON bears any costs for maintenance, servicing and repair. Outside Europe, (EPK II) ENERCON and the customer share the risk for possible defects on the wind turbine’s main components. ENERCON pays for material costs and the replacement on site, and the customer bears the cost for transport, crane provision and possible yield losses. This is the reason why the annual fee for EPK II is considerably lower than the fee for EPK I.

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>EPK I</th>
<th>EPK II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guarantee of a technical availability of up to 97 %*</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Yield-oriented cost structure</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Agreement term of twelve years (with possible extension)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four maintenance operations per year</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Delivery of all required materials</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Material transport to site</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Servicing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing servicing operations</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Delivery of all required materials</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Material transport to site</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Repair</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing all repairs</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Delivery of all required materials and main components (tower, rotor blades, hub, machine house, generator, etc.)</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Main component transport to site</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Providing crane for main component replacement</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Remote monitoring (24 hours) by ENERCON SCADA</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

*Percentage individually defined in EPK contract and not valid during main component breakdowns for EPK I.
**Excluding damage caused by customer or third parties.
PRODUCT OVERVIEW
## TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</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 class (IEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E33</td>
<td>330 kW</td>
<td>33.4 m</td>
<td>876 m²</td>
<td>36 m–50 m</td>
<td>variable, 18–45 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN I and IEC/NVN II (depending on hub height)</td>
</tr>
<tr>
<td>E44</td>
<td>900 kW</td>
<td>44 m</td>
<td>1,521 m²</td>
<td>45 m/55 m</td>
<td>variable, 12–34 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN I A</td>
</tr>
<tr>
<td>E48</td>
<td>800 kW</td>
<td>48 m</td>
<td>1,810 m²</td>
<td>50 m–76 m</td>
<td>variable, 16–30 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN II</td>
</tr>
<tr>
<td>E53</td>
<td>800 kW</td>
<td>52.9 m</td>
<td>2,198 m²</td>
<td>60 m/73 m</td>
<td>variable, 12–29 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN S (Vav = 7.5 m/s, Vext = 5.7 m/s)</td>
</tr>
<tr>
<td>E70</td>
<td>2,300 kW</td>
<td>71 m</td>
<td>3,959 m²</td>
<td>64 m–113 m</td>
<td>variable, 6–21.5 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN I and IEC/NVN II (depending on hub height)</td>
</tr>
<tr>
<td>E82</td>
<td>2,000 kW</td>
<td>82 m</td>
<td>5,281 m²</td>
<td>78 m–138 m</td>
<td>variable, 6–19.5 rpm</td>
<td>28 – 34 m/s</td>
<td>IEC/NVN II</td>
</tr>
</tbody>
</table>

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