Technical description

ENERCON E-175 EP5 wind energy converter

ENERCON
ENERGY FOR THE WORLD

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Applicable documents

The titles of the documents listed are the titles of the original language versions, with translations of these titles in brackets where applicable. The titles of superordinate standards and guidelines are indicated in the original language or as an English translation. Document IDs always refer to the original language versions. If the document ID does not contain a revision, the most recent revision of the document applies. This list contains documents concerning optional components if necessary.

Document ID	Document
D02766054	Technische Daten E-175 EP5 (Technical specifications – E-175 EP5)

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List of abbreviations

CFRP	Carbon fibre reinforced plastic
FACTS	Flexible Alternating Current Transmission System
FT	FACTS Transmission (electrical configuration with FACTS properties)
FTQ	FACTS Transmission with Q+ option (electrical configuration with extended reactive power range)
FTQS	FACTS Transmission with Q+ option and STATCOM option (electrical configuration with extended reactive power range and STATCOM option)
FTS	FACTS Transmission with STATCOM option (electrical configuration with STATCOM option)
GFRP	Glass-fibre reinforced plastic
SCADA	Supervisory Control and Data Acquisition
STATCOM	Static compensator

1 Product overview

Fig. 1: Product overview

The wind energy converter generates electrical energy from the wind. Wind flowing towards the wind energy converter causes the rotor to rotate clockwise. This rotational movement is converted into electrical energy. The wind energy converter operates automatically.

The wind energy converter essentially consists of the tower, the rotating nacelle with adjustable rotor blades and electrical components for generating and conditioning the electrical energy.

Gearless

The wind energy converter drive system comprises very few rotating components. The hub and the rotor of the generator are directly interconnected without a gear to form one solid unit. This reduces mechanical load and increases the technical service life. It reduces maintenance and service costs and also keeps operating costs to a minimum. Since there are no gears or other fast-rotating parts, the energy loss between generator and rotor as well as sound emissions are reduced.

Active pitch control

The active pitch control limits rotor speed and the amount of power extracted from the wind. The maximum output of the wind energy converter can then be limited to nominal power, even at short notice. Pitching the rotor blades into the feathered position stops the rotor without any load on the drive train caused by the application of a mechanical brake. The energy supply for emergency pitching of the rotor blades is located in the pitch control cabinets.

Indirect grid connection

The electrical power produced by the generator is fed via a full-scale converter into the grid. The full-scale converter decouples the generator completely from the grid and the electrical properties of the generator are irrelevant to the behaviour of the wind energy converter on the grid. The grid feed system with full-scale converter ensures maximum energy yield with excellent power quality.

The generator can be operated at an optimum operating point, e.g. speed, power, voltage, at any wind speed, by decoupling it from the grid.

2 Components of the ENERCON wind energy converter

2.1 Rotor blades

The rotor blades are made of GFRP, CFRP, balsa wood and foam and are a major factor in the wind energy converter yield and sound emissions. The shape and profile of the rotor blades were designed with the following criteria in mind:

- High power coefficient
- Long service life
- Low sound emissions
- Low mechanical loads
- Efficient use of material

The rotor blades of the wind energy converter were specially designed to operate with variable pitch control and at variable speeds. A polyurethane-based surface coating protects the rotor blades from environmental influences such as UV radiation and erosion. This coating is visco-hard and highly resistant to abrasion.

Microprocessor-controlled pitch units adjust each of the 3 rotor blades independently of each other. 2 blade angle measurements constantly monitor the set angle of each blade, and the 3 blade angles are adjusted individually. This enables quick and precise setting of the blade angles according to the prevailing wind conditions.

2.2 Nacelle

The hub rotates around the fixed axle pin on 2 rotor bearings. Among other components, the rotor blades and the generator rotor are attached to the hub. The slip ring unit is located at the tip of the axle pin. It transmits electrical energy and data between the stationary and rotating parts of the nacelle via sliding contacts.
The stator support is the load-bearing element of the fixed generator stator. The stator support is firmly connected to the main carrier. The stator supports the electrical windings in which the electric current is induced.
The main carrier is the central load-bearing element of the nacelle. All parts of the rotor and generator are attached to it either directly or indirectly. The main carrier rotates on the tower head by means of the yaw bearing. The entire nacelle can be rotated by the yaw drives so that the rotor is always optimally aligned with the wind.
The machine house casing comprises multiple sections and is fastened to the nacelle floor by means of steel profiles.

2.2.1 Generator

A permanently excited synchronous generator of internal rotor design is used in the wind energy converter. The wind energy converter operates at variable speeds in order to optimally exploit the wind energy potential at all wind speeds. The annular generator therefore produces alternating current with fluctuating voltage, frequency and amplitude.

The windings in the stator of the generator form several independent three-phase systems. These systems are actively rectified in the nacelle. The inverters then reconvert them into three-phase current whose voltage, frequency and phase position conform to the grid. The transformer in the nacelle converts the voltage generated to the level of the grid into which the current is fed. The transformer is connected to the receiving grid via the medium-voltage switchgear.

Consequently, the generator is not directly connected to the receiving grid of the utility and is decoupled from the grid by the full-scale converter.

2.3 Tower

The tower of the wind energy converter is a tubular steel tower, hybrid steel tower or hybrid tower.

The tubular steel tower is a sheet steel tube consisting of a small number of large steel sections. Depending on the tower version, the lowermost steel section may be in one piece or subdivided into several longitudinal elements. The longitudinal elements are first joined at the installation site to form a single steel section. Flanges with drill holes for assembly are welded onto the ends of the steel sections. The steel sections are stacked on top of one another and bolted together at the installation site. They are linked to the foundation by means of a foundation basket.

The hybrid steel tower is a sheet steel tube consisting of a small number of large steel sections. The lower steel sections are subdivided into a number of edged section plates. The upper steel sections are in one piece. The edged section plates are first bolted together to form steel sections at the installation site. The individual steel sections are stacked on top of each other and bolted together at the installation site. This is done for the longitudinally-divided steel sections by connection plates and for the one-piece steel sections by flange joints. They are linked to the foundation by means of a foundation basket.

The lower part of the hybrid tower is made of concrete segments and the upper part of steel sections. The concrete segments are assembled from precast elements that are stacked on top of each other at the installation site. The upper steel sections are placed onto the concrete segments and bolted in place. The concrete segments are prestressed vertically by means of prestressing steel tendons. The prestressing tendons run either vertically through ducts in the concrete segments or externally along the interior tower wall. They are anchored to the tower foundation.

All towers receive the final paint top coat or weather and corrosion protection at the factory. This means that ideally no further work is required on the tower surface after installation.

3 Grid management system

The permanent magnet synchronous generator is coupled to the grid via the grid feed system. This system essentially consists of a modular rectifier and inverter system with a common DC link each.

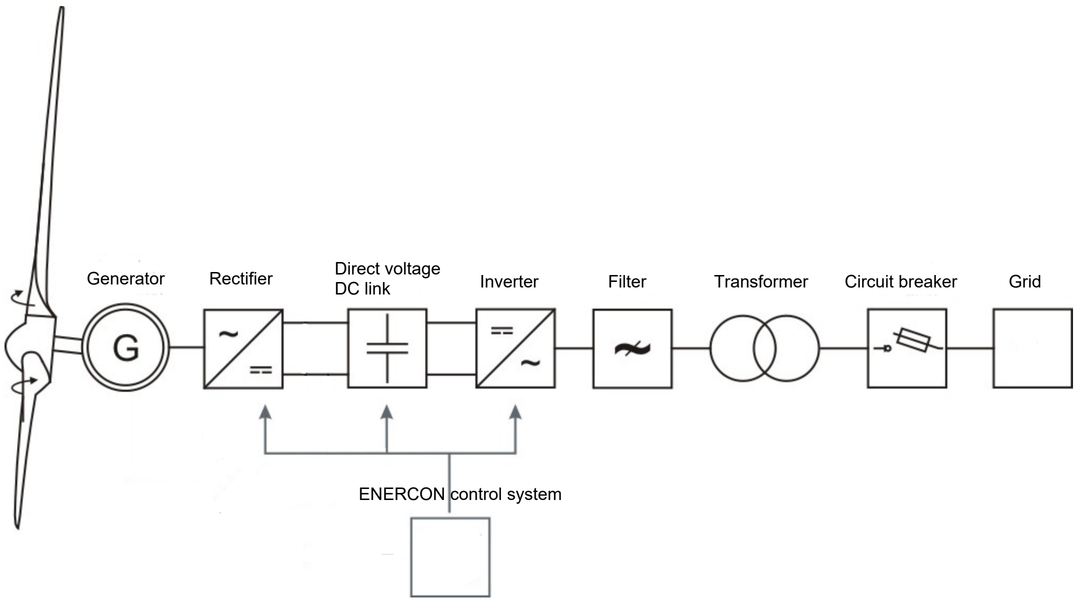

Fig. 2: Simplified electric diagram of a wind energy converter

The grid feed system and pitch control are managed by the control system to achieve maximum energy yield and excellent power quality.

Optimum power transmission is achieved by decoupling the generator from the grid. Any sudden changes in wind speed are translated into controlled changes in the power fed into the grid. In a similar way, any disruptions from the grid have virtually no effect on the mechanics of the wind energy converter. The electric power fed in by the wind energy converter can be precisely regulated from 0 kW up to the nominal power.

In general, grid operators specify the characteristics required for a certain wind energy converter or wind farm to be connected to a receiving grid. To meet different requirements, ENERCON wind energy converters are therefore available in a range of configurations.

The inverter system in the nacelle is designed according to the particular configuration of the wind energy converter. A transformer in the nacelle converts the low voltage to the desired medium voltage.

Reactive power

If necessary, a wind energy converter equipped with the standard FACTS open-loop control system can supply reactive power in order to contribute to the reactive power balance and to maintaining voltage levels in the grid. The maximum reactive power range varies, depending on the configuration of the wind energy converter.

FT configuration

By default, the wind energy converter comes equipped with FACTS technology that meets the stringent requirements of specific grid codes. It is able to ride through grid faults of a few seconds (undervoltage, overvoltage, automatic reclosing, etc.) and thus to remain connected to the grid during a fault.

If the voltage measured at the reference point exceeds a defined limit value, the wind energy converter changes from normal operation to a special fault operating mode.

Once the fault has been cleared, the wind energy converter returns to normal operation and feeds the available power into the grid. If the voltage does not return to the operating range admissible for normal operation within an adjustable time frame, the wind energy converter is disconnected from the grid.

While the system is riding through a grid fault, various fault modes using different grid feed strategies are available, including feeding in additional reactive current during the grid fault. The control strategies include different options for setting fault types.

Selection of a suitable control strategy depends on specific grid code and project requirements that must be confirmed by the particular grid operator.

FTS configuration

FT configuration with STATCOM option

Same as FT configuration; however, the STATCOM option additionally enables the wind energy converter to output and absorb reactive power regardless of whether it is generating and feeding active power into the grid. It is thus able to actively support the power grid at any time, similar to a power plant. Whether or not this configuration can be used needs to be determined on a project-by-project basis.

FTQ configuration

FT configuration with Q+ option

The FTQ configuration has all of the features of the FT configuration. In addition, it offers an extended reactive power range.

FTQS configuration

FT configuration with Q+ and STATCOM options

The FTQS configuration has all of the features of the FTQ and FTS configurations.

Frequency protection

ENERCON wind energy converters can be used in grids with a nominal frequency of 50 Hz or 60 Hz.

The range of operation of the wind energy converters is defined by a lower and upper frequency limit value. Overfrequency and underfrequency events at the reference point of the wind energy converter trigger frequency protection and cause the wind energy converter to shut down after the maximum delay time of 60 seconds has elapsed.

Power-frequency control

If temporary overfrequency occurs as a result of a grid fault, the wind energy converter can reduce its power feed dynamically to contribute to restoring the balance between the generating and transmission networks.
As a pre-emptive measure, the active power feed can be limited during normal operation. During an underfrequency event, the power reserved by this limitation is made available to stabilise the frequency. The characteristics of this control system can be adapted to various specifications in a flexible manner.

4 Safety system

The wind energy converter comes with a large number of safety features whose purpose is to permanently keep the wind energy converter inside a safe operating range. In addition to components that ensure safe stopping of the wind energy converter, these include a complex sensor system. This system records all relevant operating states of the wind energy converter on an ongoing basis and makes the corresponding information available through the ENERCON SCADA remote monitoring system.

The control system of the wind energy converter detects a fault with the sensors and attempts to continue operating the wind energy converter with reduced power. If this does not control the defect causing the fault, the wind energy converter is brought into the safe state by the safety control system.

4.1 Safety equipment

Emergency stop button

In the wind energy converter, there are emergency stop buttons on the control console in the tower base, on the nacelle control cabinet and, if necessary, in the tower entrance area as well as at other locations. Actuating an emergency stop button activates emergency pitching of the rotor blades. This brakes the rotor aerodynamically. An emergency stop renders the wind energy converter only partially dead.

Power is still supplied to the following:

- Beacon system components
- Lighting
- Sockets

4.2 Sensor system

Checking the sensors

Proper functioning of all sensors is either regularly checked by the wind energy converter control system itself during normal wind energy converter operation or, where this is not possible, in the course of wind energy converter maintenance work.

A large number of sensors continuously monitors the current status of the wind energy converter as well as all the relevant surrounding parameters. The sensor system provides the relevant information via a remote monitoring system. The wind energy converter control system analyses the signals and regulates the wind energy converter to optimally exploit the available wind energy at any given time and to ensure operating safety at the same time.

Redundant sensors

Redundant sensors are installed for some operating states to allow plausibility checks by comparing the reported values. Defective sensors are reliably detected and can be repaired or replaced through activation of a back-up sensor. The wind energy converter is thus usually able to continue safe operation without the need for immediate service work.

Speed monitoring

The wind energy converter control system regulates the rotor speed by adjusting the blade angle in such a way that the nominal speed is not significantly exceeded, even if the wind is very strong. If the nominal speed is exceeded by a defined value, however, the wind energy converter control system stops the wind energy converter. The wind energy converter can be restarted via the remote monitoring system.

If a fault occurs, the wind energy converter is stopped by an emergency pitching motion.

Air gap monitoring

The air gap between the rotor and stator of the generator must not be less than a specified width. The air gap is monitored by dedicated sensors. If the air gap falls below a specified value, the wind energy converter is stopped. The wind energy converter can be restarted as soon as the cause has been eliminated.

Temperature monitoring system

Some components of the wind energy converter are cooled. Temperature sensors also continuously measure components that need to be protected from high temperatures.

In the event of high temperatures, the wind energy converter's power is reduced or the wind energy converter is stopped, if necessary.

Some measuring points are equipped with additional overtemperature switches. The overtemperature switches similarly cause the wind energy converter to be stopped once a certain temperature has been exceeded. When it has cooled down, the wind energy converter can be put back into operation once the reason for the overtemperature has been investigated.

Cable twisting monitoring

The tower cables have plenty of space in the upper tower area enabling the nacelle to be turned left and right without damaging and/or overheating the tower cables. Depending on the degree of twisting and level of the wind speed, the wind energy converter open-loop control system decides when the tower cables require untwisting.

5 Open-loop control system

The wind energy converter open-loop control system is based on a programmable logic controller that uses sensors to query all wind energy converter components and collect data such as wind direction and wind speed. Using this information, it adjusts the operating mode of the wind energy converter accordingly. The wind energy converter display in the tower base and in the nacelle shows the current status of the wind energy converter and any faults that may have occurred.

5.1 Yaw system

The yaw bearing with a gear rim is located on the tower head. The yaw bearing allows the nacelle to rotate, thus allowing yaw control of the nacelle.

When the difference between the wind direction and the rotor axis direction exceeds the maximum permissible value, the yaw drives are switched on and align the nacelle with the wind direction. The yaw motor open-loop control system ensures smooth starting and stopping. The open-loop control system monitors the yaw control. If it detects any irregularities, yaw control is deactivated and the wind energy converter is stopped.

5.2 Pitch control

Functional principle

The pitch unit changes the position of the rotor blades and thus the angle of attack at which the air strikes the blade profile. Changes to the blade angle change the lift at the rotor blade and therefore also the force with which the rotor turns.

In automatic mode (normal operation), the blade angle is adjusted to ensure optimal exploitation of the wind's energy while avoiding overload of the wind energy converter. Any boundary conditions, such as noise optimisation, are also observed. In addition, the pitch unit is used to decelerate the rotor aerodynamically.

If the wind energy converter achieves its nominal power and the wind speed continues to increase, the pitch unit turns the rotor blades just far enough out of the wind to keep the rotor speed and the amount of energy extracted from the wind, i.e. the energy to be converted by the generator, within or just slightly above the nominal values.

Blade angle

Special rotor blade positions (blade angle):

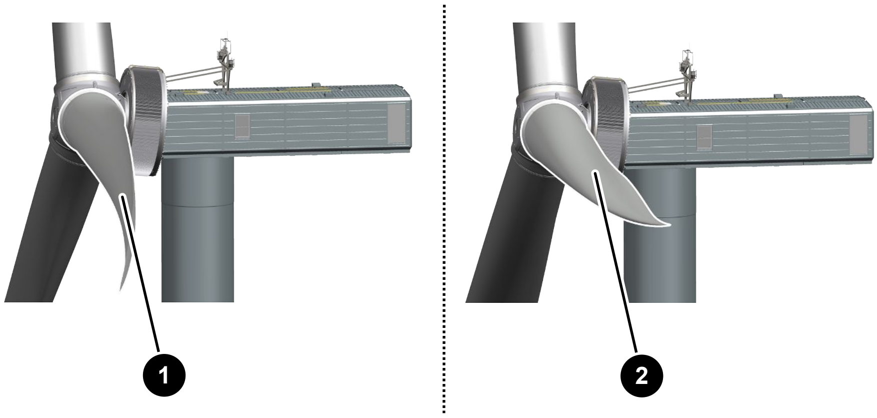

Fig. 3: Special rotor blade positions

Rotor blade position	Explanation
1	Position in partial load operation. The rotor blades generate maximum lift. The rotor turns.
2	Feathered position. The rotor blades do not generate lift. The rotor is braked aerodynamically and comes to a standstill or rotates only minimally.

5.3 Start of the wind energy converter

5.3.1 Start lead-up

As long as the main status is > 0, the wind energy converter remains stopped. As soon as the main status changes to 0, the wind energy converter is ready and the start-up process is initiated. If certain boundary conditions for start-up, e.g. charging of the emergency stop capacitors, have not been fulfilled yet, status `0:3 Start lead-up` is displayed.

During start lead-up, a wind measurement and alignment phase of 150 seconds begins for the wind energy converter.

5.3.2 Wind measurement and nacelle alignment

After completing start lead-up, status `0:2 Turbine operational` is displayed.

If the open-loop control system is in automatic mode, the mean wind speed is above approx. 1.8 m/s and the wind direction deviation is sufficient for yawing, the wind energy converter starts alignment with the prevailing wind direction. The wind energy converter goes into idle mode approx. 60 seconds after completing start lead-up. The rotor blades are pitched slowly into the wind while a check is performed on the emergency stop capacitors.

If the wind energy converter is equipped with rotor blade load control sensors, the rotor blades stop at an angle of 70° and adjust the rotor blade load control sensors, which may take several minutes. During this time, the status `0:5 Calibration of load control` is displayed.

If the mean wind speed during the wind measurement and alignment phase of approx. 150 seconds is above the current cut-in wind speed, the start-up process is initiated (status `0:1`). Otherwise, the wind energy converter remains in idle mode (status `2:1 Lack of wind: Wind speed too low`).

Power consumption

As the wind energy converter is not generating any active power at that moment, the electrical energy required for the wind energy converter's own power consumption is taken from the grid.

5.3.3 Power feed

As soon as a sufficient DC link voltage is available, the feed-in process is initiated. After the speed has increased due to sufficient wind and with a power setpoint > 0 kW, the line contactors (low-voltage side) are closed and the wind energy converter starts feeding power into the grid.

The power increase gradient (dP/dt) after a grid fault or a regular start-up can be defined in the open-loop control system within a certain range.

5.4 Operating modes

After completion of the start-up process, the wind energy converter switches to automatic mode (normal operation). While in automatic mode, the wind energy converter constantly monitors wind conditions, optimises rotor speed and generator power, aligns the nacelle position with the wind direction and records all sensor states.

In order to optimise power generation under diverse wind conditions when in automatic mode, the wind energy converter changes between 3 operating modes, depending on the wind speed. In certain circumstances, the wind energy converter stops if provided for by its configuration. In addition, the utility into whose grid the generated energy is being fed can be given the option to directly influence the behaviour of the wind energy converter by remote control, e.g. for temporary reduction of the grid feed.

The wind energy converter switches between the following operating modes:

- Full load operation
- Partial load operation
- Idle mode

5.4.1 Full load operation

Wind speed ≥ nominal wind speed

At wind speeds at and above the nominal wind speed, the wind energy converter uses pitch control to maintain the rotor speed at its setpoint, thereby limiting the power to the nominal value.

5.4.2 Partial load operation

Cut-in wind speed ≤ wind speed < nominal wind speed

During partial load operation (i.e. the wind speed is between cut-in wind speed and nominal wind speed), the maximum possible power is extracted from the wind. The rotor speed and the power output are determined by the current wind speed. Pitch control already starts as the wind energy converter approaches full load operation in order to ensure a smooth transition.

5.4.3 Idle mode

Wind speed < cut-in wind speed

At wind speeds below the cut-in wind speed, no current can be fed into the grid. The wind energy converter runs in idle mode, i.e. the rotor blades are turned almost completely out of the wind (blade angle ≥ approx. 60°), and the rotor turns slowly or stops completely if there is no wind at all.

Slow movement (idling) puts less load on the rotor bearings than longer periods of complete standstill; in addition, the wind energy converter can resume power generation and grid feed more quickly as soon as the wind picks up.

5.5 Safe stopping of the wind energy converter

The wind energy converter can be stopped by manual intervention or automatically by the control system.

The causes are divided into groups by risk.

Stopping the wind energy converter by means of pitch control

In the event of a malfunction that is not safety-relevant, the wind energy converter open-loop control system pitches the rotor blades out of the wind, causing the rotor blades not to generate any lift and bringing the wind energy converter to a safe stop.

Emergency pitching

The emergency stop capacitors store the energy required for emergency pitching and are kept charged and undergo continuous testing during wind energy converter operation. For emergency pitching, each pitch motor is supplied with energy by the associated emergency stop capacitors. The rotor blades move in a controlled manner into a position in which no lift is generated; this is called the feathered position.

Since the 3 pitch units are interconnected but also operate independently of each other, if one component fails, the remaining pitch units can still function and stop the rotor.

Emergency braking

If an emergency stop button is pressed, or if the rotor lock is actuated while the rotor is turning, the control system initiates an emergency braking procedure.

Here, the emergency pitching of the rotor blades brakes the rotor from nominal speed virtually to standstill within a maximum of 60 seconds.

6 Remote monitoring

By default, all ENERCON wind energy converters are equipped with the ENERCON SCADA system that connects them to Technical Service Dispatch. Technical Service Dispatch can retrieve each wind energy converter's operating data at any time and instantly respond to any irregularities or malfunctions.

All status messages are also sent via the ENERCON SCADA system to Technical Service Dispatch, where they are permanently stored. Practical experience gained from long-term operation can then be incorporated into the further development of ENERCON wind energy converters.

Connection of the individual wind energy converters is through the ENERCON SCADA Server that is usually located in the substation or the transmission substation of a wind farm. An ENERCON SCADA Server is installed in every wind farm.

At the operator/owner's request, monitoring of the wind energy converters can be performed by a third party.

7 Maintenance

To ensure long-term safe and optimum operation of the wind energy converter, maintenance is required at regular intervals.

The wind energy converters are regularly serviced, once a year, depending on requirements.

During maintenance, all safety-relevant components and functions are checked, e.g. the pitch unit, yaw control, safety systems, lightning protection system, anchorage points and safety ladder. The bolt connections on load-bearing joints (main components) are checked. All other components are visually inspected to check for any irregularities or damage. Lubrication systems are refilled.

Maintenance intervals and scope may vary, depending on regional guidelines and standards.