

WIND TURBINES

Wind turbines convert wind energy into electrical energy and feed it to the grid. Currently, the upwind three-bladed rotor design is most commonly used. In this design, the rotor and nacelle are mounted on a tower and are actively guided in the direction of the wind using electric yaw-azimuth drives. Pitch drives position the blades in or out of the wind. The rotor drives a horizontal axis connected to the generator. An AC voltage of up to 690 V is produced from the generator. The transformer in the nacelle or in the tower base steps up this voltage to approx. 10 to 30 kV AC so that the electrical energy can then be transferred over long distances using the grid.

Wind turbines usually feed into high- and medium-voltage systems, with large offshore wind farms sometimes even being connected to extra-high-voltage systems. Each feeder into the grid must be approved and must adhere to the grid operator's technical regulations. Converters adjust the voltage and frequency to the required power quality. Wind turbines are usually grouped together as onshore or offshore wind farms. The most common onshore wind turbines generate from 2 to over 6 MW and usually measure around 170 m to the hub and 250 m to the very top. Offshore turbines, meanwhile, generate around 4 to 14 MW of electrical power. Manufacturers are moving towards producing even taller and more efficient wind turbines to make the best use of locations that have already been approved for wind farms. Regular maintenance reduces downtimes and increases turbine efficiency.

All electrical test equipment for wind turbines from a single source

<ul style="list-style-type: none"> Three-phase insulation diagnostics Temperature corrections AC, DC and True-RMS voltmeters LCR meters Four-wire low resistance (Kelvin) Displays the rotary field direction and phase sequence <p>MTR105: electric motor/generator tester</p>	<ul style="list-style-type: none"> Up to 220 A test current Battery operated Measurement memory Report through PC software Easy to use and lightweight (1 kg) <p>MOM2: low resistance testing</p>	<ul style="list-style-type: none"> PD diagnosis of high- and medium-voltage insulation Phase-resolved PD patterns PD spectrum option Can be used as a standalone device Bright LCD screen <p>ICMcompact: PD diagnostics for devices</p>	<ul style="list-style-type: none"> Measuring range: 30 TQ 15 kV test voltage PI, DAR, DD, SV, ramp Report through PC software, time, date, stamp IP65 outdoor case Battery/main operation <p>S1: DC insulation diagnostics, 15 kV</p>	<ul style="list-style-type: none"> For cables up to 36 kV Peripheral fault detection Cable testing/diagnostics Analyses older cables Compact, small, easy to use Standalone device, no PC required <p>VLF Sinus 62: cable testing/diagnostics</p>	<ul style="list-style-type: none"> Tests batteries during operation Dynamic discharge Automatic shutdown Optional recording of all cells Report through PC software <p>TORHEL 900: battery-load tester</p>	<ul style="list-style-type: none"> Measurement memory Built-in demagnetisation One set of leads for all tests One test form for complete transformer test Report through PC software <p>MWA series: transformer testing</p>
<ul style="list-style-type: none"> 2- or 3-wire loop testing without triggering the RCD RCD type-B testing Earth-resistance measurements Very intuitive operation Memory, report through PC software <p>MFT1845: IEEE C37.20.1 and C37.20.7</p>	<ul style="list-style-type: none"> Measuring range: 0.05 Ω–1500 Ω Leakage currents: 0.02 mA–35 A Elliptical opening up to 35 mm Measured value memory/interface <p>DET24C: earth resistance testing</p>	<ul style="list-style-type: none"> Highly accurate soil analysis based on Wenner and Schlumberger methods High resolution up to 1 mΩ Automatic frequency adjustment Measured value memory/interface <p>DET2/3: earth resistance testing</p>	<ul style="list-style-type: none"> Single-/three-phase testing Secondary/primary testing 3 currents/4 voltages Can be used as a fully standalone device 900 V AC/105 A AC single-phase <p>SVERKER 900: protective device, transformer, primary</p>	<ul style="list-style-type: none"> Integrated touchscreen Output 45 A, 300 VA per phase 4 voltage channels, 3 current channels Dynamic/transient RTMS software <p>SMRT46D: automatic protection testing</p>	<ul style="list-style-type: none"> Circuit breaker timer, single interrupter per phase Analogous input for travel measurement Easy to use, safe, intuitive USB interface for report through PC software <p>EGIL: circuit breaker analyser</p>	<ul style="list-style-type: none"> Weight approx. 1 kg Battery operated Measurement memory 10 A test current Report through PC software <p>DLRO10HDX: lightning protection testing</p>



Mechanical and electrical tests on the wind turbine

Gearbox

The gearbox forms part of the drivetrain, together with the rotor and generator. Wind turbine manufacturers often use gearboxes that change the speed and torque between the rotor and the generator, usually in the form of a spur gear or planetary gear. The shaft turns slowly with high torque, the generator turns quickly with low torque. The speed depends on the tip speed ratio and is from 6 to 20 rpm. The generator turns at a faster speed than the rotor shaft — between 900 and 2000 rpm. The generator usually connected via a gearbox. However, in some wind turbines, the rotor shaft directly drives the generator.

Generator

The generator converts the mechanical rotation of the rotor into electrical energy. Synchronous generators, asynchronous generators and doubly-fed asynchronous generators (DFAG) are used in wind turbines. These require regular inspection. Particular attention should be given to monitoring the internal insulation, the low resistance of the contacts and that the connections are correct for the relevant phase.

Power transformers

The transformer in a wind turbine steps up the voltage from generation level to transmission level so that electrical power can be transferred over long distances. In wind turbines, it is usually transformed from 690 V AC to 10 to 30 kV AC. The most important performance characteristic data of each transformer are the 'turn ratio' and 'rated power'. The iron core, as well as all primary and secondary windings in the turbine, are usually cast into an insulating filling made of resin making them inaccessible from the outside. The internal insulation must be inspected and tested routinely using AC and/or DC techniques. Winding resistance and turn ratio must then be tested and analysed following IEEE and IEC recommendations. This ensures that almost all types of faults, such as short-circuits, breaks in windings or connection faults, can be identified at an early stage.

Partial discharge measurements

Partial discharges (PD) are emitted at all damaged or weakened points in an insulation system in almost every high- and medium-voltage electrical component. These are emissions of free charge carriers, which make faults detectable before they can have a fatal effect. PD can be reliably detected, located and even precisely analysed to assess the level of hazard. With a PD test device, such data can be gathered during operation and without having to isolate the turbine. PD measurement is therefore ideal for continuous online monitoring and can provide the operator with precise and up-to-date information about the condition of the turbine.

Current transformer

The current transformer enables large currents to be monitored and measured. It converts the primary current of the high-voltage side into a secondary current that can be used for protection, control, metering and revenue purposes. The secondary current behaves in the same way as the primary current, so changes to the primary current can be detected using measuring devices. In essence, a current transformer features primary and secondary windings and a core. Different core designs are used based on whether it is used for protection or measurement purposes. If the core is used for measuring purposes, it must go into saturation in order to protect the technology.

Protective relays

Protective relays react to the secondary currents supplied by the current transformer. As these behave in the same way as the primary currents, the protective relays detect any faults in the grid. If faults are detected, a TRIP command is immediately sent to the circuit breaker and the turbine is taken off the grid. Routinely testing all of the protective relays is therefore an important prerequisite for the statutory compensation to feed electricity into the grid. Suitable protection test devices simulate a wide variety of line faults to trigger the protective relay. There are many causes of line faults. The most common types of protection in wind turbines are IDMT and DMT time overcurrent protection devices. The definite minimum time relay (DMT) triggers at a predefined time as soon as the current exceeds a defined value. The tripping time of the inverse definite minimum time relay (IDMT) decreases as the current increases. The voltage and frequency protection devices react to abnormalities in these important parameters. IEC have released a new standard for frequency protection, IEC 60255-181:2019, to get a common view in this domain.

Circuit breaker

The circuit breaker disconnects the primary circuit when it receives a trip command from the protective relay. It has the capability to disconnect a short-circuit current, which is many times higher than the nominal current. The circuit breaker consists of a switching chamber and an operating system. When the circuit breaker operates, an arc develops in the switching chamber, which, in wind turbines, is usually eliminated using the insulating gas SF₆. The circuit breaker condition is determined through measuring the main contact operating time, coil current, station voltage and the travel during the operation. EGIL is used for routine tests of circuit breakers.

Maintenance

When testing in accordance regulations, wind turbine operators must ensure that statutory requirements for electrical equipment and insurance are observed. This must be carried out by a qualified electrician at a suggestion of every four years. This prevents legal consequences and minimises the risk of liability in the event of accidents due to defects in electrical equipment.

Lightning protection system

Lightning strikes cause a large number of downtimes or power losses for wind turbines and the taller the tower, the higher the number of strikes. As wind turbines are expected to only increase in their size, the number of downtimes is also likely to grow. On this basis, lightning protection testing is more important than ever. The weather mast, roof cooler, control panels, nacelle-hub junction, nacelle-tower junction and machine support must be tested at several points to ensure low resistance. Test leads of up to 100 metres on a cable reel and Kelvin-type clips are ideal for this purpose. The lightweight, battery-operated DLRO10HDX is designed to tackle such tasks with ease.

Control panel

The control panel contains the controller and connections for the electrical devices located both in the nacelle and inside the tower base. All control panels must be tested in accordance with IEC 61493-2. The test begins with by performing a visual inspection for defects and settings values. The emergency stop systems and fans are then checked to ensure they are functioning correctly. A device that complies with VDE 0100, such as MFT1845, is then used to test the following: RCD cut-off times, insulation, loop impedance, protective conductors and the low resistance of the contacts.

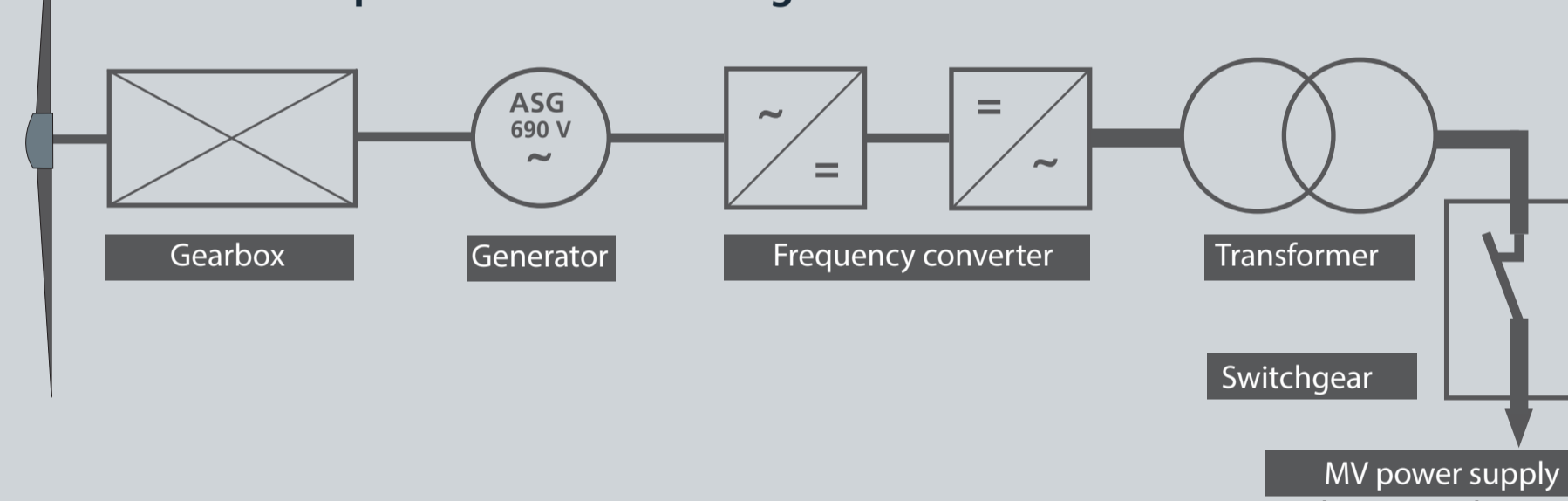
Medium-voltage cables

The medium-voltage cables feed the transformed voltage into the grid. The cable sheath and sealing ends must be checked for visible damage. VLF Sine Wave 62 is used to conduct VLF testing, a yes/no test that ensures that newly laid cables, sleeves and sealing ends are functioning correctly. A PD measurement provides information about the type and location of the fault. A tan-delta measurement on older cables reveals ageing-related faults that cannot be detected by any other measurement method: defects or breaks in the shielding caused by penetration of moisture or material fatigue, pressure points due to sharp objects in the ground, improper laying or bearing load due to heavy machinery in agriculture or construction.

Generated voltage

Wind turbines generate three-phase AC voltage. The voltage depends on the power class of the turbine: Smaller turbines from 1.5 to 10 kW generate 120 V to 240 V. Large turbines up to 500 kW generate 400 V, and large turbines from 600 kW generate 690 V.

Schematic representation of voltage flow



Noise measurement

To determine the noise emissions from a wind turbine, the sound pressure level relevant to the emission is measured at a height of 10 metres and at a distance from the tip of the blade, using a wind speed of 8 m/s in the current wind direction. Background noise, power, speed and directional pattern measurement values are also important when calculating the level of noise emissions. Impulse sounds are assessed in accordance with DIN 45645. The frequency can also be used to draw conclusions about the causes of the noise and even to obtain information about the condition of the gearbox, generator or hydraulic systems.

Vibration measurements

Rotor imbalances generate vibrations on the blades, which cause damage to the drivetrain and can damage the turbine in the long term. If vibrations in the drivetrain exceed the limit values, this can even lead to the turbine collapsing. Since 2009, the VDI 3834 standard has served as a guideline for measuring and assessing wind turbines.

Brake

Using a mechanical brake as a service brake is only common in turbines with lower rated capacities. In this case, the holding brake is mechanical. Large wind turbines are aerodynamically braked by adjusting the rotor blades. Simply adjusting one blade is sufficient to fully brake a turbine: in rigid systems, this can be performed using rotatable blade tips (tip brake) — in pitch systems, the entire blade is twisted.

Hydraulic station

Accumulators in the nacelle or hub of a turbine must be capable of withstanding great forces. They are responsible for hydraulically adjusting the blades (pitch regulation), as well as the emergency stop system, the hydraulic disc brakes and the azimuth brake systems. Damaged pressure vessels present a serious danger of injury or material damage. International industrial safety regulations require an inspection of the pressure vessels during commissioning and repeatedly thereafter in accordance with a risk assessment conducted by a qualified person.

Temperature/humidity measurement

Air pressure and temperature significantly influence the annual yield of wind energy. In accordance with IEC 61400-12-1, any wind measurement must also include a measurement of the air pressure. Humidity sensors measure the humidity of the air, while temperature sensors measure the air temperature; these sensors are usually combined. Humidity has no effect on the yield calculation, however, this variable helps to assess the risk of ice. The temperature sensor should be installed at a height of at least 10 m, otherwise heat radiation from the earth's surface will influence the measurement.

Pitch drives

The pitch drive turns the blade axis so that it is in an optimal position in terms of the current wind direction. In changeable wind-speed conditions, the angle of the rotor blades has to be adjusted to ensure that the generator operates within an optimal speed range. Electric motors must be tested in accordance with IEEE, IEC or local standards. A visual check for damage and to ensure sufficient lubrication must be carried out as part of regular maintenance tasks.

Yaw-azimuth drives

The yaw-azimuth drive turns the nacelle and the rotor into the wind to optimally transfer the high torque values of wind turbines in the multi-megawatt class. Up to twelve motor drives are used per turbine. Electric motors must be tested in accordance with IEEE, IEC or local standards. A visual check for damage and to ensure sufficient lubrication must be carried out as part of regular maintenance tasks.

Contact connections

Low transition resistances in all line, cable and electrical component connections are essential for the safe operation of an electrical system. Transition resistance in busbars are of particular importance, as they are the points where all the electrical energy converges. If the resistance is too high due to poor connections, corrosion or other factors, this may cause a high temperature that in turn may lead to higher power losses and thermal accelerated aging. Repeated low resistance testing after initial commissioning is therefore one of the most important tests of all.

Foundation earth (ground) electrode

The foundation connects the tower to the substrate and bears all the static and dynamic loads of the wind turbine. The earthing system is contained within the foundation, consisting of a steel mesh with band steel rings. This system leads all overcurrent, short-circuit currents or transients from lightning strikes to the ground. If the resistance is too high, the system will be damaged. The resistance of the earthing system must be monitored regularly, as it increases continuously due to ageing or corrosion.

Battery storage

After a power failure, stationary batteries continue to power up all the key components of the turbine. They work in parallel standby operation and are permanently connected to the charging rectifier and system components. The battery is charged from the low-voltage system via the charging rectifier in order to maintain its charge level. In case of a power outage, the charging stops and the battery supply power to the protection circuits. UPS battery systems at the grid feed-in point are much larger in size and must be regularly tested to through a capacity test to verify their total capacity.

