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 ever 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.

*ENERCON FCU – constant voltage despite fluctuating active power feed-in*
ENERCON MAIN CONTROL UNIT (MCU)

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 a as 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.