Lower your cost of energy with an optimized permanent magnet generator and full-power converter package.
MAXIMIZED ENERGY YIELDS AND SUPERIOR GRID CONNECTION

Wind turbine manufacturers, owners and operators are seeking the ideal drive train configuration to increase annual energy production (AEP), minimize total life cycle costs (TLC) and fulfill the strictest grid code requirements.

The Switch Drive™ is a fully optimized permanent magnet generator (PMG) and full-power converter (FPC) package, enabling high reliability, better overall efficiency and fault ride-through (FRT) capability.

Today, PMGs and FPCs represent the most advanced technology in the wind power industry. They ensure fewer failures, due to the fact that there are no wearing parts, and require less maintenance. The use of permanent magnets requires no external power source to initiate a magnetic field. This reduces costs, simplifies the system and improves system efficiency.
We have challenged the wind industry, first by making PMGs and FPCs the preferred technology for wind turbines, and now by enabling the technology to be commercially available.

The Switch product portfolio covers all wind power applications from 1 MW to 8 MW and higher, including direct-drive, medium-speed and high-speed PMGs. Our FPCs are optimized to work with our PMGs as a fully optimized drive train package.
A WINNING COMBINATION FOR LOWERING THE COST OF ENERGY

High availability
The Switch PMGs and FPCs typically have an average availability of 97% or higher in all operating conditions. A highly serviceable design and no wearing parts minimize the need for maintenance and increase production time.

Outstanding system efficiency
Each of The Switch PMG drive trains delivers superior efficiency over the entire wind speed range. PMGs start producing power already at lower wind speeds and demonstrate very high efficiency, even at partial loads where turbines operate most of the time. This results in proven higher efficiency and increased AEP rates.

Optimal design
For each project, we work in close collaboration with our customers to optimize the design specifically for their wind turbine. Every solution is purpose-built for the environment in which it will operate. This significantly lowers operation and maintenance (O&M) costs over the lifetime of the equipment. Streamlined processes and short lead times result in predictable time-to-market.

Minimal maintenance
All solutions from The Switch require minimal maintenance and feature a highly serviceable design to speed up maintenance routines. PMG technology eliminates the use of wearing parts, which ensures fewer failures and significantly reduces the need for maintenance. Our remote equipment monitoring system and 24/7 technical support allow our customers to implement a proactive service plan, avoiding unexpected downtime and costly failures.

Superior grid connection behavior
Our products fulfill the world’s strictest grid code requirements. The Switch FPCs support FRT and 100% reactive power compensation capability. The active power extracted from the turbine, the reactive power produced, and the generator shaft torque can be individually and precisely controlled over the entire speed range.
The Switch offers three different topologies to cover all wind power applications from 1 MW to 8 MW and higher. Each topology is designed to best match specific wind conditions and the required turbine designs.

**Low-speed, direct-drive permanent magnet generators**

The Switch low-speed, direct-drive PMGs operate without any gearbox and fast-rotating parts, resulting in increased reliability and superior drive train efficiency. The typical speed range is between 10 rpm and 20 rpm.

All generators can be designed with a segmented stator construction. This provides redundancy and makes it possible to repair the generator in the nacelle without full disassembly. In addition, our generator design offers the option to use the generator bearing as a turbine main bearing and to integrate the turbine brake system into the generator construction. Benefits are simplicity, fewer components and therefore, higher reliability.
High-speed permanent magnet generators
The Switch high-speed PMGs operate with a three-stage gearbox and feature a speed range between 1000 rpm and 2000 rpm. They offer an extremely small generator size and very high efficiency.

As a stand-alone component, these PMGs can be used with many different turbine designs. Existing double-fed induction generators can be easily replaced with The Switch high-speed PMGs without requiring any changes to the nacelle layout.

The Switch PMGs are available for low and medium voltage and can be designed with an inner or outer rotor construction.

Medium-speed permanent magnet generators
The Switch medium-speed PMGs operate with a single- or two-stage gearbox at a generator speed of typically between 100 rpm and 500 rpm. Combining the advantages of low- and high-speed technology, these PMGs offer extremely high availability and reliability, resulting in increased AEP.

FusionDrive®, the most compact medium-speed solution available on the market today, utilizes the same frame for both the generator and gearbox. The generator active parts are assembled directly around the secondary gear stage. Thus, the generator and gearbox can utilize the same bearings, and the gearbox lubrication oil can be used to cool the generator. This solution allows a significant reduction in mass and in the dimensions of the generator and gear combination.
PERMANENT MAGNET GENERATOR
DESIGN ADVANTAGES

To guarantee flawless functionality at different operational points, our design teams carefully select the proper materials for each component and accurately calculate the generator.

The first stage of the design process includes the calculation of the PMG using advanced machine calculation programs. In the second stage, the design is finalized, and both design and generator dimensions are verified using the finite element method.

The Switch considers worst-case scenarios in all its PMG designs, including short circuits at maximum operating temperatures, which can lead to demagnetization. Also torque pulsations are taken into account and reduced to a minimum.

The Switch PMGs are designed for reliable operation under all normal and abnormal conditions, as well as a long lifetime, which is currently calculated to be more than 20 years.
Windings
The Switch offers two different winding options: **Form wound**, the most standard winding option in the market with over 75 years of proven operational reliability. **Litz wire**, the ideal option for high-speed applications, offering a minimized skin effect.

Insulation
We have selected a mica-based insulation system with vacuum-pressure impregnation for all applications, because it reduces any elevated voltage stress coming from the frequency converter.

Cooling design
Even though the losses in a PMG rotor are extremely low, it is necessary to cool the rotor to eliminate hot spots. Our efficient cooling concept, consisting of a primary and secondary cooling circuit, better protects the generator design from demagnetization, reduces rotor losses to a minimum and extends the lifetime of the components.

The IP54-class enclosure effectively protects the generator against corrosion, making the cooling concept safe for offshore applications. The Switch PMGs are available with air or liquid cooling.
PERMANENT MAGNET GENERATOR FEATURES

Rotor design
In every The Switch PMG, high-quality Neodymium-Iron-Boron (NdFeB) magnets are used. These rare-earth magnets have a very high energy density and deliver excellent performance with corrosion resistance and temperature tolerance. High remanence flux density and coercivity force make them an ideal choice for industrial motors.

Although the magnetic material has developed remarkably, it is still important to protect it against humidity to secure its properties. All NdFeB magnets used in The Switch PMGs are coated against corrosion and typically also hermetically sealed to maximize safety.

Surface-mounted magnets for direct-drive and medium-speed PMGs. This magnet arrangement takes advantage of the full magnetic excitation and allows the maximum power to be captured from the magnet. The magnets are typically protected with a hermetically sealed module construction.

Embedded magnets for high-speed PMGs. The magnets are built inside a sealed corrosion-resistant metal enclosure to increase mechanical strength. The hermetic seal provides perfect protection from the environment.
FULL-POWER CONVERTER
DESIGN ADVANTAGES
The Switch FPCs are optimized to work with a wide range of PMG concepts. Designed for the best overall system efficiency and highest-level reliability, the robust line inverters demonstrate superior grid connection behavior and fulfill the world's strictest grid code requirements for harmonics, flicker and FRT.

Our FPCs feature a lightweight construction and modular design to match all wind conditions and power requirements. Power increases by duplicating the number of cabinets. This modularity allows easy handling during setup, replacement and maintenance, as well as full redundancy. The failure of one converter does not cause any turbine downtime. The turbine continues operation at a lower power production rate, guaranteeing better AEP rates.

Exceptional thermal management and cooling functionality enable smooth operation in environmentally challenging sites. Our converters have proven performance reliability in extreme temperatures and humid conditions.

The Switch FPCs have been designed specifically for wind power applications and feature a highly serviceable design. Together with remote monitoring, they allow for the highest possible availability and reliability.

Both standard and tailored solutions are available for all our converters.
Full-power converter hardware

With over 6.5 GW installed capacity, The Switch has extensive experience in designing, manufacturing and supplying FPCs for wind power generation.

**Generator inverters**
The generator inverters convert electricity from AC to DC and control generator torque. The DU/DT filter smoothen the fast voltage transients caused by switching and sudden change in voltage level.

**Line inverters**
The line inverters convert electricity from DC to AC and control the DC link by feeding generator power to the grid. To match utility grid regulations, the grid filters clean the line inverter output power, resulting in extremely low harmonic distortion.

**Cabinet and cooling**
The Switch converter cabinet frame design is exceptionally rugged. Cabinet construction is of class IP54 to withstand even the harshest environmental conditions. We have optimized our cabinet design to best match the requirements of different locations. Our product offering includes an option for very humid conditions, as well as options for extremely low or high temperatures.

The converter cabinets are fully liquid cooled. Internal air-to-liquid heat exchangers cool the air inside the cabinets for any non-liquid cooled components. All cabinets feature easy access for maintenance needs.
**Dynamic electric brake**
The dynamic electric brake ensures turbine grid connection during fault events by enabling the converter control to handle the energy flow in an optimal event-by-event manner. It also allows smooth torque control throughout the events and adds protection against possible transient voltages.

**Main circuit breakers**
The Switch FPCs are default equipped with grid and generator breakers. The breakers can include integrated digital protection relays to fulfill specific customer requirements. They isolate the converter from the turbine’s electric system for servicing.

With smart protection management, the failure of one component does not impact other components. Protective components include the main circuit breaker, which provides isolation from the grid and digital protection relay, and fast semiconductor fuses that protect the converter in case of failure.
FULL-POWER CONVERTER
GRID PERFORMANCE

Normal operation voltage range 0.9 - 1.1 U_N

Time (s)
and stabilize grid voltage and frequency according to the applicable grid code. The FRT performance of The Switch FPCs for symmetrical and asymmetrical voltage drops as well as phase jumps has been field tested with excellent results.

Current harmonics and flicker
Regulations on current harmonics and flicker have been tightened to ensure high quality electricity. The Switch FPCs use sophisticated grid filtering to guarantee the highest possible electricity quality. This results in a proven total harmonic distortion (THD) of <1.5%, the lowest in the entire industry. The exceptionally low THD and the extremely stable flicker co-efficient place fewer demands on the electricity network and allow for a better connectivity with a wider range of networks.

Fault ride-through capability
Grid transmission disturbances caused by lightning, equipment failure and damaged power lines are unavoidable. Flexible power and torque control ensure smooth turbine operation, especially during grid disturbances, as the FPCs decouple the generator from the grid.

The Switch FPCs stay connected during different kinds of grid faults, including zero voltage dips and overvoltage surges. This ensures continuous torque and active power control. The converters support the grid with active and reactive current during the dips and stabilize grid voltage and frequency according to the applicable grid code. The FRT performance of The Switch FPCs for symmetrical and asymmetrical voltage drops as well as phase jumps has been field tested with excellent results.

Reactive power support
By supplying reactive power on demand or a scheduled basis, The Switch FPCs enable easy and adjustable power factor control and grid voltage support. Predetermined grid voltage levels and power quality are automatically maintained within a fraction of a second.

If required, all of the current capacity can be used for reactive power generation, allowing a 100% reactive power feed, even in the absence of wind.

Lightning protection
The Switch concept for lightning protection is based on the generic IEC 62305 lightning protection standards and the IEC TR 61400-24 lightning protection standards specifically for wind turbines. These represent the maximum level of safety in case of lightning strikes.

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The wind turbine controller (WTC) communicates through a fieldbus (Profibus DP, CanOpen, Modbus, Modbus over TCP/IP). Digital and analog input/output (I/O) available for control and signals (e-stop, run enable, etc).

HMI operating panel for each inverter unit. Commissioning and service tools for PC.

Internet Remote diagnostics and online monitoring.

Since The Switch FPCs are able to handle changes in the network better than traditional converters, they offer advantageous control flexibility for adapting to ever-changing operating conditions.

Our software solutions have been designed for robust control in tough conditions, since we know that you need connectivity, intelligence and communication with your wind turbine system when you cannot be there.

**Control connectivity**
The turbine controller communicates through a fieldbus, giving converter torque, power or speed reference and control commands. As a default,
The Switch FPCs offer a configurable data exchange interface to the turbine controller, supporting the varying needs of different turbine models and allowing easy converter integration.

**Application software**  
Our experienced software engineering team tailors the software based on the unique requirements of your turbine. The Switch application software includes a comprehensive parameter interface to optimize the converter performance for varying conditions. Additionally, customer-specific functions or special interfaces can be built into the application. Our software complies with the IEC 61131-3 standard.

**Commissioning tool**  
Our PC-based commissioning tool offers easy startup, parameter setting and documentation. It includes the ability to monitor signals, read fault logs, and set and read internal data loggers. All The Switch FPCs also include an LCD display as back up.

**Remote management**  
The Switch remote management gives quick information through online monitoring. PC-based commissioning tools, remote connectivity and a reliable server platform create a toolset for maintaining a comprehensive database of the performance and service history over the entire converter lifetime.
We believe that everything relevant to efficiency and reliability needs to be tested to ensure outstanding equipment performance. The Switch follows IEC 60034 testing standards for rotating electrical machinery and has all mandatory equipment to carry out the tests in its own facilities.

Every PMG and FPC completes routine testing before leaving the factory. New designs pass an even more comprehensive type testing to verify system operation and performance. The Switch type testing includes full-load and back-to-back tests. Additional tests, such as overload tests or air gap measurements, can also be made.

Our specially designed test fields accurately simulate the operating conditions in a wind turbine, including all challenging operating conditions. This allows us to optimize the drive train performance so that our customers are able to achieve the highest possible system availability and efficiency, resulting in increased AEP rates.
We aim to be the technology leader for electrical power conversion.