
BROCHURE

Generators for wind power

Proven generators – reliable power

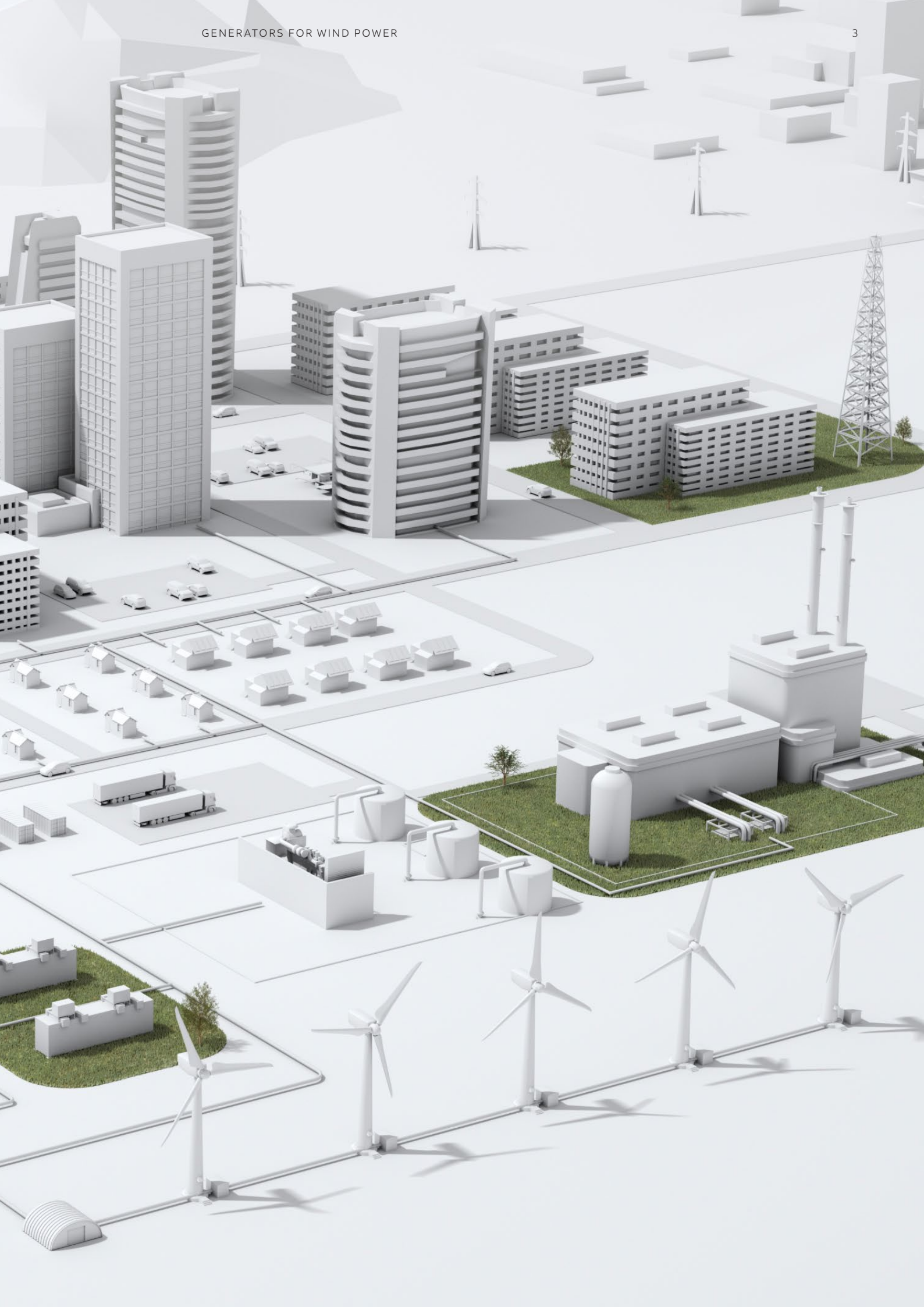


- ABB has delivered over 35,000 generators for wind turbines during the past 30 years, corresponding to about 30 GW of power.
- We make generators for all drivetrain concepts, gearless or geared, both doubly-fed and full converter type and for all power and voltage levels up to 20 MW and 15 kV. The majority of offshore turbines now operating rely on ABB generators.

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We provide motors, generators and mechanical power transmission products, services and expertise to save energy and improve customers' processes over the total life cycle of our products, and beyond.





Over 35,000 wind generators in 30 years

ABB is the world's leading supplier of motors and generators. We supply motors and generators for a full range of industrial, marine and power generation applications. Our product portfolio extends up to 80 MW and 15 kV.

Wind power

ABB has supplied more than 35,000 generators during the past 30 years to leading wind turbine customers all over the world. We have solutions for all the main drivetrain concepts from direct drive to medium and high speed, and we supply generators and converters in perfectly matched packages. We have been the leader in permanent magnet (PM) technology since its introduction for electrical machines in the 1990s.

Our global organization with its network of local service centers enables us to provide fast response to our customers, minimizing downtime and maximizing power production. By partnering with us, turbine manufacturers can ensure they remain on schedule and within budget, especially when introducing new products.

Quality built in

We manufacture high quality motors and generators that offer great performance and efficiency combined with the lowest O&M costs. Our technology leadership is built on innovation, consistent investments in R&D and more than 6,000 engineers and researchers working with 70 universities around the world.

Quality is built into our design, manufacturing processes and the materials and components we use. We source our purchases from reliable suppliers only, and we perform thorough testing in all phases of manufacturing. In addition to our own quality programs, using tools like Failure Mode and Effect Analysis (FMEA), we follow the ISO 9001 and 14001 standards. The quality systems in place at our global manufacturing facilities have also been verified by end users and leading turbine manufacturers.

Offshore expertise

ABB has a long track record in manufacturing high quality marine and offshore motors and generators. Today, our production totals around 50,000 units per year. Our solutions meet rigorous marine requirements and are certified to major classification standards like DNV GL.

In offshore wind power, proven ABB generators offer high efficiency and reliability. In fact, the majority of the offshore turbines now operating rely on ABB generators. These are mostly high speed squirrel cage and medium speed PMGs. We have supplied generators for projects ranging from Hyvind, the world's first floating turbine; and from Middelgrunden (2000), the first large offshore park, to the 600 MW London Array I wind farm.

Comprehensive offering for wind turbines and parks

ABB is the largest worldwide supplier of electrical products and solutions for wind turbines and parks.

Our products ensure efficient and safe power production in all turbine subsystems, from the generator to the grid. The generator and converter form the heart and brains of the electrical drivetrain system, which also includes the stator, contactor and breaker. The turbine control and protection system is based on PLCs for safe operation. Motors and drives enable reliable operation of the yaw and blade pitch system, as well as the hydraulic and cooling systems. Our offering includes electrical protection and disconnect systems and lightning protection.

ABB has supplied a number of turn-key wind park grid connections and High Voltage DC transmission systems for remote offshore plants.



Generators for wind turbines

Fixed speed

- Single and two speed
- Air and water cooled
- Cast iron and steel housing
- State-of-the-art winding technology
- Tailor-made for classic turbines

Doubly-fed

- Standard product platform
- Patented rotor design
- 2.5 kV rotor insulation
- Composite winding support
- Overspeed up to 3000 rpm
- Proven slip ring unit

Full converter

- Induction and permanent magnet generators
- Low, medium and high speed
- High efficiency at all wind speeds
- Maximum production of kWh
- High power and small size



Fixed speed generator



Doubly-fed generator



Medium speed permanent magnet generator

ABB – solutions for all main drivetrain concepts

Selecting your electrical drivetrain

The main concepts are doubly-fed (DF) and full converter (FC), using gearless low speed or geared medium or high speed generator solutions. There is no single optimum solution and the ideal choice will always be 'a perfect compromise' chosen according to market factors and wind conditions.

The most obvious technical criteria are high system efficiency, for maximum kWh production, combined with small size and low weight, for low foundation and logistics costs. Reliability means availability, and it is realized by using proven components. Grid code compliance must be backed by simulations and full-scale testing. Overall success depends on working with partners who have the necessary know-how and experience to develop a system in a short, but realistic, time-to-market.

The generator and gear solution must be designed together for an optimal speed that delivers the best system performance. The design of the generator and

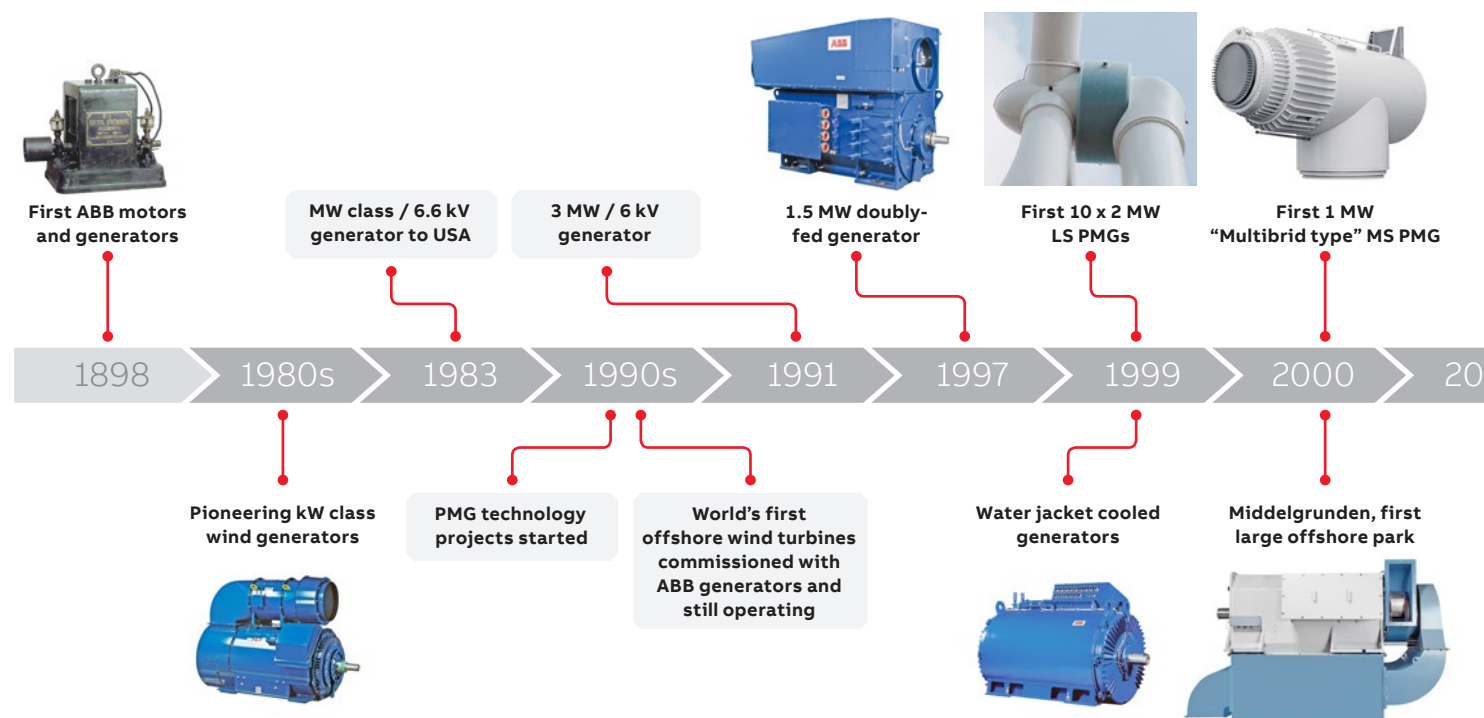
converter must be closely coordinated to produce a perfectly integrated package for full electrical system compatibility. The goal is continuous maximum production of kWh with the lowest O&M cost and a long lifetime. Decisions made at the design stage will also influence serviceability, exchangeability and O&M costs over the life of the turbine – ie, they will affect the life cycle profit of the wind park. By contrast, the initial investment cost is not particularly significant for the end user.

Proven ABB solutions

Low speed direct drive

ABB low speed direct drive (DD) permanent magnet generators have been running since 1999. Direct drive turbines provide good system efficiency, even though the large ring generators themselves deliver only modest efficiency. The efficiency of a PMG DD system is especially good in low wind areas because there are no gear losses, and up to 3 MW the size of the turbine is fairly manageable. With no gear the low nominal speed and high energy of

More than three decades of technology leadership



the wind turning the long blades creates high torques. To cope with these forces, a heavy, large diameter, multi-pole generator construction must be used. This requires large amounts of steel, copper and magnet material, which increases the foundation, crane and logistics costs. There are also technical challenges like the need to realize a very narrow air gap between a large diameter rotor and stator in a construction that is subject to bending by wind loads.

Medium speed – semi-integrated solution

ABB medium speed (MS) PMGs provide over 98% efficiency, which is the highest in the market. This compact, lower speed design offers a proven way to reduce top head mass without compromising reliability. The nominal speed influences the size of the generator and can be selected between 100 and 500 rpm using a single or two-stage gear. There are two main ways to implement the MS solution.

Fully integrated type: the gearbox and generator share the same frame, bearings and shaft, enabling a very

compact solution with low weight. In this design ABB has been supplying proven 1, 3 and 5 MW generators since 2000.

Semi-integrated type: the separate generator and gear are only partly integrated via a flange connection. This enables additional benefits like easy dismounting for servicing and low lifting weights. It also offers savings in tower and foundation costs, and allows the use of serial produced and individually tested plug-in units.

High speed – the mainstream solution

There are three proven high speed (HS) generator types: squirrel cage, doubly-fed and PM. High speed is the leading solution both on- and offshore. The combination of HS drivetrain and full converter concept using ABB PM generators ensures the best kWh production and the smallest size and weight, and it also enables easy manufacturing and logistics. Using small, standard components results in a fast time-to-market for new turbines. Most of the ABB generators in use around the world today are HS types.

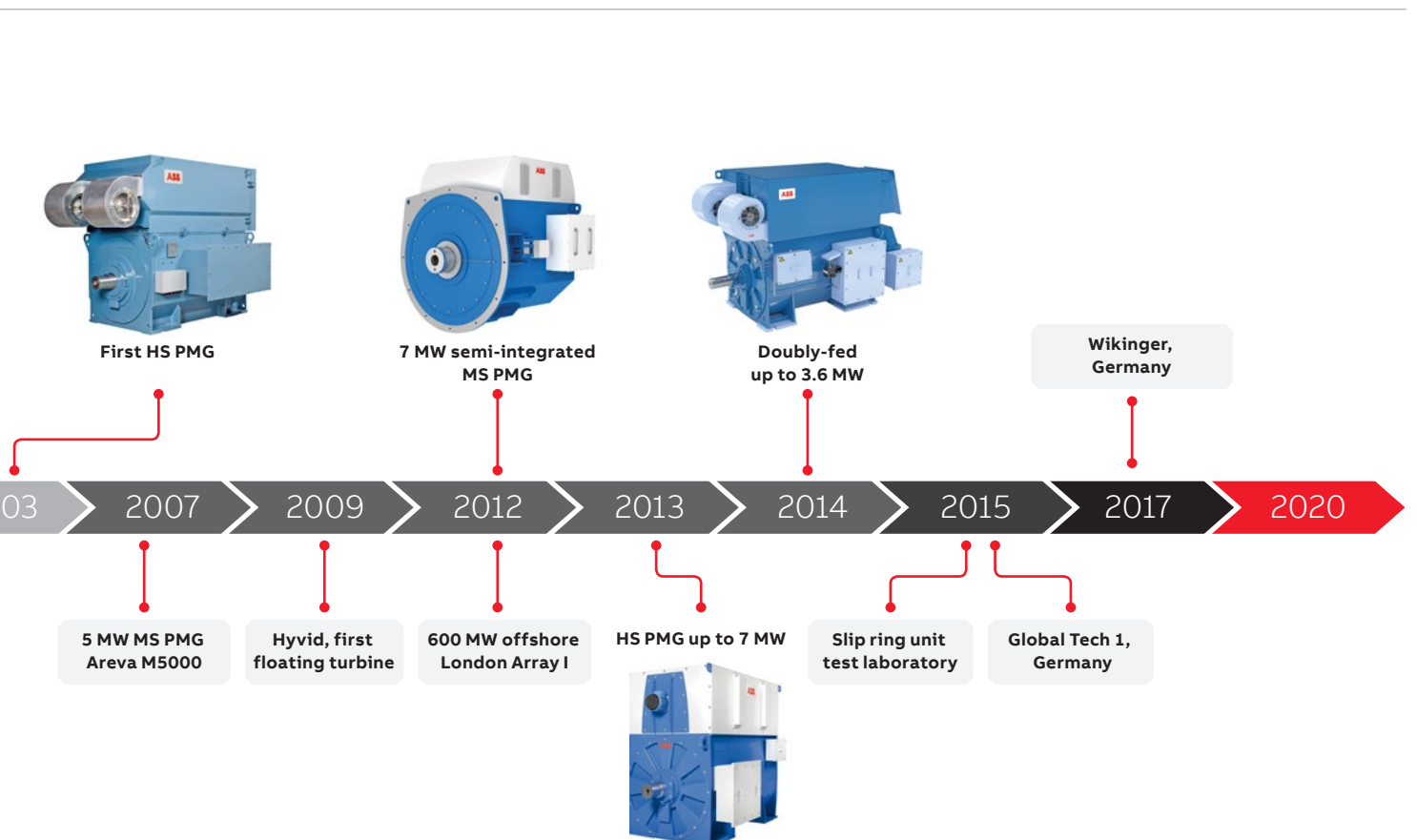


ABB design and manufacture mean reliable performance

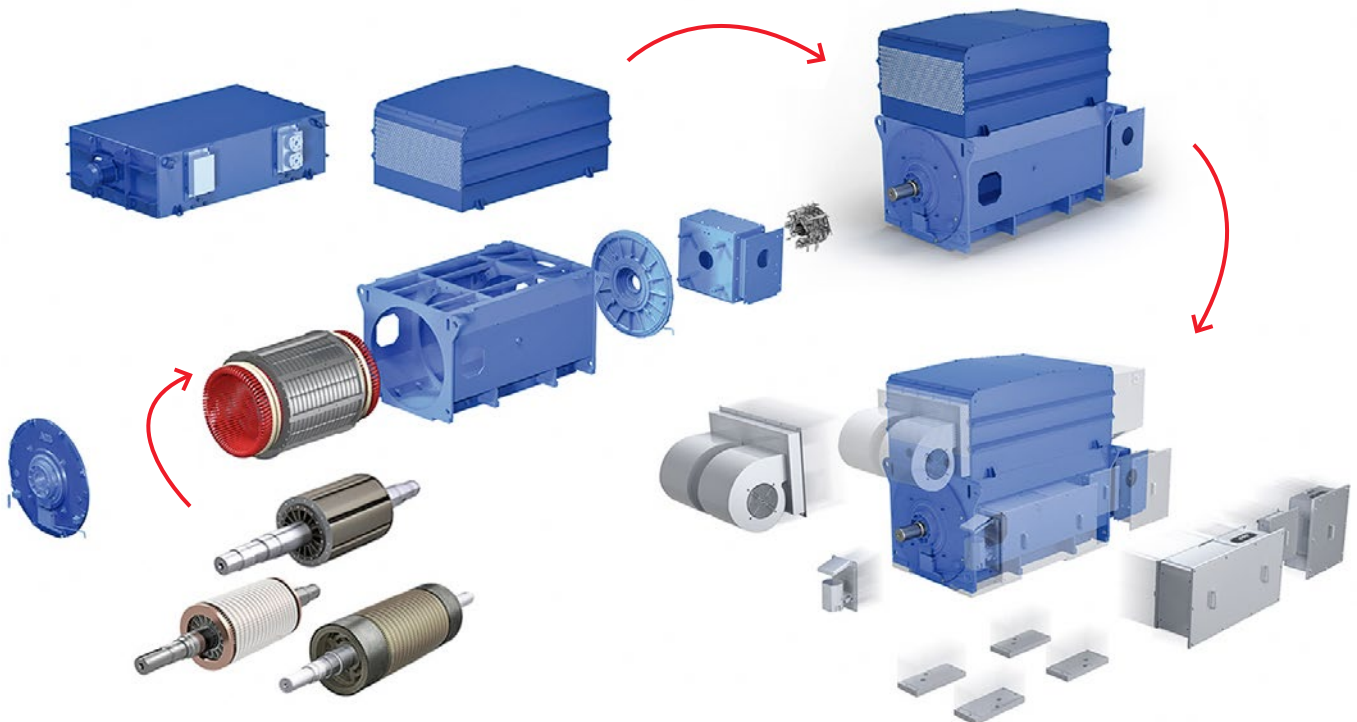
At ABB reliability is based on the know-how and experience we have accumulated in 120 years of working with demanding industrial, marine and power applications. Quality is built in to our products through our proven design and manufacturing processes, and through first-class components. We have special expertise in winding and insulation systems, PM technology and advanced rotor and slip ring constructions.

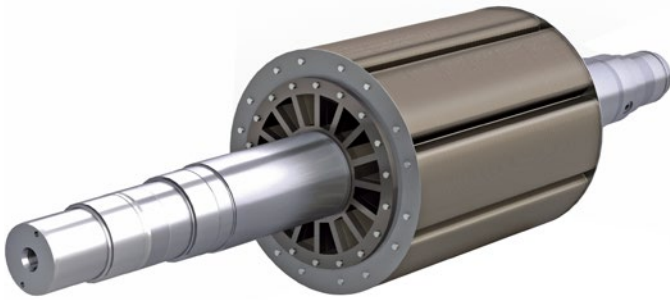
Design – based on thousands of type test results

ABB has created a unique design tool that incorporate our experience and actual measured data from thousands of type tests covering all industrial sectors. It provides the precise calculated data we need to build high performance generators. We use advanced design methods such as 3D and FEM (finite element method) simulation to optimize mechanical, electrical and thermal characteristics. FEM simulations also help us to efficiently reduce vibration and mechanical noise during the design phase.

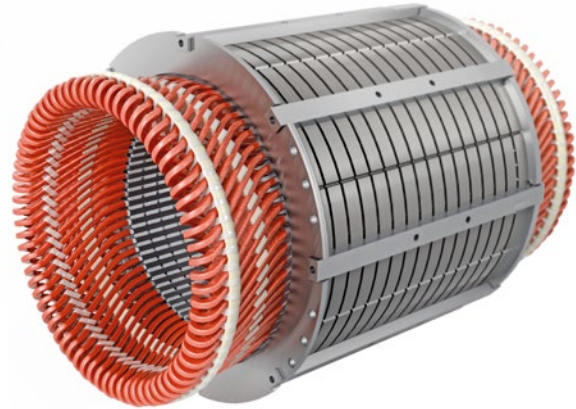
Our electrical design know-how enables us to build generators with optimum efficiency. Having low losses, less cooling fan power is needed, noise levels are also reduced and low running temperatures eliminate shutdowns caused by bearing overheating. Our grid friendly generators feature low Total Harmonic Distortion (THD), minimizing additional losses, overheating, vibration and electrical noise. The generator designs also benefit from 30 years of converter expertise.

The ABB flexible modular concept fits most turbine designs.





Patented HS PM rotor



Robust stator construction

Manufacturing – quality built in

The heavy duty frame is designed with FEM tools, resulting in a stiff construction with very low vibration levels. The stator core is laminated using high grade electrical steel plates for superior efficiency. We have patented rotor designs that use special winding end support rings and reliable magnet fixing to ensure high overspeed withstand.

ABB's know-how in windings and insulation has been proven in tens of thousands of motors and generators. We use reliable class F high voltage insulation technology, because in demanding wind applications this gives greater flexibility to withstand the thermal movements of the winding without the formation of cracks. Our advanced insulation and vacuum pressure impregnation systems maximize operational lifetime and enable a high momentary overload capacity.

The bearing construction design is important for a long lifetime. In high speed types we use pre-loaded bearings for accurate, smooth and silent operation and the massive brass cage is a factory standard. Converter applications give rise to bearing currents, but our proven bearing end shield insulation systems prevent the bearing damage these currents could otherwise cause.

All ABB generators are tested for optimum performance and thorough testing is undertaken in all phases of manufacturing. For example, every low voltage winding coil is separately tested with medium voltage before being installed in the stator. A final comprehensive test is carried out on all generators before shipment to the customer. We also undertake accelerated product lifetime testing.

Leader in PM technology for more than two decades

We have been developing PM technology for different motor and generator applications since the 1990s. Our reliable PM generators are designed for the highest fatigue and peak loads, ensuring continuous operation and a long lifetime, as well as low noise levels.

In PM generators the rotor uses powerful and carefully selected NdFeB magnets in place of the windings. This eliminates the need for separate excitation – and associated losses – enabling high power intensity and high efficiency, especially at partial loads.

Our experience in magnetic circuit design enables us to use optimized magnet geometry for each low, medium and high speed case to achieve superior efficiency. Proven magnet fastening methods and special corrosion protective magnet modules enable trouble-free operation and long lifetimes. The correct dimensioning and low operating temperatures of our generators prevent demagnetization, even during grid fault situations.

We have developed standard product platforms, enabling us to build reliable, cost-efficient solutions for different turbine types. Our proven PM generators offer maximum annual production of kWh with the lowest lifetime costs.

Proven ABB generators for leading wind turbine manufacturers

ABB has reliable solutions for both doubly-fed (DF) and full converter (FC) concepts. We make all synchronous PM types from direct drive to medium and high speed. Powers range from 1 to 8 MW in low and medium voltage (with ratings up to 20 MW and 15 kV available).

Asynchronous generators since the 1980s – pioneering wind power

Asynchronous generators can be used in fixed speed, doubly-fed and also full converter concepts. They are normally high speed types.

Squirrel cage generators – straightforward and robust

These generators are used in the conventional fixed speed stall concept with the generator directly coupled to the grid. They can also be used in the full converter concept.

- Powers up to 7 MW, with higher powers available
- Typical rated speed between 1000 and 1500 rpm
- Voltages from 690 to 3300 V and more

Doubly-fed, semi-variable speed generators since 1997 – economical

This is a mainstream pitch concept where the rotor windings also feed power to the grid via a small converter. It is an economical way to obtain variable speed and produce reactive power, and to increase the energy yield. ABB has been involved with asynchronous wound rotor slip ring motors for more than 50 years.

- Powers up to 6 MW, with higher powers available
- Typical rated speed between 1000 and 1500 rpm
- Voltages from 690 to 3300 V and more

Stators and rotors

ABB offers high performance stators and rotors to be integrated into high power wind turbines, typically for medium speed and direct drive generators.

- Full and segmented stators with total vacuum pressure impregnation
- Both low and high voltage
- Typical power from 5 MW upwards



— High speed induction generator



— Standard slip ring generator



— Stator and rotor

Synchronous PM generators since 1999 – high efficiency and small size

The full converter concept totally separates the generator from grid disturbances. It offers the best performance, advanced grid compliance and full control during grid transients. Combined with PM technology it enables better efficiencies, especially in low wind conditions at partial load. Reliable ABB PM generators are built for the highest fatigue and peak loads. ABB produces all three PM solutions from direct drive to high speed.

Low speed PM generators (LS PMG) since 1999

ABB LS direct drive PMGs form a structurally integrated unit with the wind turbine. Inner and outer rotor designs are available.

- Powers up to 3 MW, with higher powers for onshore available
- Typical rated speed between 14 and 30 rpm
- Voltages from 690 to 3300 V and more
- Segmented stator design for offshore

Medium speed PM generators (MS PMG) since 2000

Compact MS PMGs represent a reliable slower speed solution. ABB offers the highest efficiencies: over 98% at full load, and even at only 20% load the figure is still 98%. We make both fully and semi-integrated types, for single or 2-stage geared systems. Proven ABB MS PMGs offer small size and weight to reduce top head mass. A modern 7 MW MS PMG with a nominal speed of around 400 rpm can be about 3 meters in diameter and weigh under 30,000 kg.

- Powers up to 7 MW, with higher powers available
- Typical rated speed between 100 and 500 rpm
- Voltages from 690 to 3300 V and more

High speed PM generators (HS PMG) since 2003

ABB's HS PMGs provide high power from the smallest frame size, with high efficiency over the whole speed range. They offer turbine OEMs a fast-track route from DF to the benefits of the full converter (FC) concept without extensive re-engineering.

- Powers up to 7 MW, with higher powers available
- Typical rated speed between 1000 and 2000 rpm
- Voltages from 690 to 3300 V and more



Low speed direct drive (DD) permanent magnet generator



Medium speed permanent magnet generator



High speed permanent magnet generator

Generating better profitability for owners and operators

ABB supports customers' efforts to maximize their profitability by supplying products that deliver efficiency, availability and a low Levelized Cost of Energy (LCoE).

Our solutions are built for advanced grid code compliance and high power quality. They offer reliable operation at the highest peak and fatigue loads.

We design generators and converters for integration into perfectly matched packages which enable full system compatibility without compromising reliability.

Balancing investment and operating costs

The focus for wind turbine owners is on maximizing power production from the wind, in combination with low operation and maintenance costs and a long lifetime. Component costs are much less significant for turbine owners, as their involvement spans 20 years or more. It therefore makes sense to select components that will deliver high efficiency and reliability, rather than trying to minimize component costs.

ABB generators achieve the highest efficiencies in the market with lower running temperatures for continuous uninterrupted energy production and long lifetimes. The highest annual kWh production together with low

maintenance costs results in the best life cycle profit (LCP) and low cost of ownership.

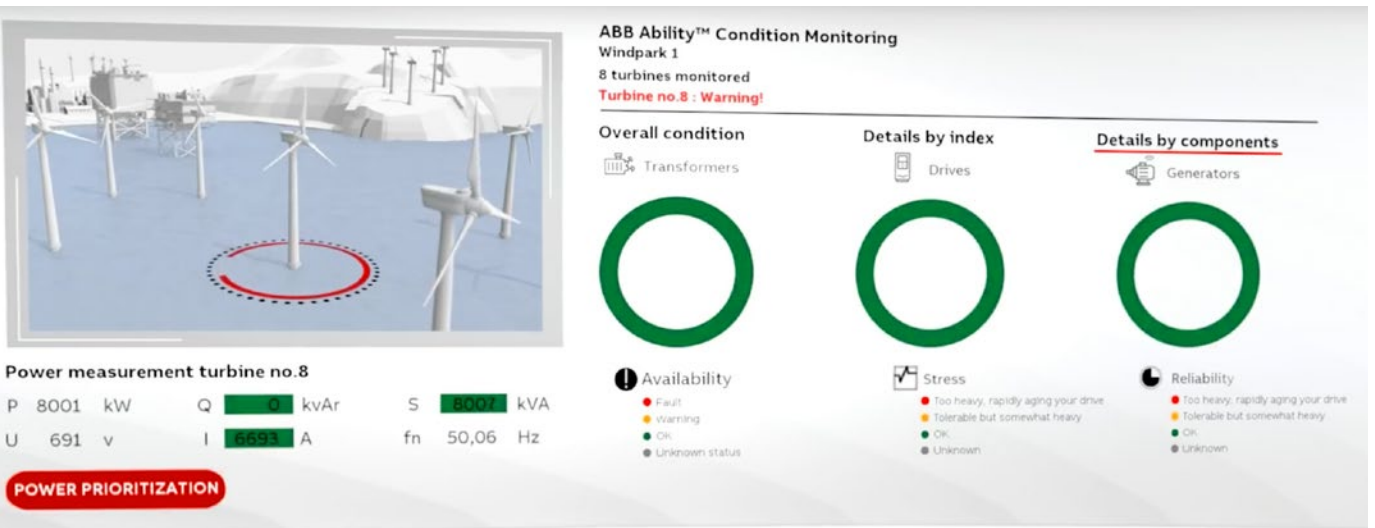
ABB Ability™ remote services reduce the cost of energy

Remote services cut the cost of energy by improving turbine availability and reducing unplanned maintenance. The services are based on data collected from the turbine powertrain and processed in our cloud platform.

Condition Monitoring delivers real-time visibility of the entire turbine fleet. Email alerts and automated reports enable the wind park's O&M team to take corrective and preventive action.

Remote Assistance provides specialized 24/7 support to the park's O&M team. It pinpoints the action needed to resolve issues quickly.

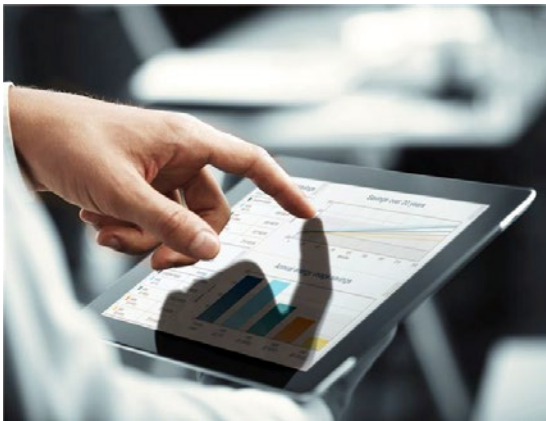
Remote condition monitoring gives early warnings of potential faults, allowing effective maintenance planning and early intervention. The ultimate goal is to eliminate unplanned maintenance entirely.



Life cycle services and support

From pre-purchase to migration and upgrades

ABB offers a complete portfolio of services to ensure trouble-free operation and long product lifetimes. These services cover the entire life cycle. Local support is provided through a global network of ABB service centers and certified partners.



Pre-purchase



ABB's front-end sales organization can help customers to quickly and efficiently select, configure and optimize the right generator for their wind turbine.

Installation and commissioning



Professional installation and commissioning by ABB's certified engineers represent an investment in availability and reliability over the entire life cycle.

Engineering and consulting



ABB's experts provide energy efficiency and reliability appraisals, advanced condition and performance assessments and technical studies.

Condition monitoring and diagnosis



Unique services provide early warnings before failures occur. Data can be collected by an engineer on-site or by remote monitoring. With the ABB Ability™ platform data can be transmitted to the cloud and accessed and analyzed remotely, allowing even greater insight into the health of the equipment.

Maintenance



ABB offers life cycle management plans and preventive maintenance products. The recommended four-level maintenance program covers the entire product lifetime.

Spare parts



Spare parts and support are offered throughout the life cycle of ABB products. In addition to individual spares, tailored spare part packages are also available.

Repair and refurbishment



Support for all ABB generators and other brands is provided by ABB's global service organization. Local units provide major and minor repairs as well as overhauls and reconditioning. Specialist teams can also deliver emergency support.

Migration and upgrades



Life cycle audits determine the optimum upgrades and migration paths. Upgrades range from individual components to replacements of generators.

Training



Product and service training courses take a practical approach. The training ranges from standard courses to specially tailored programs to suit customer requirements.

Service contracts



Service contracts are tailored to the customer's needs. The contracts combine modules from ABB's range of services and 120 years of experience to deploy the optimal service practices.





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For more information, please contact
your local ABB representative or visit

abb.com/motors-generators/segments/wind-power

Additional information

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