

GE Energy

2.5 MW Wind Turbine

a product of
ecomaginationSM



imagination at work



The evolution of power

Minute by minute, the world is growing. Economic development and increased attention to sustainability mean the world needs a steady supply of cleaner, reliable power. GE continuously stays a step ahead, driving cutting-edge wind turbine technology.

Building on a strong power generation heritage spanning more than a century, the 2.5 MW wind turbine is evolutionary technology based on a unique design strategy. Higher efficiency, increased reliability, maintainability and seamless grid integration make it a powerhouse of precision. In fact, GE's 2.5 MW wind turbine leads the industry by producing the highest annual energy yield in its class, creating more value for our customers.

Drawing on GE's experience of more than 12,000 1.5 MW wind turbines in operation worldwide, the 2.5 MW wind turbine is designed to meet the growing demands of the wind industry. Product evolution is one of the things GE does best and our product strategy is focused on results that contribute to our customers' success. Our reputation for excellence can be seen in everything we do.



Global footprint

GE Energy is one of the world's leading suppliers of power generation and energy delivery technologies—providing comprehensive solutions for coal, oil, natural gas and nuclear energy; renewable resources such as wind, solar and biogas, and other alternative fuels. As a part of GE Infrastructure—which also includes the Water and Oil & Gas businesses—we have the worldwide resources and experience to help customers meet their needs for cleaner, more reliable and efficient energy.

GE has six wind manufacturing and assembly facilities in Germany, Spain, China and the United States. Our facilities are registered to ISO 9001:2000 and our Quality Management System, which incorporates our rigorous Six Sigma methodologies, provides our customers with quality assurance backed by the strength of GE. We believe wind power will be an integral part of the world energy mix throughout the 21st century and we are committed to helping our customers design and implement energy solutions for their unique energy needs.



The new industry standard

Suitable for a wide variety of sites Higher efficiency

Designed for IEC class II and class III, the 2.5 MW wind turbine can be deployed on over 85% of the sites being developed today. Rated at 2.5 MW, it generates a leading amount of annual energy production and its 100 m rotor also makes it an excellent solution for low wind sites.

The 2.5 MW wind turbine also excels on sites that are constrained by environmental regulations. GE's innovative and patented rotor blade technology provides the 2.5 MW wind turbine with very competitive acoustic performance. In fact, with the optional noise-reduced operation modes, the 2.5 MW wind turbine can be deployed even at sites with the most stringent noise restraints, while simultaneously maintaining a high energy yield.

The 2.5 MW wind turbine can be equipped with various towers resulting in hub heights of 100 m, 85 m and 75 m, meeting potential tip height constraints and maximizing energy yield.

With more than 100 units installed and over 1 million operating hours, customers in seven countries around the world are already benefiting from our advanced 2.5 MW technology.

The 2.5 MW wind turbine is equipped with a permanent magnet generator, ensuring high efficiency even at low wind speeds. Compared to a conventional doubly-fed system, the efficiency in the partial load range is remarkably higher, resulting in increased revenues for wind power producers. Employing magnets instead of copper coils in the generator rotor reduces electrical losses in the generator and current flow through the rotating parts of the generator.

Optimal maintainability

The interior of the nacelle is designed to optimize maintainability and ergonomics for the maintenance crew. It provides an environment that facilitates safe and efficient maintenance and inspection work.

Automatic lubrication systems for the grease-lubricated bearings are used to accommodate for a 12-month maintenance interval under normal operating conditions. Not only does this minimize turbine down-time and provide the opportunity to avoid maintenance in the windiest seasons, it also provides the operator of remote sites with the opportunity to plan for maintenance in the season that the turbine is most accessible.

The optional elevator and climb-assist facilitate ergonomically optimal operations and maintenance of the turbine, enabling people to visit more wind turbines per day. This improves availability and reduces the size of the labor force required to operate a wind plant.

Technical Data

2.5xl

Operating data

• Rated capacity:	2,500 kW
• Cut-in wind speed:	3,0 m/s
• Cut-out wind speed:	25 m/s
• Rated wind speed:	12,5 m/s
• Wind Class - IEC:	IIIa, IIb

Rotor

• Number of rotor blades:	3
• Rotor diameter:	100 m
• Swept area:	7854 m ²

Tower

• Hub heights:	75 m, 85 m, 100 m
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Reliability by design

With technology centers of excellence in the United States, Europe, India and China, our teams of engineers and scientists use Six Sigma methodology, coupled with the latest computational modeling and power electronic analysis tools, to manufacture wind turbines with the reliability, efficiency and maintainability necessary to meet the challenges our customers face in today's energy environment.

GE's commitment to customer value and technology evolution is demonstrated by our ongoing investment in product development. Since entering the wind business in 2002, GE has invested over \$750 million in driving reliability and efficient wind technology.

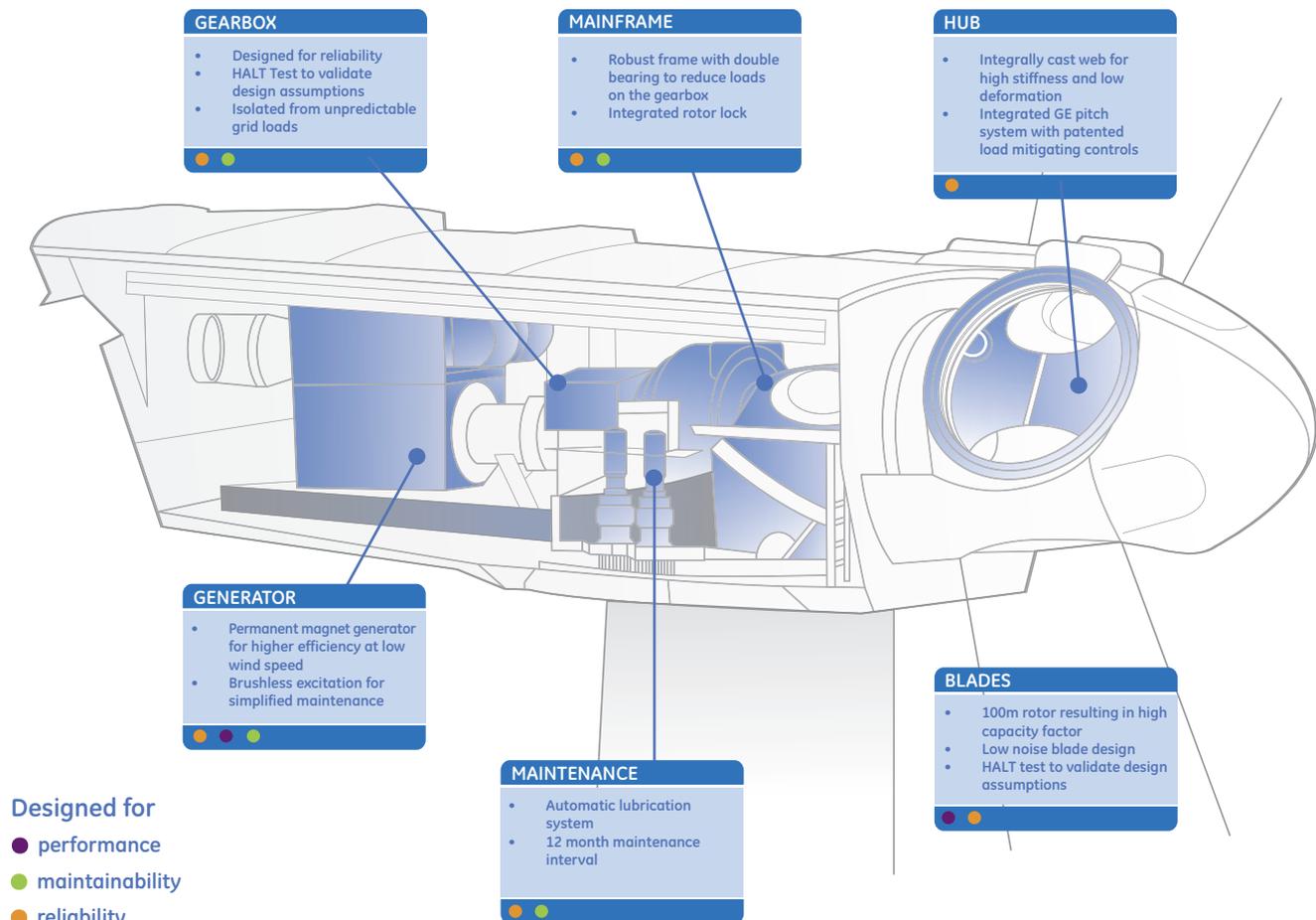
Advancing technology

A double-bearing main shaft minimizes gearbox thrust and bending loads by transmitting loads through the bedplate to the tower. The gearbox is only subjected to torque loading which is controlled by the wind turbine through the converter, resulting in less severe and better predictable loads than in conventional drivetrain designs.

The double-bearing main shaft also improves overall drivetrain reliability and improves gearbox lifetime predictability. Additionally, a full power converter separates the generator and gearbox from the grid, allowing them to remain essentially unaffected by transient grid loads. This unique system design results in robust and reliable power conversion.

The main bearings remain well lubricated even under severe conditions due to grease lubrication, which unlike oil, requires no heating at low ambient temperatures in order to keep its lubricating properties.

The hub design contains an integrally cast web in the blade root opening, providing high stiffness to the hub assembly. Higher stiffness results in less deflection of the hub, and therefore less loads on the components mounted to the hub. Consequently, stresses on the pitch bearing and pitch drive are reduced significantly when compared to conventional designs.



The 2.5 MW wind turbine is designed according to our Design for Reliability (DFR) methodology.

DFR starts with the definition of reliability goals and the environmental conditions in which the wind turbine components must operate. The reliability targets are then broken down to component level models that are developed to predict reliability.

A key step in the DFR process is validating design assumptions on both component levels and system levels. Different types of testing are used for validation, including climate chamber testing, compliance testing and Highly Accelerated Life Testing (HALT). HALT is a very efficient tool to flush-out design flaws rapidly. In the test, components are subjected to loads of the entire design life, but in a very short time frame.

The next step is field validation. The 2.5 MW design was validated with more than four years and 500,000 hours of operating experience. After extensive field validation, one turbine was decommissioned so that our engineers could teardown and inspect all of the major components.

The last step of the DFR methodology is production auditing. Where validation is focused on ensuring that the design is free of flaws, the production audit is focused on ensuring that each unit is delivered with consistent quality by understanding the impact of manufacturing variability.

DFR COMMON STEPS	TESTING & EVALUATION
1 GOAL SETTING	 <ul style="list-style-type: none"> SHOP TESTING FIELD TESTING ACCELERATED TESTING COMPLIANCE TESTING
2 SYSTEM MODELING	
3 DESIGN AND PREDICTION	
4 TESTING AND EVALUATION	
5 PRODUCT AUDIT	

GE technological expertise:

Energy

- Controls, materials, technology
- Fulfillment & logistics capability
- Efficient supply chain management



Aviation

Aerodynamic and aero-acoustic modeling expertise



Rail

Gearbox and power converter technologies

Global Research

- Energy conversion
- Material sciences
- Smart grids



Optimized wind power plant performance

Electrical system design

The electrical system design of the 2.5 MW wind turbine consists of a permanent magnet generator and full power conversion. In the lower tower section, the power module efficiently converts the energy from the permanent magnet generator into power that provides frequency and voltage control required by transmission system operators. The integration of the converter and transformer down tower, rather than the nacelle, ensures that vibration loads do not affect the reliability of the power electronics. The converter cooling system has been designed to minimize moving parts for reliability and features passive coolers that use the same wind that powers the turbine.

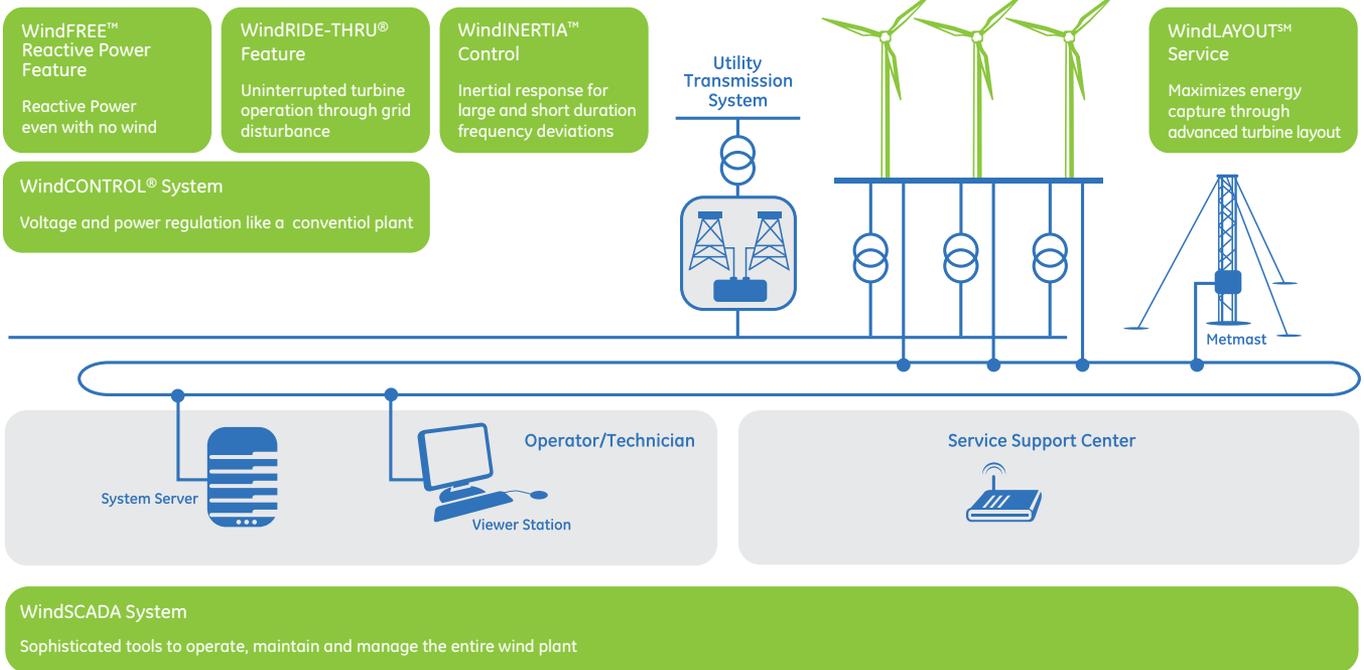
Seamless grid integration

Wind turbine performance is a critical issue in light of increasingly stringent grid requirements. GE's unrivaled experience in power generation makes us the industry leader in grid connection. By providing a sophisticated set of grid-friendly benefits similar to conventional power plants, GE's unique integrated suite of controls and electronics take your wind power station to the front line of performance and seamless grid integration.

The full-size power converter concept is an important technical advantage to reduce grid constraints and to maximize the connectable MW capacity at the network. GE technology can support the grid through reactive power supply and with the WindCONTROL® system, it can be operated similar to a conventional power plant.

With the WindFREE™ Reactive Power feature, the 2.5 MW wind turbine can generate reactive power even when the wind is not blowing. Consequently, it reduces the need for additional VAR-generating equipment, thus minimizing investments in electrical infrastructure.





Feature	Description	Benefits
WindRIDE-THRU® Turbine Operation System	<p>Uninterrupted turbine operation through grid disturbances</p> <p>Offered in two standard packages:</p> <ul style="list-style-type: none"> • Low Voltage Ride Through • Zero Voltage Ride Through 	<p>Meets present and emerging transmission reliability standards similar to those demanded of thermal generators</p>
WindCONTROL® Power Regulation System	Voltage and power regulation like a conventional power plant	<p>Provides frequency droop and power ramp limiters to help stabilize power system frequency</p> <p>Reduces Balance of Plant costs</p>
WindFREE™ Reactive Power System	Provides reactive power even with no wind	<p>Provides smooth fast voltage regulation by delivering controlled reactive power through all operating conditions</p> <p>Eliminates the need for grid reinforcements specifically designed for no-wind conditions, and may allow for more economic commitment of other generating resources that will enhance grid security</p>
WindSCADA System	Tools to operate, maintain and manage the wind power plant	<p>Intuitive operation and maintenance control</p> <p>Secure user-access</p>
WindINERTIA™ Control	GE's WindINERTIA™ control provides an internal response capability for wind turbines that is similar to conventional synchronous generators during under-frequency grid events	By utilizing the mechanical inertia of the rotor, GE's WindINERTIA™ power pulse characteristics to provide a 5% to 10% increase in turbine power over operational wind speeds.
WindINERTIA™ Service	Maximizes energy capture through advanced turbine layout	Utilizes a powerful set of advanced optimization tools that directly integrate turbine performance, mechanical loads, site conditions, and project constraints for maximizing energy production

World-class customer service

GE's wind turbine fleet is one of the fastest growing and best-run fleets in the world. Utilizing our decades of experience in product services in the power generation industry, GE provides state of the art solutions to ensure optimal performance for your wind plant.

24x7 Customer Support

GE's customer support centers in Europe and the Americas provide remote monitoring and troubleshooting for our installed fleet of wind turbines around the world, 24 hours a day, 365 days a year. The customer support centers are able to quickly perform remote resets for over 250 turbine faults. It is one of the most effective ways to ensure continuous monitoring and fault resets of your wind assets by qualified technology experts.

Technical skills and in-depth product knowledge

GE's wind customer support centers have dedicated teams to dispatch for troubleshooting, repair and maintenance, available 24 hours a day, 365 days a year. This model assures wide coverage of large wind turbine fleets without compromising technical skills or quality.

GE taps into our extensive product knowledge for timely resolution of many issues. All turbine faults are investigated using a structured technical process, which is then escalated as necessary. We also use feedback from this process in product development.

Operations and maintenance support

Driven by a highly skilled work force and the operating knowledge of over 12,000 1.5 MW wind turbines, GE offers a wide range of services tailored to the operation and maintenance needs of your wind assets. Our offerings range from technical advisory services, transactional services and remote operations to full on-site operations support, including availability guarantees.

Parts offerings

GE has utilized the extensive Parts and Refurbishment experience of its Energy Services business to establish a global center of excellence for wind parts operations. The wind parts resources are aligned to provide a full range of offerings for all types of parts and refurbishment needs, including routine maintenance kits, consumables and flow parts, and key capital parts such as gearboxes and blades.

With the launch of our 24/7 parts call center, and the development of online ordering tools, we are increasing the channels that our wind plant operators can utilize to order required wind turbine parts, including emergency requests for down-turbine needs.

For wind plant operators looking for additional benefits that a contractual parts relationship with GE can offer, the wind parts team has developed tailored offerings that can provide ongoing inventory-level support and parts lead-time guarantees. One of the exciting advantages of a GE wind parts and refurbishment program is membership to the capital parts pool, providing a priority access to often hard-to-source capital parts.

Long-Term Asset Management Support

GE is your reliable partner as we strive to build long-term relationships with asset managers. Utilizing our strengths, we can provide parts solutions, field technician and customer training and a wide range of specialized services to complement local on-site capabilities.



Project execution

GE understands that grid compatibility, site flexibility, and on-time delivery are critical to the economics of a wind project. For that reason, the 2.5 MW wind turbine has been engineered for ease of integration and delivery to a wide range of locations.

Our global project management and fulfillment expertise offer customers on-time delivery and schedule certainty. Regardless of where wind turbine components are delivered, GE's integrated logistics team retains ownership and responsibility for this critical step. Utilizing the GE Energy Power Answer Center, our engineering and supply chain teams are ready to respond to any technical, mechanical or electrical questions that may arise.

As one of the world's largest power plant system providers, GE is uniquely positioned to provide customers with full-service project management solutions.

With offices in North America, Europe, and Asia, our world-class Power Plant Systems division utilizes decades of fulfillment expertise in project management, logistics, plant start-up and integration from Gas Turbine, Combined Cycle, Hydro, and Aero plants.

Environmental Health and Safety, a GE commitment

Maintaining high Environmental Health and Safety (EHS) standards is more than simply a good business practice; it is a fundamental responsibility to our employees, customers, contractors, and the environment we all share.

GE is committed to maintaining a safe work environment. We incorporate these values into every product, service and process, driving EHS processes to the highest standards.



Powering the world...responsibly.

For more information, please visit
www.ge-energy.com/wind



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