

Technology for Improved Reliability in the GE 2.5 Wind Turbine Series

Burkhard Schwarz
General Electric, Wind Energy



Abstract

In the launch of a new product, energy production and cost are critical, but if **reliability** can not be assured, the product cannot be a success. The **GE 2.5** wind turbine series is based on the design of the GE 1.5sle platform, but the growth to 2.5MW with a 100m rotor diameter required the development of new technologies to achieve the aggressive annual energy production target.

Innovative blade designs and design methods were used to allow the blade to flex and unload, yet remain strong enough for extreme loads and 20 year fatigue life, and to minimize weight. Other **enhancements to the drive train**, main bearings, gearbox and generator further improve reliability. A four parallel thread design is employed in the full power converter system to maintain availability in the event of a single component failure. **Advanced controls** are used to control turbine blades and loads, but also to automatically diagnose and correct issues.

Examples are given of initial issues found in service and how those **problems were corrected, leading to 98% reliability** in the engineering prototypes and the initial 400 units.

Evolution & Innovation

GE 2.5MW series.....

...is an evolution of the 1.x platform which has over 15,000 units installed globally
350 units in operation, >\$100MM technology investment, > 3,000,000 operating hours in 3/2011



	2.x	'04	'10	
Rotor size (m)	88	100/103		+15m
Cap. factor (%) 7.5m/s	34.7	41.9		+7 Pts
Cap. factor (%) 8.5m/s	39.5	47.7		+9 Pts
Availability (%)	92	98		+6 Pts

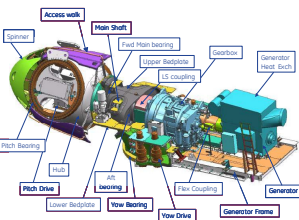
Technology improvements & new variants

- 103m rotor for IEC TCIII
- 2.75MW nameplate
- Greater electrical efficiency

14 countries ... 2.7GW of orders

Technology & Validation

GE 2.5 Turbine Design



Gearbox

Accelerated Lifetime Test

- Gearbox operated at elevated torque levels
- Load peaks up to 300% / -200%
- Test Duration -500 h with no failure
- ~60 measurement channels for
 - > vibration
 - > loads
 - > temperatures
 - > pressures
- Visual Inspection & oil samples every 80 h
- Gearbox endoscopy at 160 and 320 h
- Reports after disassembly and check by supplier



Blades

Accelerated Fatigue Testing

- Loads simultaneously applied at up to six pulling stations
- Five million edge wise cycles
- Three million flap wise cycles
- Test load factor 1.35 according to IEC 61400-2 for 20 years lifetime
- Blade Eigenfrequencies and blade mass measurements
- Post Fatigue Static Test



Advanced loads control

Advanced Loads Control (ALC) is a load mitigation strategy...

- 1) Control asymmetric loads on rotor plane through individual blade pitch
- 2) Control tower side-to-side and wind direction vibration through torque and pitch action

- A product evolution enabler...
- Allows expansion of cutoff from 20m/s to ~25m/s...increasing AEP
- Decreases hub, tower & mainshaft loads
- Changes:
 - > low speed shaft proximity sensors mounted on bearing block
 - > additional yaw sensor and additional inputs to the top box
- Upgrades:
 - > reinforced, higher-ratio pitch drives
 - > upgraded tower vibration monitor

Proven Design for 20 Year Life Capability

Installations & Orders

GE 2.5... The world's largest operating fleet (100m rotor)

Country	Ordered Units	Total MW
Japan	43	108
Portugal	14	35
Germany	49	115
Netherlands	2	5
Belgium	16	40
France	15	38
Poland	85	213
Spain	82	205
Turkey	154	385
Sweden	99	248
Romania	120	300
Italy	56	140
Ireland	21	53
United States	338	845
Total	1094	2730

Fintinele, Rumania
Europe's largest wind farm
120* 2.5-100

400 2.5 turbines installed

Validations completed

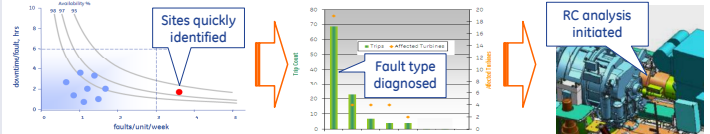
- Operating temperature ... Japan, Spain, Turkey
- Turbulence intensity ... Portugal, Japan, Turkey
- Altitude ... Turkey
- Wind speed ... The Netherlands, Turkey
- Grid ... Turkey, Eastern Europe
- Humidity, seismic, typhoons ... Japan
- 60Hz operation ... Japan

Diverse site conditions validated design envelope

Reliability

GE 2.5-100 Fleet Performance Analysis

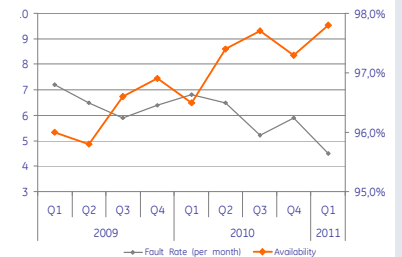
Systematic Fault and Outlier Detection: Sustainable Design Correction & Optimization



Top Design Upgrades

- ✓ **Generator Circuit Breaker**
 - Thermal Overload/ Eddy Currents
 - Switch redesigned
- ✓ **PLC Fault Collection**
 - Electromagnetic Interference
 - Copper shield installed
- ✓ **UPS**
 - Automatic turbine restart after grid outages disturbed due to peak voltages/ frequencies
 - Firmware update uploaded
- ✓ **Yaw brake**
 - Excessive yaw brake pad wear
 - Disc surface roughness reworked

GE 2.5-100 Availability Trend



Europe's Largest Wind Farm

Fintinele, Romania

120 operating units
GE 2.5-100

