New technologies for emerging wind markets: turbines for low wind and grid friendliness

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Wind Turbines for Low Wind Sites

Technologies to reduce COE for Low Wind

Vestas

Improved Wind Turbine Technology

- **Larger Blades** to capture more energy from the available wind
- **Taller Towers** to get the blades higher into the wind
- **Better power electrics** to meet grid requirements and reduce reactive equipment

Transport and Construction Enabling Technologies

- Tower Design
- Large Diameter Steel Tower
- PowerPlantController
- Tower Crane
- Blade Lifter

Wind turbine solutions for low wind

Vestas

What's the maximum wind power that can be extracted from the wind?

$$\dot{E} = \frac{1}{2}\rho \cdot A \cdot v^3$$

Where:
$\dot{E}$ = Kinetic Energy
ρ = Air density
A = Swept area
V = Wind Speed

- A maximum of 59.3% can be utilized to useful energy

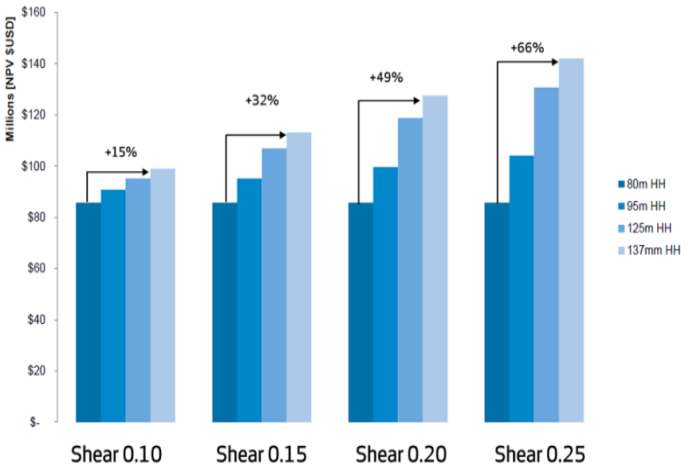
How do we increase the production of a WTG?

- **By increasing the swept area (A)**

  Bigger rotors

- **Increase in Wind Speed**

  Taller towers



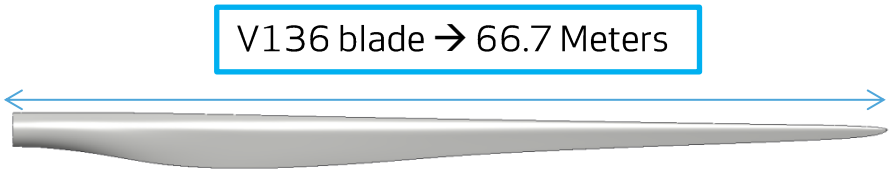
Measured wind speed 5.7 m/s @ 80m
k wind shape factor 2.0

Transport Solution

Blade Lifter (Rocket Launcher)

Enables large blades to be transported into tight locations by supporting the blade from the root end and be raised or rotated to get around obstacles such as:

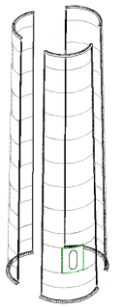
- Trees
- Buildings
- Overhead Power Lines
- Sharp corners or bends



Tower Solution

Vestas

Large Diameter Steel Tower (LDST) technology is designed for ease of transport and quick installation



LDST technology combined with sectional design allows for improved COE through efficient and optimized transportation and construction

Assembly process

1

2

3

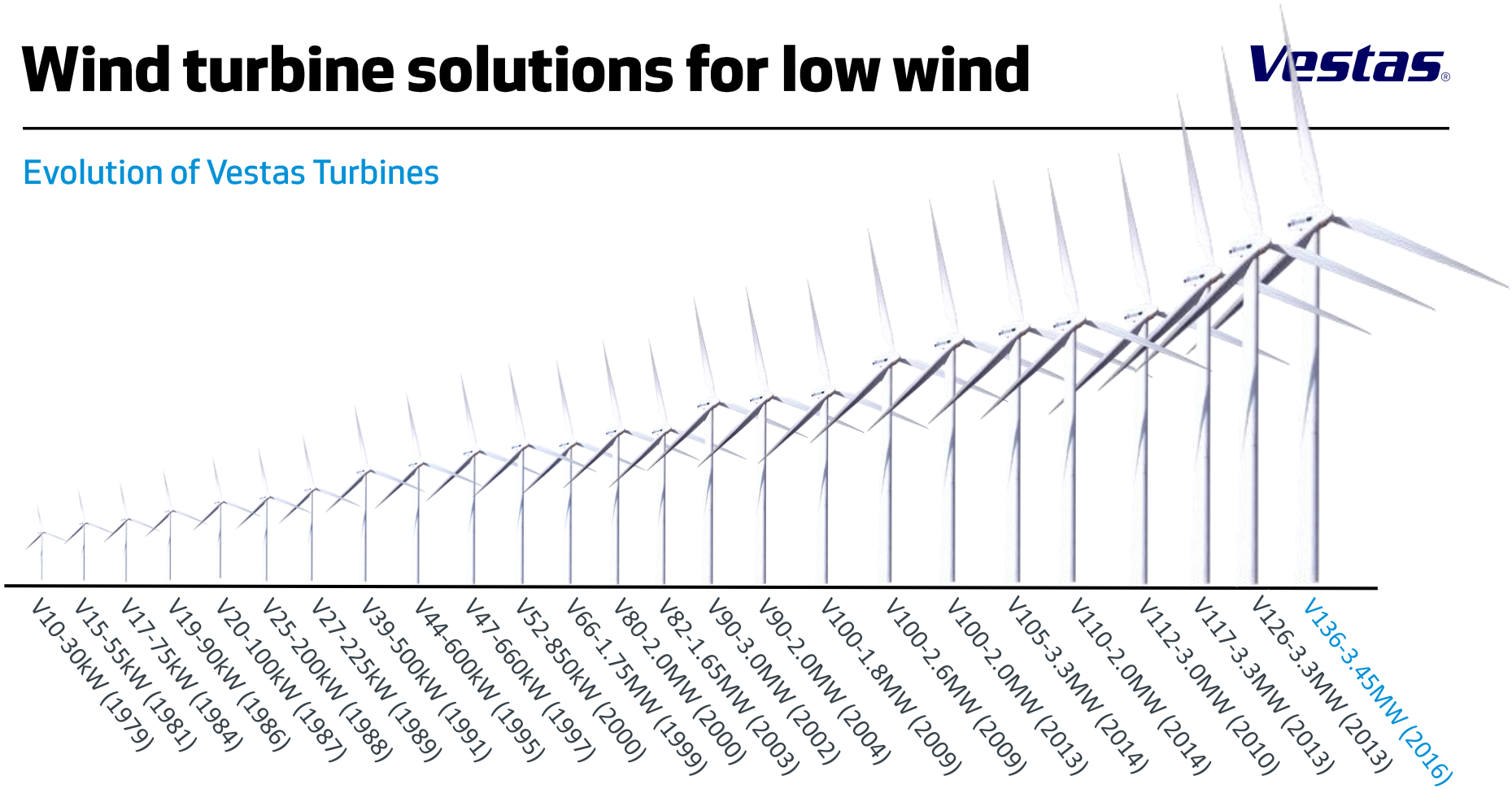
4

5

6

Wind turbine solutions for low wind

Evolution of Vestas Turbines



& Up to 149mHH

Where is the limit?

Turbine size and hub height is limited by transport, tower design and installation capabilities

Are these solutions applicable to all sites?

Some of the counties in the region like in the Philippines combines low wind conditions with…

- **Typhoon risk**
- **Building code**

In Vestas we have solutions that help to cope with extreme wind speeds and different building code requirements while optimizing the Energy Production.

- **Yaw Power Back-Up System**
- **Typhoon towers**

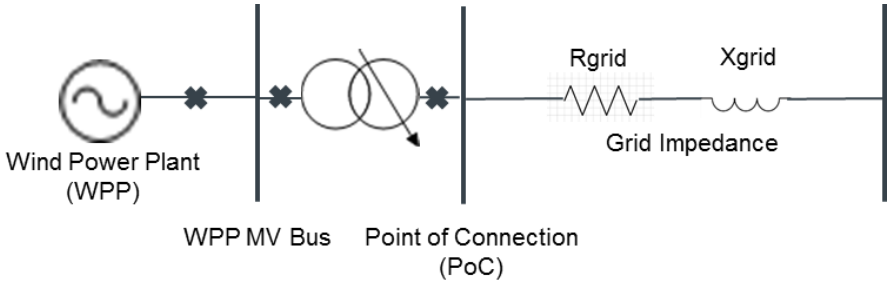
Ultimate goal is to reduce LCOE (Levelized Cost of Energy)


Grid-friendly
Wind Farms

Weak Grid: Definition

- Short Circuit Ratio (SCR) < 3 and Xgrid/Rgrid ratio < 5;
- The SCR indicates the amount of power (Swpp) that can be accepted by the power system without affecting the power quality (V, f, harmonics, flicker) at the PoC.
- Low grid inertia constant (H).

Where,
SCR = Smin/Swpp;
Smin = Minimum fault level at the WPP MV bus without the WPP [MVA];
Swpp = WPP rating [MW].



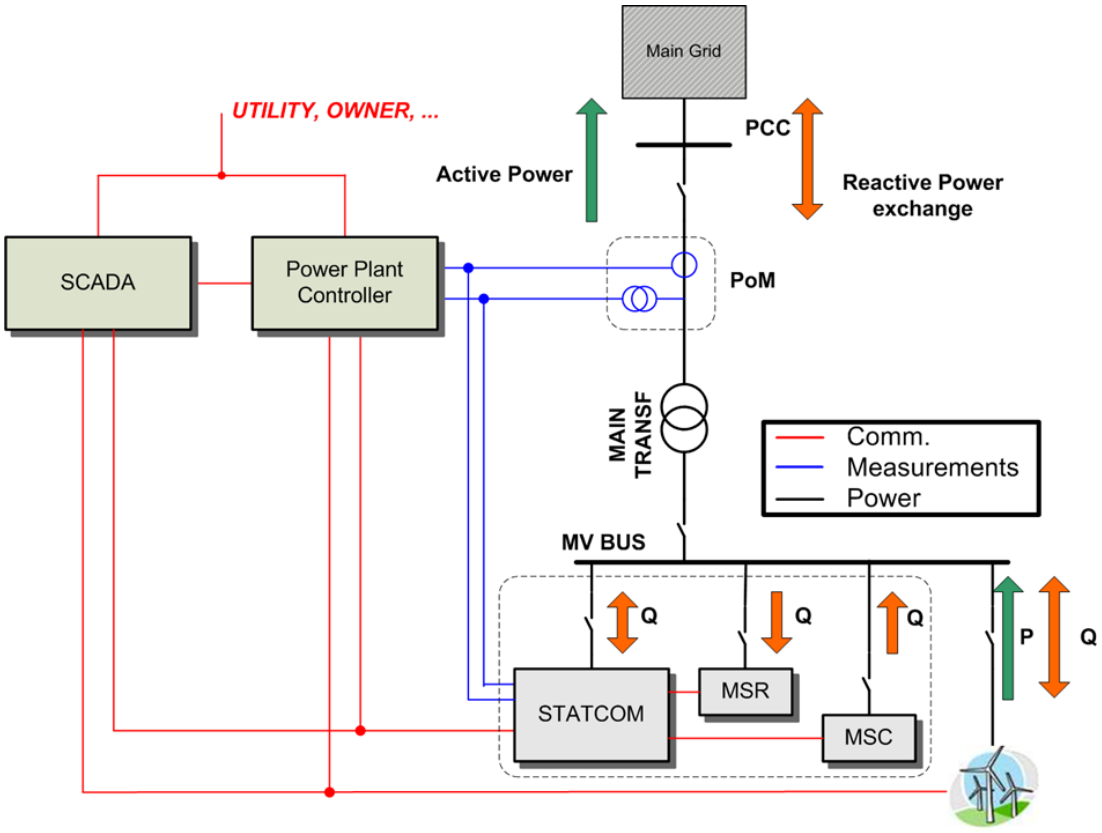
Weak gird market exists everywhere from US to Australia including emerging markets.
Every year Vestas interconnect more than 500 MW WPP to the low fault level grid point.

Connection to a low fault level grid point is technically challenging due to:

- Voltage stability
- Poor post fault recovery
- BoP-WTGs and WPP level controllers coordination

Vestas solution – Power Plant Controller

Vestas PPC manages all real-time control tasks of the Wind farm.

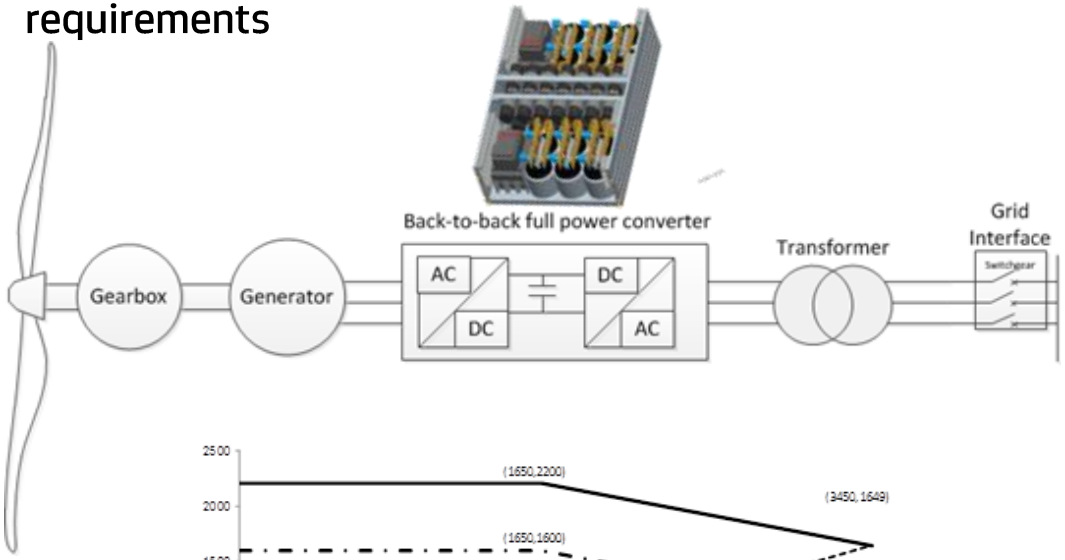


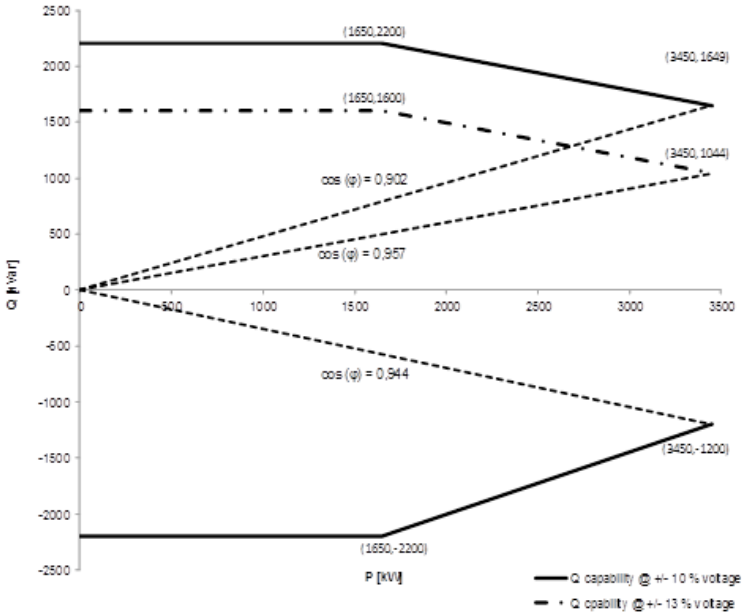
Typical WPP control concept for weak grid:

- Power Plant Controller® (PPC) is master controller and STATCOM is the slave controller for V control.
- The PPC sends Qref to STATCOM.
- The PPC controls the cap banks.
- Synchronous condenser is left to control its own terminal voltage.
- STATCOM is used for fast dynamic voltage control during and post fault.
- Capacitor banks plus WTG Q support is mainly used for steady state voltage control.
- Standard synchronous condenser AVR response time is used.
- PPC Q control should use a rise time according to grid code or contingencies analysis. .
- PPC controls the WTG P dispatch.

Vestas Solution - GridStreamer®

Vestas GridStreamer® is a Full Scale Converter System optimized to support different Grid requirements





WTG Capability	Type 4
Rated Power	From 3MW
Shunt capacitors required[1]	No
Reactive Power Capability	Yes. Leading and lagging
Reactive support when not generating	Yes
Directly coupled with grid[2]	No
P Control	Yes. Pitch-control (slow) and converter control (fast)
Q Control	Yes. Converter control
F Control	Yes
Converter[4]	Back-to-back voltage source converter
Converter Rating	100% of rated power
LVRT[5]	Yes. DC power resistor (chopper) with fast current control
HVRT	Yes

Vestas Solution – Electrical Pre-Design

Vestas Electrical Pre-Design (EPD) provides the surest way of building a productive and highly profitable wind power plant, and describes optimal control strategies for use with the Vestas Power Plant Controller® and GridStreamer®, even for Weak Grid Projects.

World wide grid code compliance with V112 plus Power Plant Controller (PPC) system

Continuous voltage range	0.9-1.1 pu
Continuous frequency range	47-53 (57-63) Hz
FRT	Yes (both LVRT and HVRT)
Zero Voltage Ride Through	0.45 s
Reactive current injection	Yes, even when no active power is being generated
Power factor range is	0.868 capacitive and 0.933 inductive
Power recovery	Yes (instantaneous P recovery)
Max short-circuit level	25 kA

Questions & Comments?