



© AREVA Wind, Jan Oelker

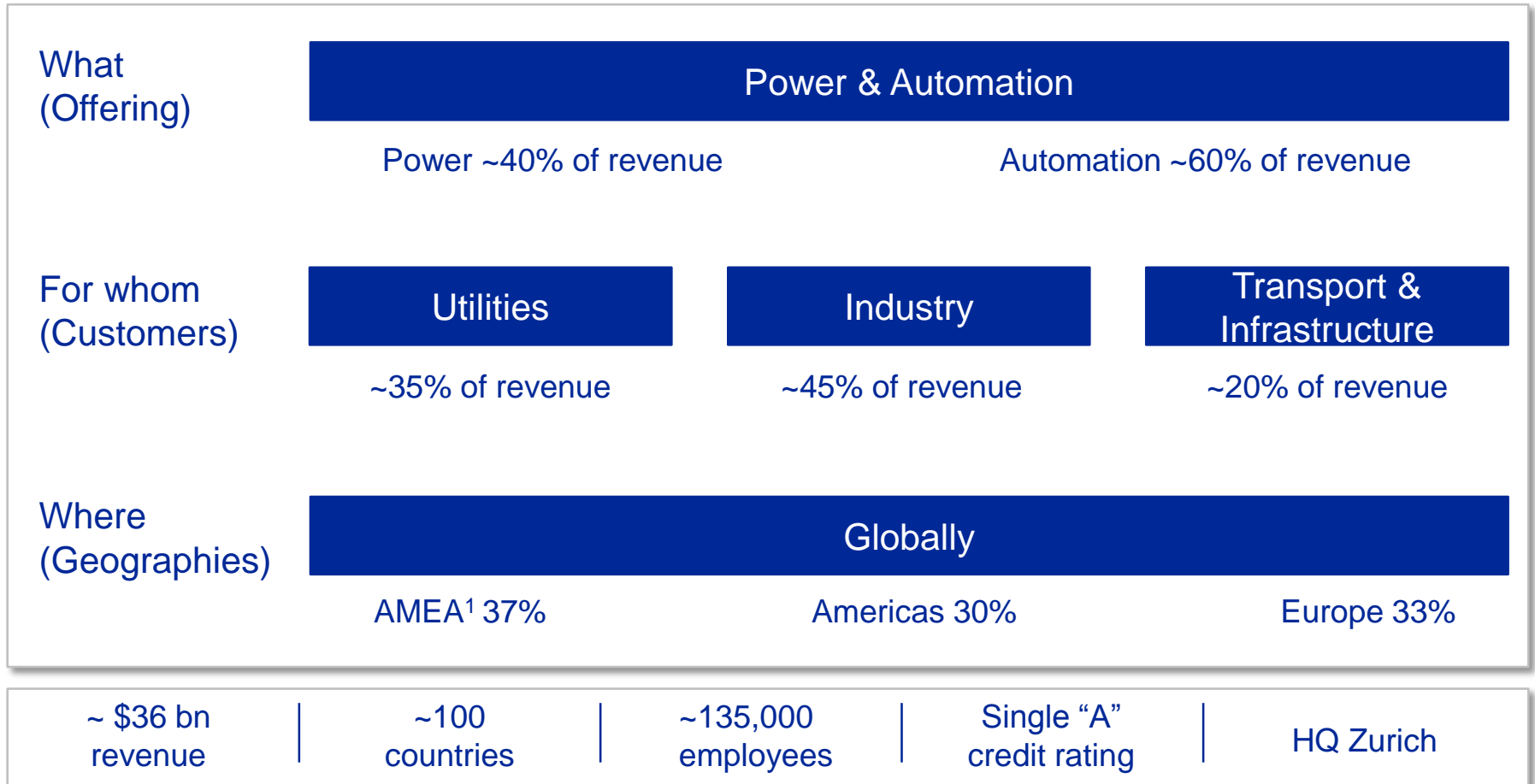
PG LAC&G | DM | 27 May 2016

# ABB converters, motors & generators

## Products for offshore wind turbines

# ABB today

A global leader in power and automation technologies

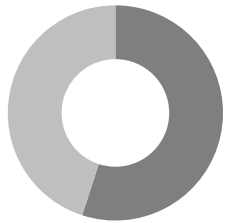


<sup>1</sup> AMEA = Asia, Middle East, Africa

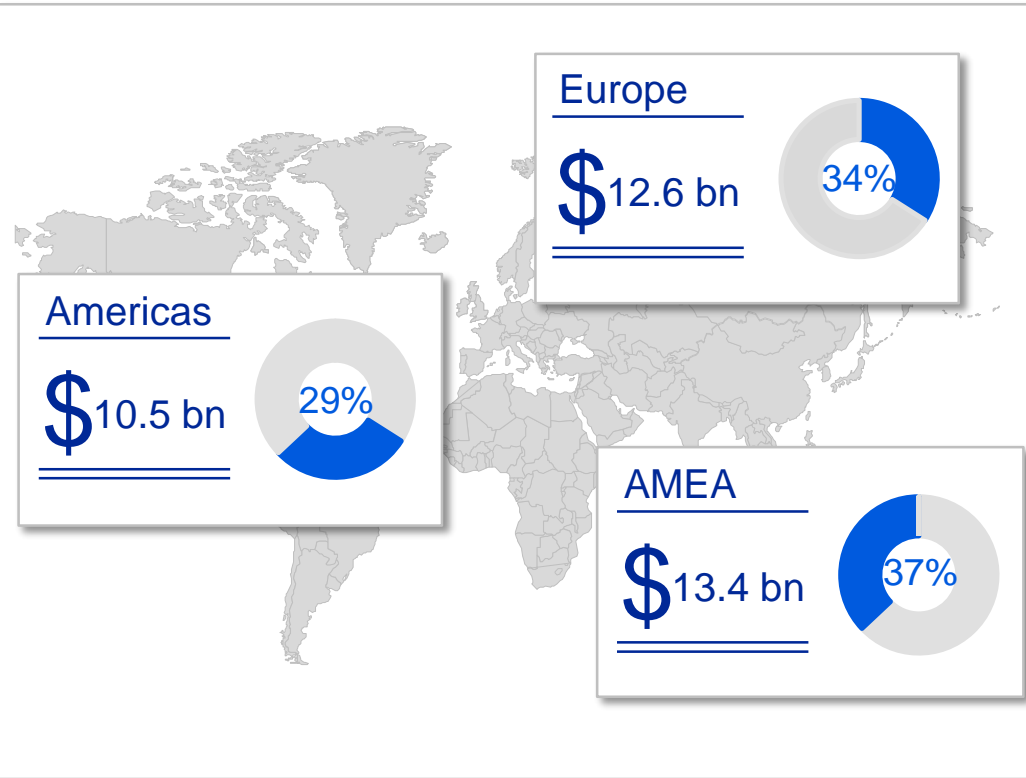
# A true global player

## Teams, culture and presence

### Revenue split 2015



- Mature markets (55%)
- Emerging markets (45%)



### Top 200 managers

>3/4  
from outside  
Switzerland and  
Sweden

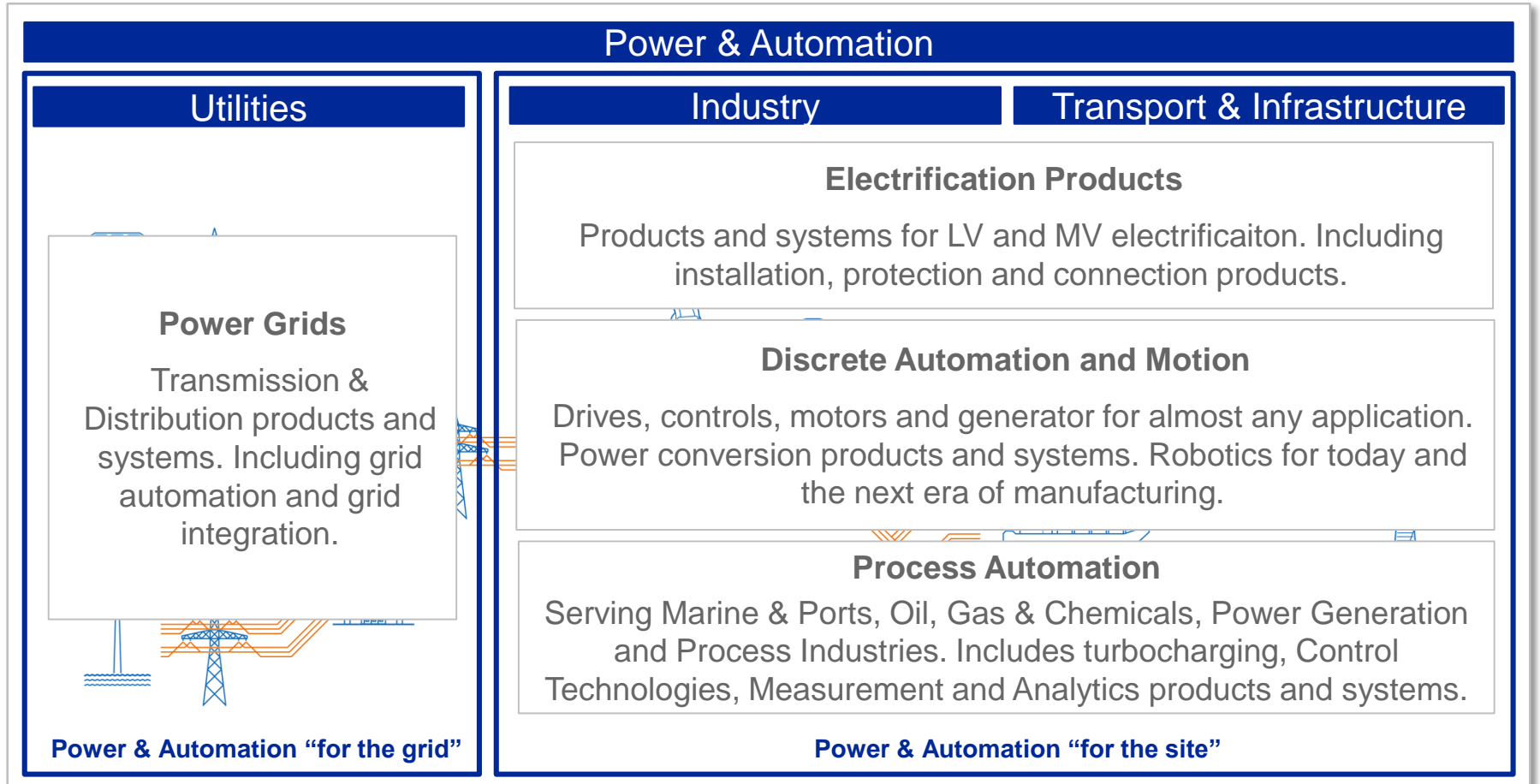
27  
nationalities from  
6 continents

8  
nationalities in  
the Executive  
Committee

**ABB has a unique global team with local presence everywhere**

# Four divisions

Aligned to fit with and create value for our customers

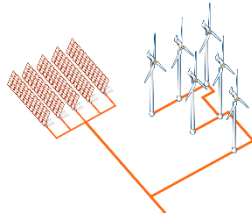


# Serving key global trends

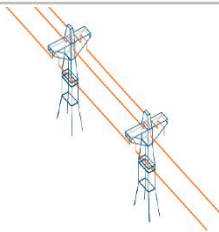
## “Big shifts” in power & automation

### “Big shift” in power

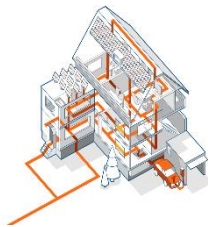
Generation mix



Power transmission and distribution

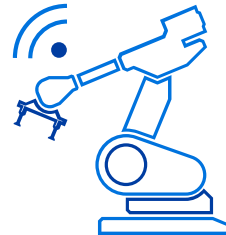


Micro- / Nano-grids

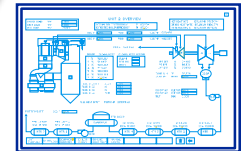


### “Big shift” in automation

Things

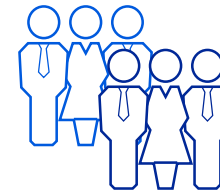


Services



Internet  
of

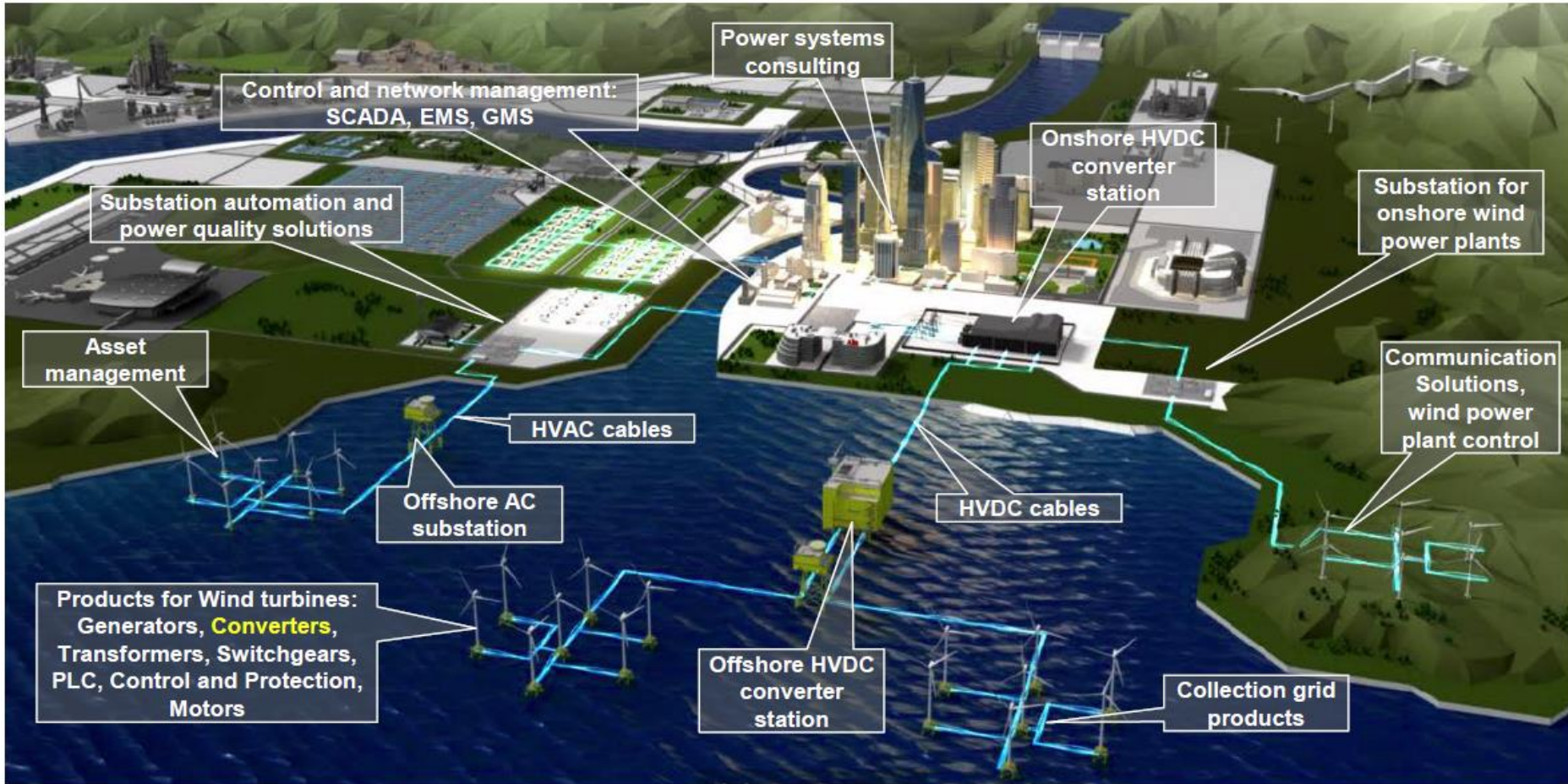
People





# Largest supplier of electricals for the wind industry

## Power generation, control, transmission & integration



EMS: Energy Management System  
HVDC: High-voltage Direct Current

GMS: Generation Management System  
PLC: Programmable Logic Controller

HVAC: High-voltage Alternating Current  
SCADA: Supervisory Control And Data Acquisition

# Power generation

## Products for wind turbines

### Wind turbine converters

- Doubly-fed/Full power low voltage (up to 6MW, 690V)
- Medium voltage (up to 10MW, 3.3kV)



### Generators

- Doubly-fed/full converter concepts. Up to 8MW, 690V – 12kV delivered. Higher powers also available.



### Transformers

- Dry-type/Liquid-filled (up to 72.5kV and 40MVA)



### Switchgears

- Medium voltage (12-40.5kV)
- High voltage (72.5kV)



### Turbine control and protection products

- For drivetrain & other sub-systems



### Turbine controllers

- PLC (Programmable Logic Controller)
- Support functions (monitoring, power supply, signal conversion)



### Motors

- Brake motors for yaw & pitch control
- AC motors for generator cooling, fans and hydraulic systems.



### Drives

- Variable speed motor control



### Enclosures & connections

- Enclosures
- Wire & cable management, connections, terminal blocks



# Products for wind turbines

## Wind turbine converters



### Low Voltage Converter

- Onshore and offshore turbines
- IGBT power modules
- Air and liquid-cooled models
- Doubly-fed converter
  - LVRT and reactive power
  - 0.85 to 6 MW
- Full power converter
  - Grid code support
  - 1.5 to 8 MW



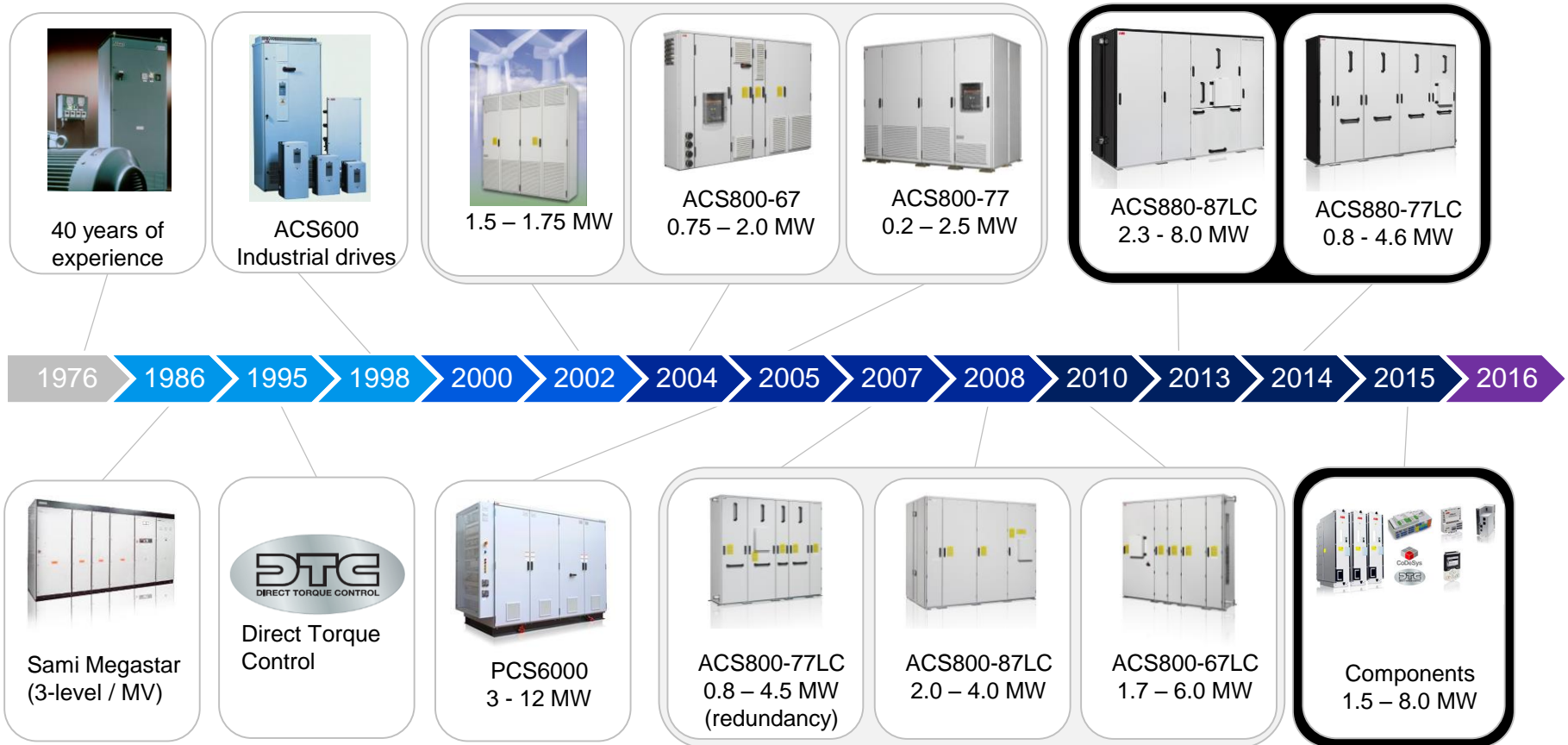
### Medium Voltage Converter

- Offshore or onshore turbines
- IGCT power modules
- 2.5 to 12 MW
- Liquid-cooled
- Grid code support
- Harmonic elimination control algorithm



# Products for wind turbines

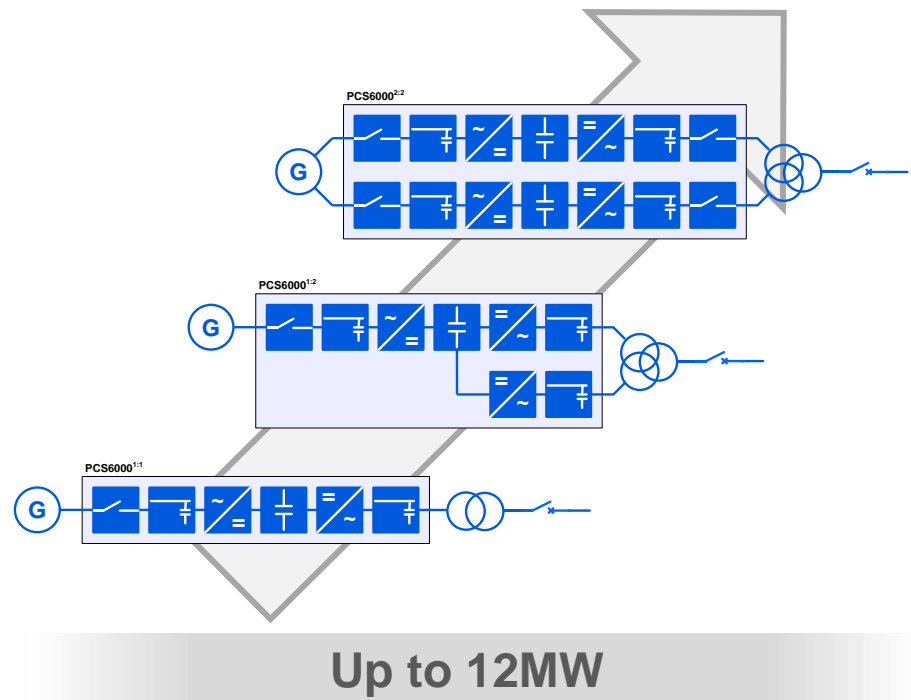
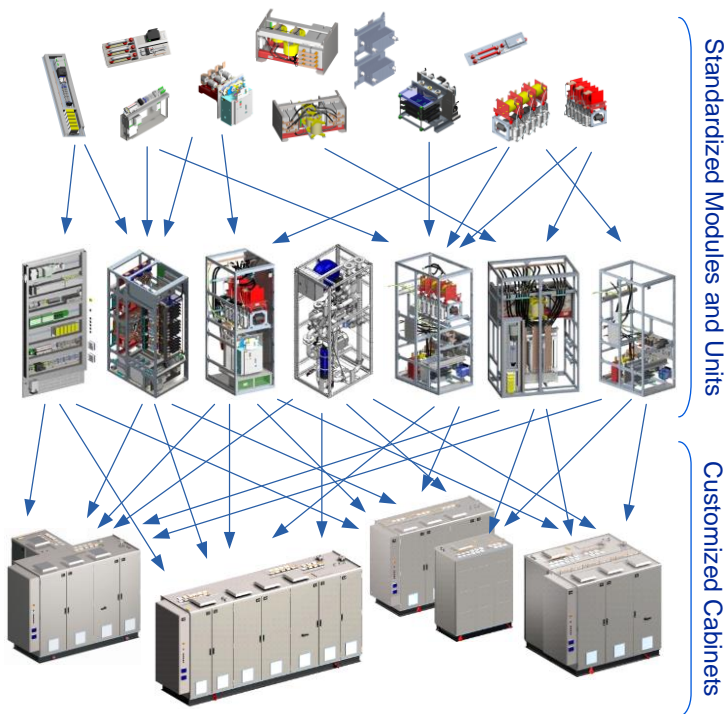
## Wind turbine converters



More than decade of utility-scale wind turbine converter leadership,  
over 15,000 converters delivered to wind industry (approx. 25 GW)

# Products for wind turbines

## Wind turbine converters – medium voltage



**PCS6000** medium voltage wind turbine converter. Power Range: **up to 12MW** Voltage Level: **3.3kV/4.16kV**

Frequency: **50/60Hz** Cooling: **Liquid Cooled** Operating Temperature: **up to 50°C** Semiconductor type: **IGCT**

Generator type / frequency: **PM or Induction / 3-120Hz** Enclosure: **IP54** Shock and vibration: **3M2 acc. IEC60721**

Special Features: **Grid Code Compliant, DNV-GL certified**

# Products for wind turbines

## Wind turbine converters – medium voltage

### Standard features

#### Torque control

To transfer the required power into the grid

#### Reactive power control

To inject reactive power into the grid to control the grid voltage

#### Grid code compliant

to ensure that the wind turbine makes it's contribution to control the grid

#### Over speed operation

To ensure that the wind turbine survives high wind gust situations

### Unique software features

#### Advanced support and remote service tools

to lower OPEX cost and increase energy produced

#### Active damping

to reduce stress on mechanical drive train and therefor increase turbines reliability

#### Special hall-test functions

enable fast testing and lower the investments for the turbine test stand

#### Flexible harmonic spectrum distribution

allow easy adaption to different grid systems and ensure always grid compliance

#### Island Mode

for lower OPEX and CAPEX cost

#### Active resonance prevention on grid side

To avoid resonances of the wind park and therefore ensures high availability

#### No sudden load changes on the drive train during LVRT

To reduce stress on mechanical drive train and therefor increase turbines reliability

#### Filter less design for higher power ratings

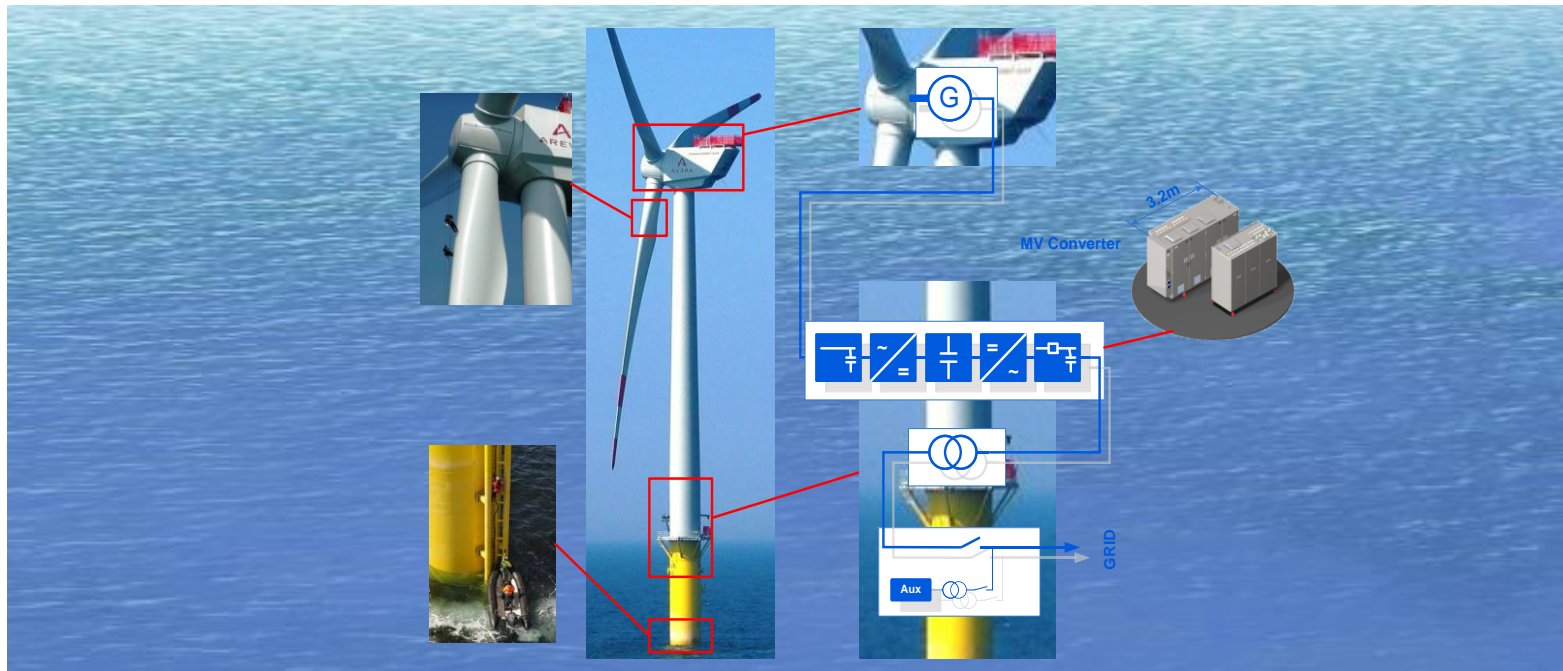
Increased reliability and efficiency leads to higher energy produced and lower OPEX

# Products for wind turbines

## Wind turbine converters – medium voltage

### Wind turbines

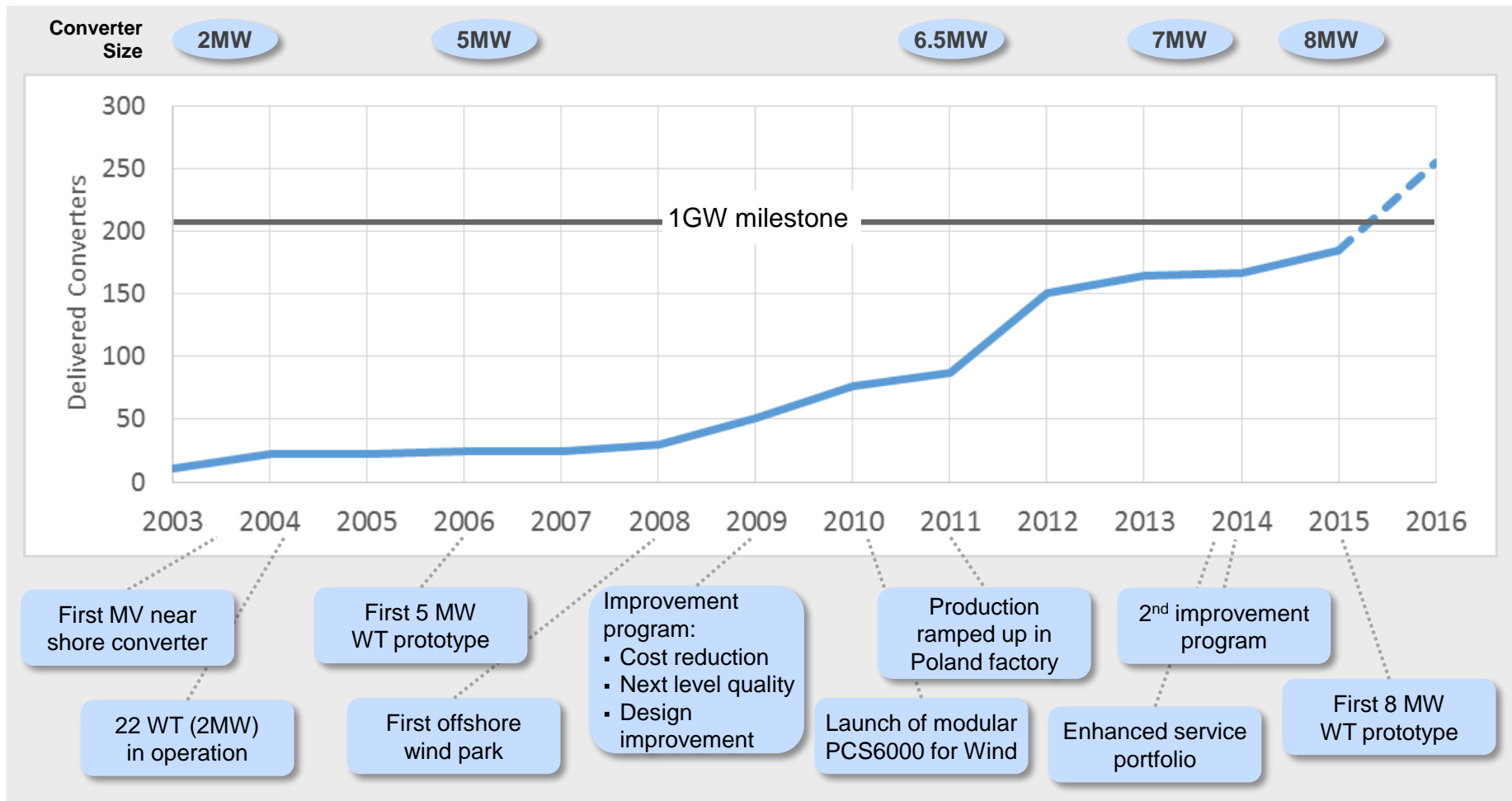
Installation in nacelle or tower possible



High flexibility in installation location without compromising performance

# Products for wind turbines

## Wind turbine converters – medium voltage



More than 10 years of continuous improvement. New models developed to meet changing market needs



# Products for wind turbines

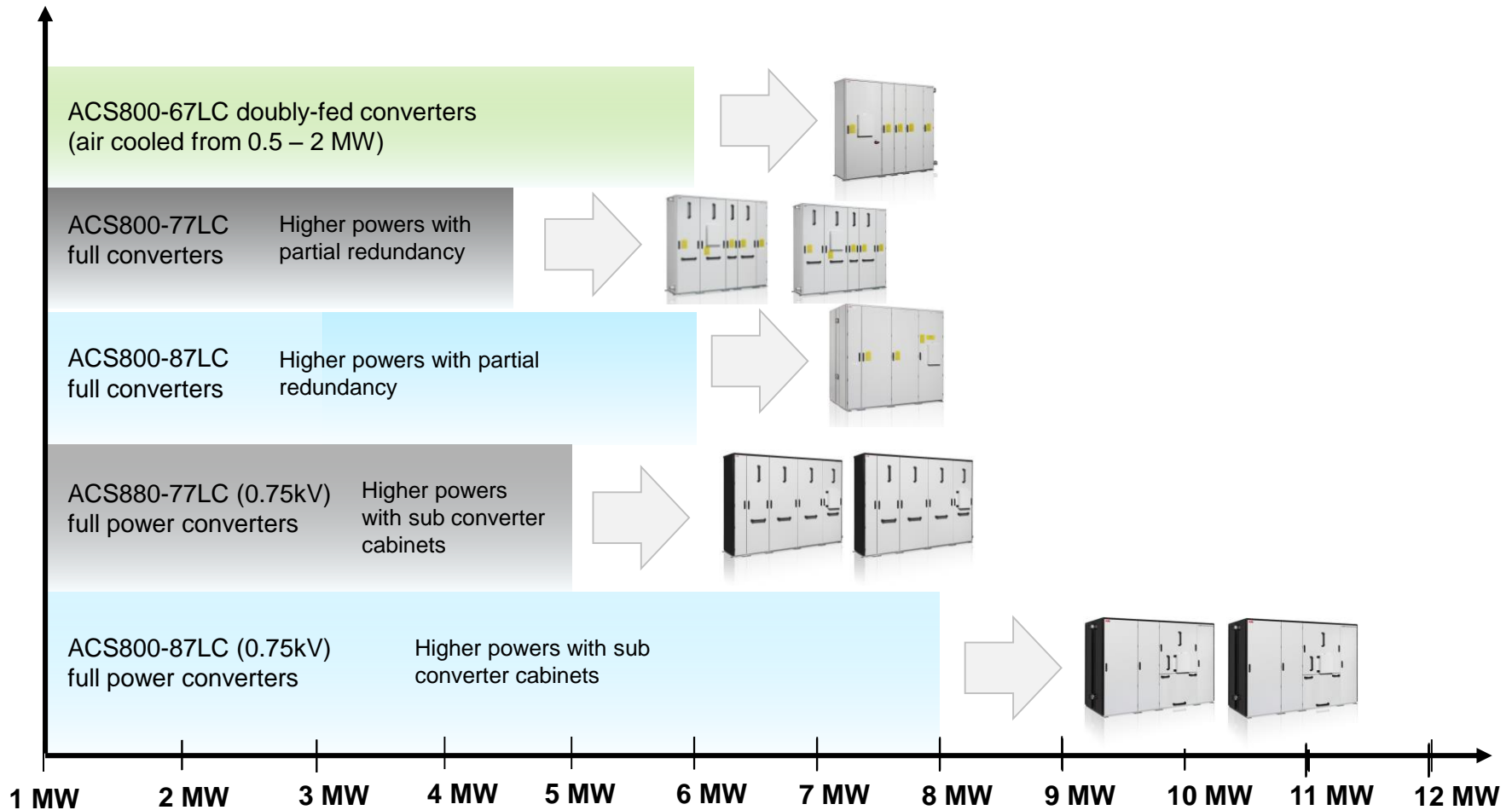
## Wind turbine converters – medium voltage



Highest number of MV converters among all players in the wind and tidal industry.  
Thirteen different wind and tidal turbine models using ABB medium voltage converters.

# Products for wind turbines

## Wind turbine converters – low voltage



Modular platform enables ease and flexible product portfolio covering a power range starting 1 MW up to 8 MW

# Products for wind turbines

## Wind turbine converters – low voltage



**DOUBLY-FED CONVERTER**

**ACS800-67LC (0.60...0.75 kV):**  
 0.85 to 6 MW (air cooler up to 2MW)  
 Liquid-cooled, fully enclosed cabinets  
 IGBT power modules  
 Lowest harmonics  
 Integrated crowbars & breakers  
 Direct Torque Control  
 High availability (less semiconductors)



**FULL POWER CONVERTER**

**ACS8XX0-X7LC (0.60...0.75 kV):**  
 0.8 to 8 MW  
 Liquid-cooled, fully enclosed cabinets  
 IGBT power modules  
 Low harmonics  
 Integrated breakers  
 Direct Torque Control  
 High availability (redundancy)

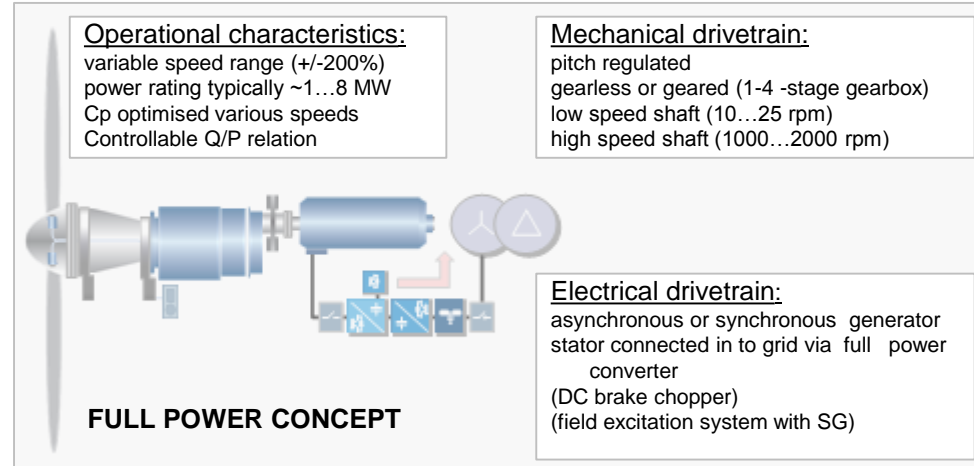
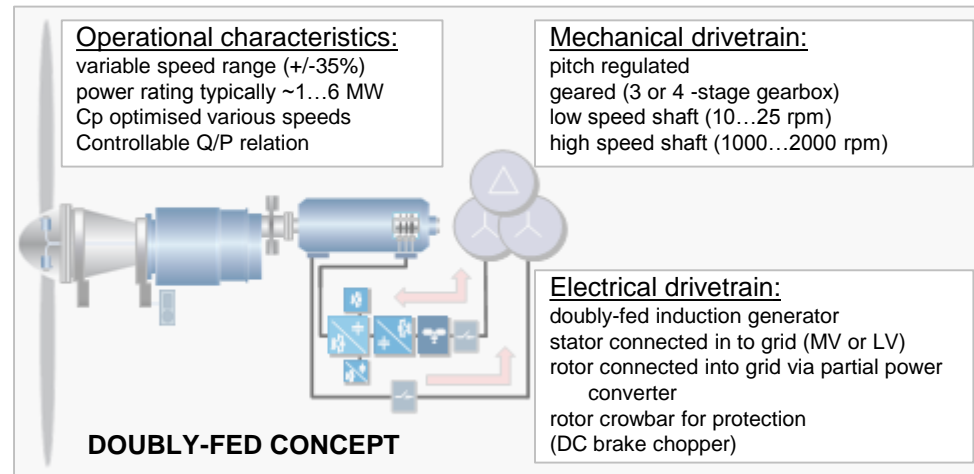


ABB has a solution for all main stream variable speed wind turbine concepts



# Products for wind turbines

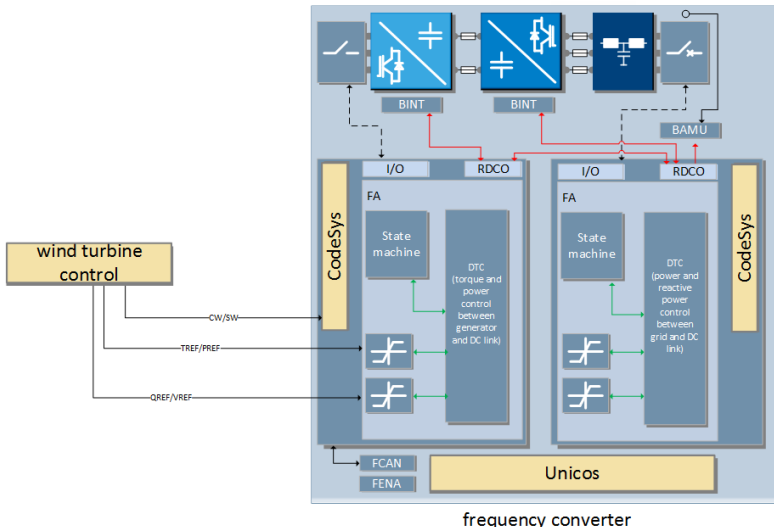
## Wind turbine converters – low voltage module package



Modular platform enables easy system integration and panel building

# Products for wind turbines

## Wind turbine converters – low voltage module package



### Standard scope of supply (specified by ABB)

#### Wind module HW package:

- Grid filter (LCL)
- Cooling fans
- ISU modules
- INU modules
- Du/dt and common-mode filters
- Coated interface circuit boards

#### Wind module FW package:

- Intuitive control panel
- Converter control boards
- Remote monitoring tool
- Support for all main fieldbus control interface options
- Embedded ABB control interface
- Embedded ABB firmware with Direct Torque Control

#### Product highlights:

- Regenerative power modules
- Direct liquid-cooling
- Modular and compact hardware design
- Advanced reliability and availability
- High power dynamic braking unit modules
- Built-in redundancy through parallel connected modules

Full module HW/FW package enabling advanced reliability and availability, remote connectivity and state-of-the-art grid code performance



# Products for wind turbines

## Wind turbine converters – low voltage module package



Customised scope of supply (specified by OEM)

### Wind module HW package:

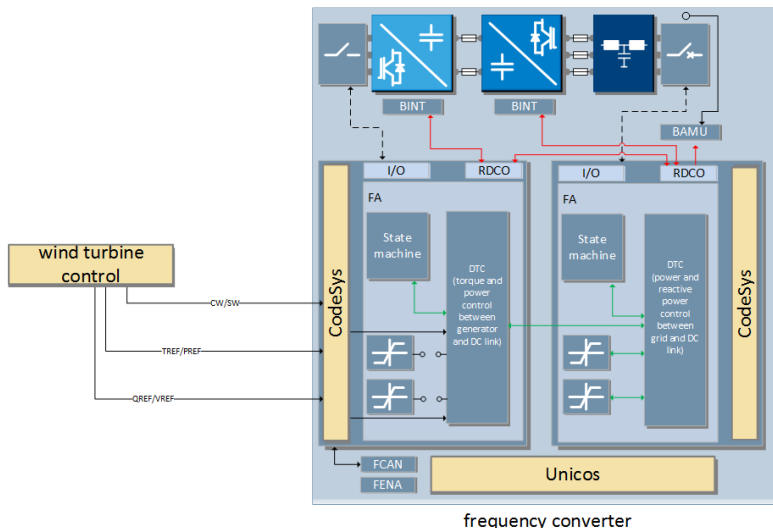
- Grid filter (LCL)
- Cooling fans
- ISU modules
- INU modules
- Du/dt and common-mode filters
- Coated interface circuit boards

### Wind module FW package:

- Intuitive control panel
- Converter control boards
- Remote monitoring tool
- Support for all main fieldbus control interface options
- Embedded ABB control interface
- Embedded ABB application with Direct Torque Control
- Customized access to ABB application (CodeSys)

### Product highlights:

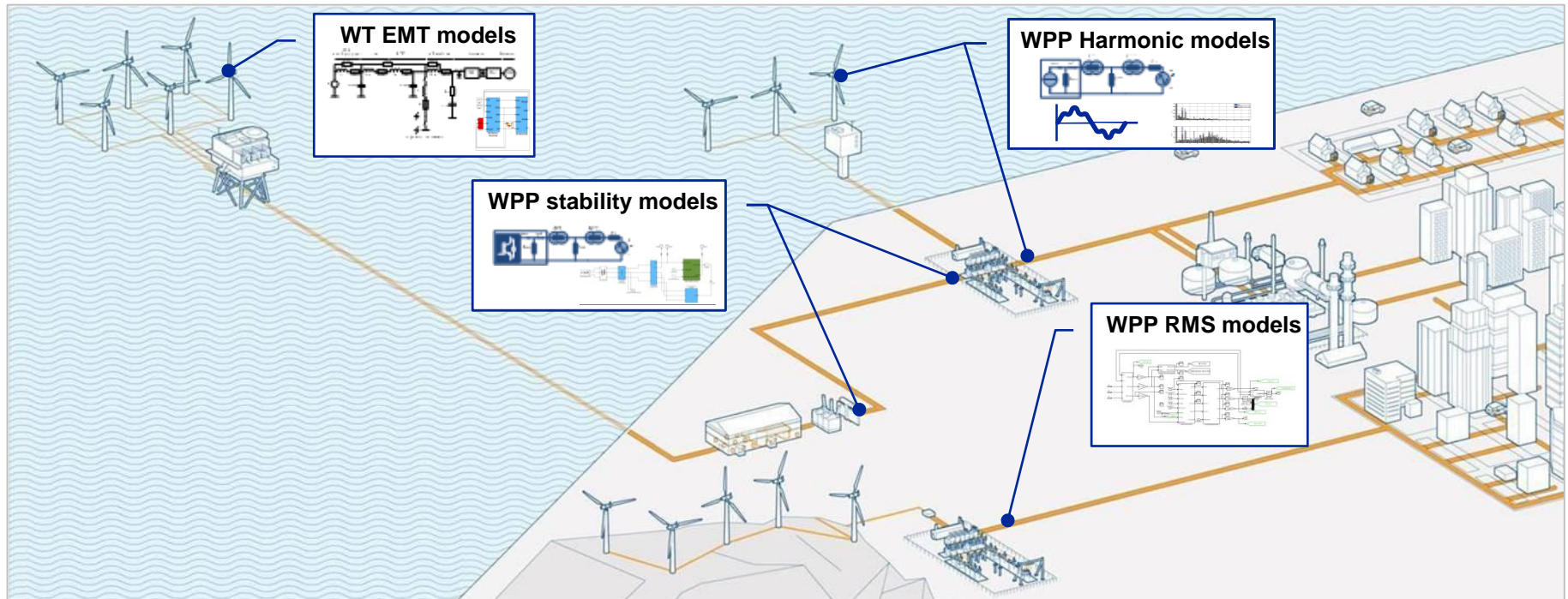
- Regenerative power modules
- Direct liquid-cooling
- Modular and compact hardware design
- Advanced reliability and availability
- High power dynamic braking unit modules
- Built-in redundancy through parallel connected modules
- IEC application programming support (CodeSys)



Reduced module HW/FW package enabling advanced reliability and availability, ABB ctrl interface and customized firmware application

# Products for wind turbines

## Wind turbine converters – simulation tools



**WT EMT model for WT at WPP:**  
 WT level (SSCI, SC current)  
 RMS model benchmarking (LVRT HVRT, torque etc.)  
 PLC control design  
 WPP owners or developers  
 Turbine OEMs and their consultants

**WT stability model for WPP at PCC:**  
 WT or WPP level  
 WT control assessment under resonances  
 PE control impacts in to WPP (eg. HVDC in offshore)  
 Control interactions of WPP to grid  
 WPP owners or developers

**WT RMS model for WPP at PCC:**  
 WT or WPP level  
 WPP transient stability studies  
 Grid faults and disturbances  
 Grid code compliance performance  
 Validated (FGW TR4, IEC61400-27)  
 DSOs & TSOs (WPP owners)  
 Turbine OEMs

**WT harmonic model for WPP at PCC:**  
 WT or WPP level  
 WPP's harmonic assessment  
 WPP harmonic compliance at PCC  
 Model validated at ABB multi-MW testing laboratory  
 WPP owners  
 Turbine OEMs

Validated electrical drivetrain simulation tools for WTG and WPP  
 grid integration performance analysis

# Power generation

## Products for wind turbines

### Wind turbine converters

- Doubly-fed/Full power low voltage (up to 6MW, 690V)
- Medium voltage (up to 10MW, 3.3kV)

### Generators

- Doubly-fed/full converter concepts. Up to 8MW, 690V – 12kV delivered. Higher powers also available.

### Transformers

- Dry-type/Liquid-filled (up to 72.5kV and 40MVA)

### Switchgears

- Medium voltage (12-40.5kV)
- High voltage (72.5kV)

### Turbine control and protection products

- For drivetrain & other sub-systems

### Turbine controllers

- PLC (Programmable Logic Controller)
- Support functions (monitoring, power supply, signal conversion)

### Motors

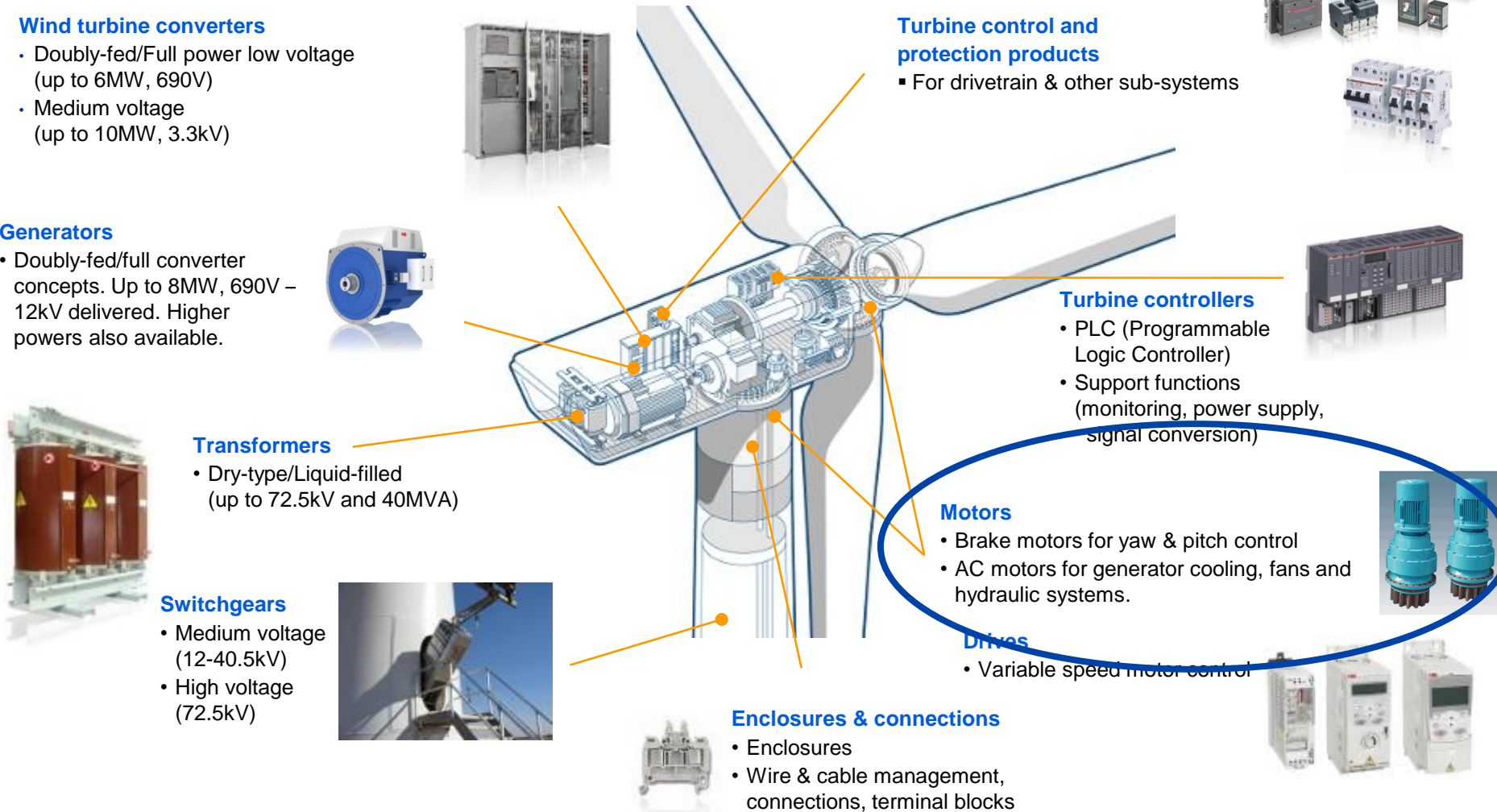
- Brake motors for yaw & pitch control
- AC motors for generator cooling, fans and hydraulic systems.

### Drives

- Variable speed motor control

### Enclosures & connections

- Enclosures
- Wire & cable management, connections, terminal blocks



# Products for wind turbines

## Low voltage motors



ABB low voltage motors are suitable for all industries, all applications – fulfilling all national mandatory efficiency regulations

- Process performance motors
- General performance motors
- Motors for explosive atmospheres
- Frequency controlled motors
- Special application motors

Outputs up to 1,000 kW

IEC frame sizes from 56 to 450



# Products for wind turbines

## Low voltage motors



### Product highlights

- Available for all common voltages
  - Premium efficiency motor selection
  - 0.06 to 55 kW
  - 2 to 8 poles
- LV induction motors used in a single wind turbine:
    - Yaw system: typically 4 units with a brake system
    - Pitching system: 2 to 3 units with brake and encoder
    - Cooling unit for electric control system: 1 set
    - Hydraulic (pumps) system for cooling (gearbox, generator, etc.): 1 set
    - Lubrication system for gearbox: 1 set
    - When LV drives are included they are integrated with the turbine control
    - LV motors with drives have been used with dedicated pumps and fans; in hydraulic systems; with yaw systems, either individually or as part of a master / follower solution



# Power generation

## Products for wind turbines

### Wind turbine converters

- Doubly-fed/Full power low voltage (up to 6MW, 690V)
- Medium voltage (up to 10MW, 3.3kV)



### Turbine control and protection products

- For drivetrain & other sub-systems



### Generators

- Doubly-fed/full converter concepts. Up to 8MW, 690V – 12kV delivered. Higher powers also available.



### Turbine controllers

- PLC (Programmable Logic Controller)
- Support functions (monitoring, power supply, signal conversion)



### Transformers

- Dry-type/Liquid-filled (up to 72.5kV and 40MVA)



### Switchgears

- Medium voltage (12-40.5kV)
- High voltage (72.5kV)



### Motors

- Brake motors for yaw & pitch control
- AC motors for generator cooling, fans and hydraulic systems.



### Drives

- Variable speed motor control



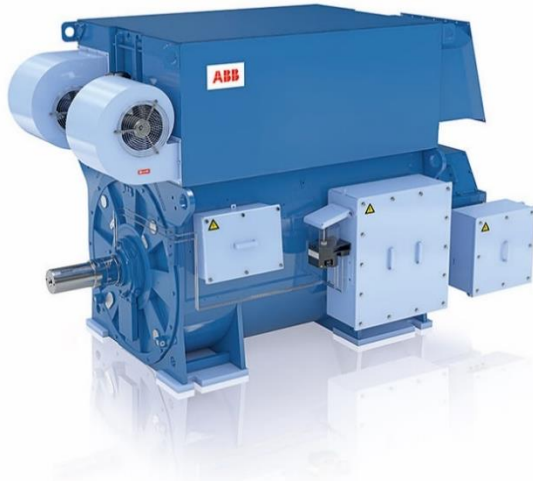
### Enclosures & connections

- Enclosures
- Wire & cable management, connections, terminal blocks



# Products for wind turbines

## Generators



- Leading global generator manufacturer
- Over 30 years know-how in wind power
- Over 35,000 generators / 30 GWs
- Powers 1 – 8 MW; up to 20 MW
- Leader in PM technology since the 1990's
- Manufacturing: EU, USA, China, India

### Doubly-fed

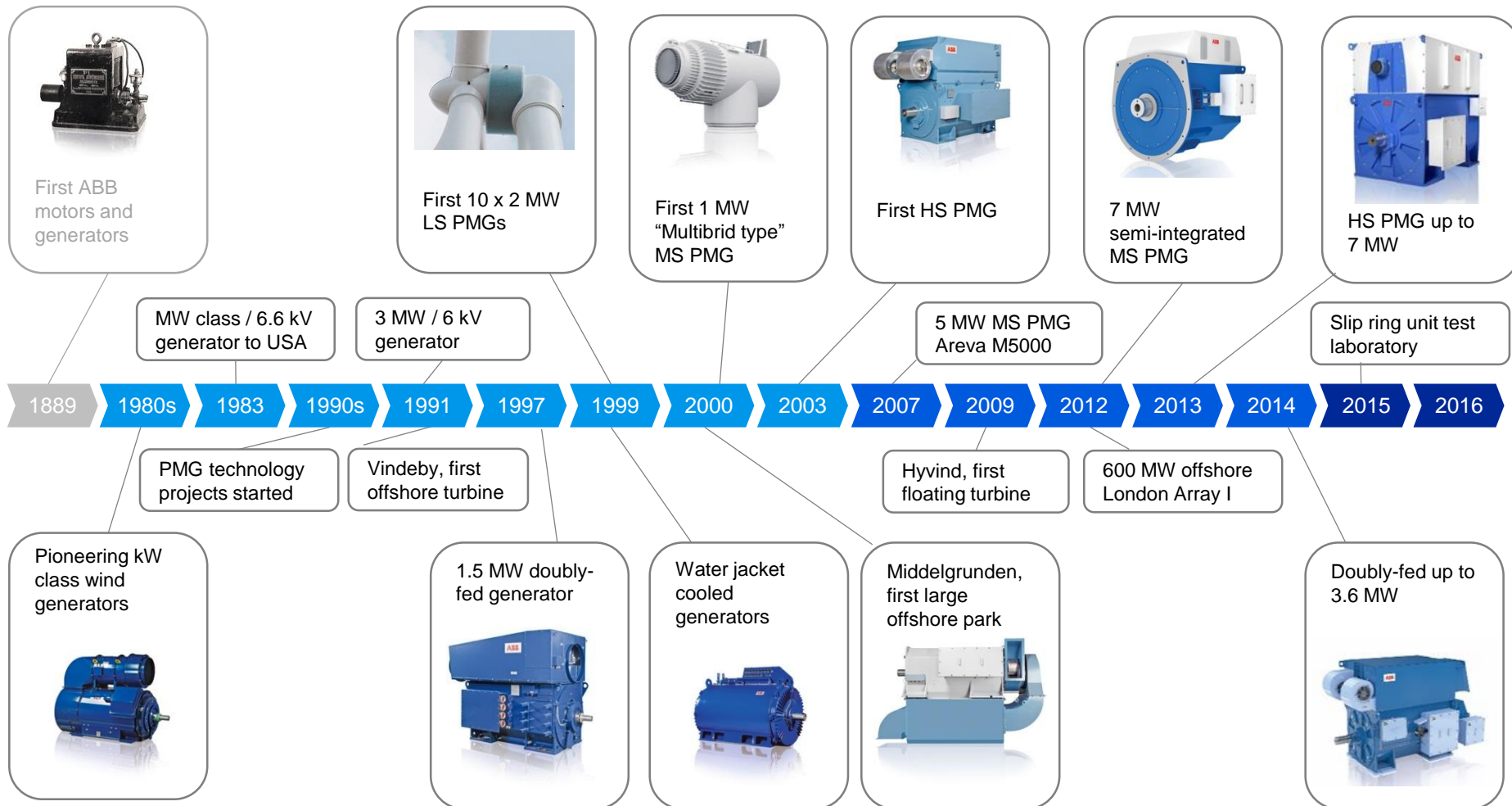
- Standard product platform
- Patented rotor design
- 2.5 kV rotor insulation
- Carbon-fiber winding support
- Overspeed up to 3000 rpm
- Proven slip ring unit

### Full converter

- Permanent magnet generators
- Low, Medium and High speed
- High efficiency at all wind speeds
- Maximum production of kWhs
- High power and small size

# Products for wind turbines

## Generators



More than three decades of technology leadership



# Products for wind turbines

## Generators



Fixed speed induction

**Description:**

- Single speed (4 pole, 1500 rpm) and two speed (4 / 6 pole, 1500 and 1000 rpm)
- Typically powers from 1.3 MW to 2.3 MW
- Directly coupled induction generator via a gearbox to wind turbine

**Advantages**

- Well proven, basic technology, low cost

**Comments**

- Technology is phased out and has been replaced by DF and full converter systems
- Many units still in operation



High speed induction

**Description:**

- Speed range 1000 – 2000 rpm
- Full converter
- Typical Powers from 1 MW to 5 MW
- Industrial drive system type adapted to wind turbine application

**Advantages**

- Fully controlled variable speed.
- High reactive power supply capability
- High power quality and efficiency



Doubly-fed

**Description:**

- High speed, typically 4 or 6 pole rotors;
- Speed 4 pole (~1700 rpm) or 6 pole (~1200 rpm)
- Typical Powers from 1 – 4 MW (and getting higher)
- Wound rotor connected to a slip ring.
- Rotor is fed through a converter and thus the turbine can run at optimal speed

**Advantages**

- Economical way to obtain variable speed, supply reactive power and to increase energy yield at high wind speeds

# Products for wind turbines

## Generators



### Permanent magnet, low speed

#### **Description:**

- Speed range typically between 10 – 30 rpm
- Multi-pole generator,  $p = 50 \dots 196$
- Powers from 1.5 MW to 8 MW
- Gearless package with full variable speed

#### **Advantages**

- All benefits of full converter drive.
- Low mechanical wear, low maintenance, no gearbox.
- Full speed control.



### Permanent magnet, med speed

#### **Description:**

- Nominal speed typically between 120 - 900 rpm (depends on gearbox)
- Multi-pole generator,  $p = 12 \dots 24$
- Powers from 1 MW to 8 MW.
- Integrated to 1 or 2 stage gearbox

#### **Advantages**

- All the benefits of full converter drive.
- High power with small space requirement.
- Low speed, low mechanical wear



### Permanent magnet, high speed

#### **Description:**

- Nominal speed typically between 1000 - 2000 rpm
- Typically 6 or 8 poles with powers from 2 MW to 7 MW.
- Mechanically similar to the doubly fed but without slip rings

#### **Advantages**

- All the benefits of full converter drive.
- Extremely high power from a small size.
- Low generator weight, compact design



# Products for wind turbines

## Generators – offshore examples



- ABB generators have been used in offshore turbines since 1991.
- ABB has more than 2'200 (7'300 MW) generators installed and generating power in offshore turbines today.
- ABB generators types currently used:
  - Fixed speed induction
  - DF induction
  - Induction with full converter
  - PM synchronous generators
- Example projects ...

# Products for wind turbines

## Generators – offshore examples



Vindeby Offshore Wind Farm (Photo: Vindmølleindustrien)

Vindeby. 11 x 450 kW. Fixed speed induction. No converter. Started operation in 1991

# Products for wind turbines

## Generators – offshore examples



Horns Rev 1: 80 x 2 MW turbines. Doubly-fed Induction Generator. Partial Converter. Operation since 2002.

# Products for wind turbines

## Generators – offshore examples



Middelgrunden: 20 x 2 MW. High speed induction with full converter. Operation since 2002.

# Products for wind turbines

## Generators – offshore examples



Burbo Bank 1 Offshore Wind Farm (Photo: Siemens)

Burbo Bank 1: 25 x 3.6 MW  
High speed induction with full  
converter. Operation since 2007.



# Products for wind turbines

## Generators – offshore examples

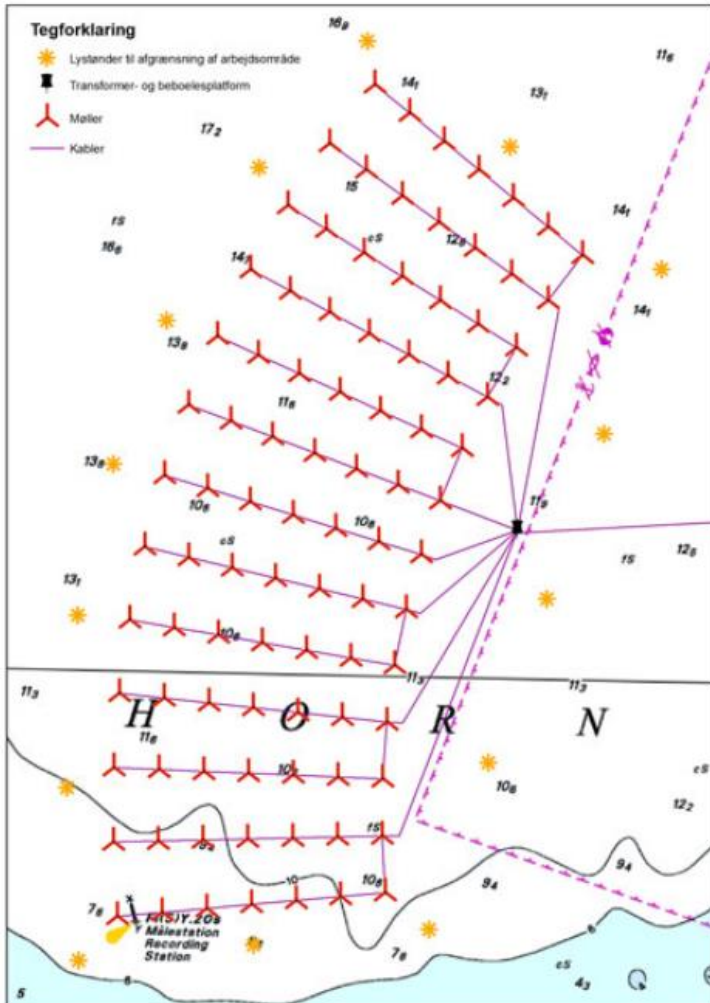


Kemi Ajos Offshore Wind Farm (Photo: WinWinD)

Kemi Ajos: 10 x 3 MW turbines. Medium speed permanent magnet generators with full converter. Operation since 2008.

# Products for wind turbines

## Generators – offshore examples



Horns Rev 2: 91 x 2.3MW.  
High speed induction with full converter.  
Operation since 2009.



# Products for wind turbines

## Generators – offshore examples



Alpha Ventus: 6 x 5 MW.  
Medium speed permanent magnet  
generator with full MV converter.  
Operation since 2009.

# Products for wind turbines

## Generators – offshore examples



Global Tech 1: 80 x 5MW.  
Medium Speed Permanent Magnet Generator with  
full converter. turbines.  
Operation since 2015



# Products for wind turbines

## Generators – offshore examples



Jiangsu Rudong Intertidal Project: 21 x 2.3 MW.  
High speed induction with full converter.  
Operation since 2012.



# Products for wind turbines

## Generators – offshore examples



Jiangsu Rudong Intertidal Project: 25 x 4MW. High speed induction with full converter. Operation since 2015.



# Products for wind turbines

## Generators – offshore examples



Hywind Floating  
Turbine:  
1 x 2.3 MW.  
High speed induction  
with Full converter.  
Operation since 2009.  
Now decommissioned  
and the next phase of  
the development has  
begun.

# Products for wind turbines

## Generators – offshore examples



Jeju Island:  
1 x 2 MW.  
Direct Drive Permanent  
Magnet Generator.  
Operating since 2011.

Power and productivity  
for a better world™

