NORPIE 2008-05-09

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ABB Oy Drives

Recent trends in variable speed wind turbine drives

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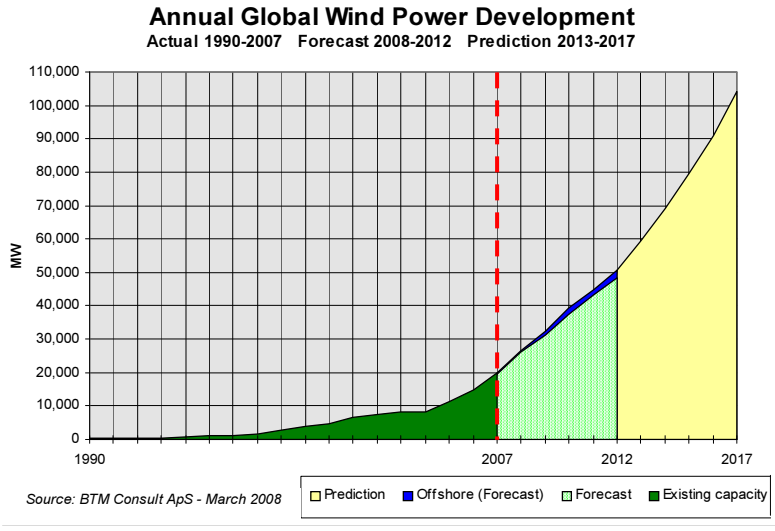
Wind Power -> 2012 -> 2017



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Wind power 2007 versus 2012

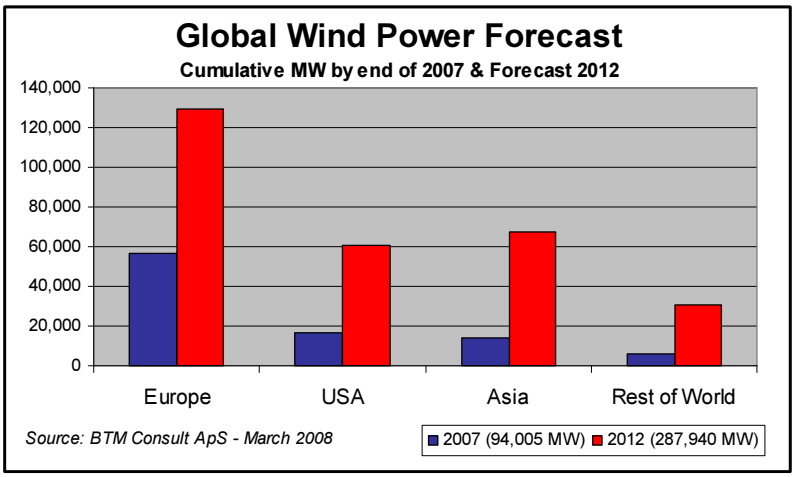


ABB – The Component Manufacturer for Wind Power

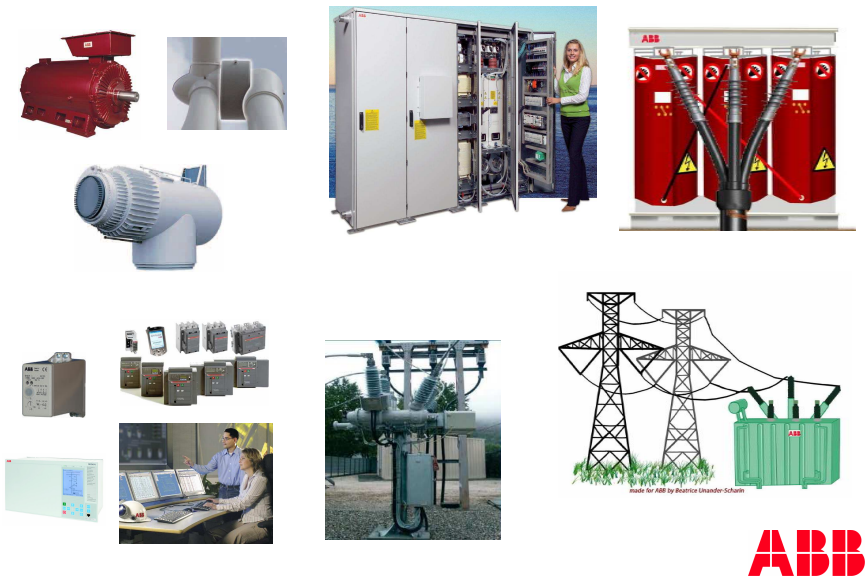


ABB – The Component Manufacturer for Wind Power

System Concepts available for Wind Power Generation

Fixed speed concept

- Traditional asynchronous machine directly coupled to grid

Variable speed concepts with frequency converters

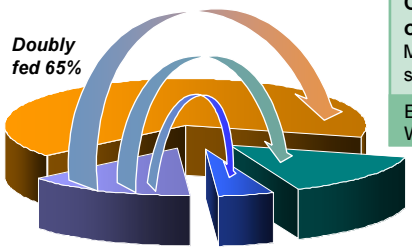
- Doubly-fed asynchronous generator with slip energy recovery frequency converter and high speed gear (typically 1500 rpm)
- Asynchronous generator with high speed gear
- Gearless synchronous generator with wound rotor
- Gearless permanent magnet (PM) synchronous generator
- PM generator with integrated low-speed gear
- PM generator with high-speed gear

System Concepts for Wind Power Generation

Market shares and trends for different concepts

With Speed Control:
Doubly fed
Wide power range

Vestas, GE Wind Energy, Gamesa, Nordex, Acciona, RePower, Ecotècnia, etc



With Speed Control: Gearless or low speed
Multi MW-class => speed control is must

Enercon, Multibrid, JSW, WinWind, MTorres, etc

Traditional (without speed control)

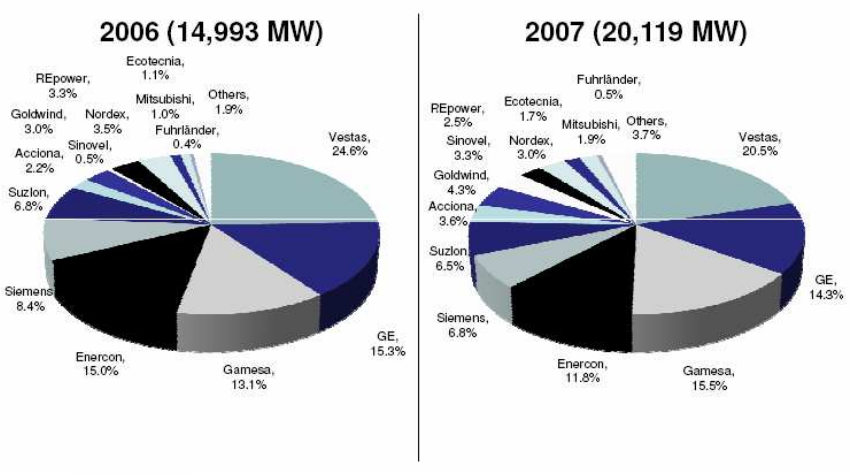
Siemens, Nordex, Vestas, Suzlon, Mitsubishi, Ecotècnia, etc

With Speed Control:
Full power converter, High speed gear

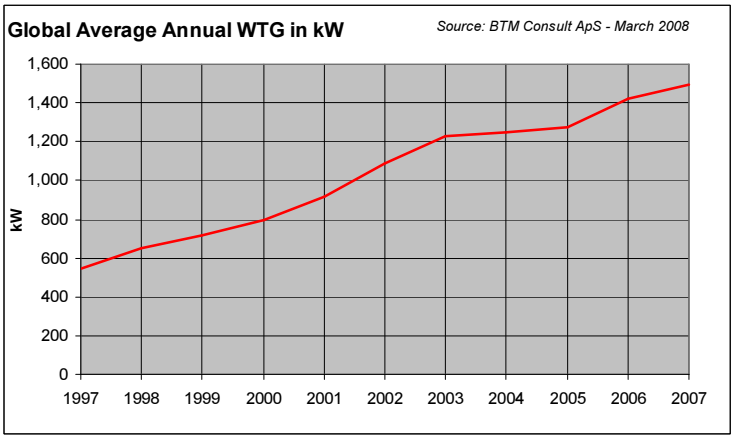
Siemens, Clipper etc

Note: 2007 market shares shown are approximate

Market shares



Turbine average power (kW)

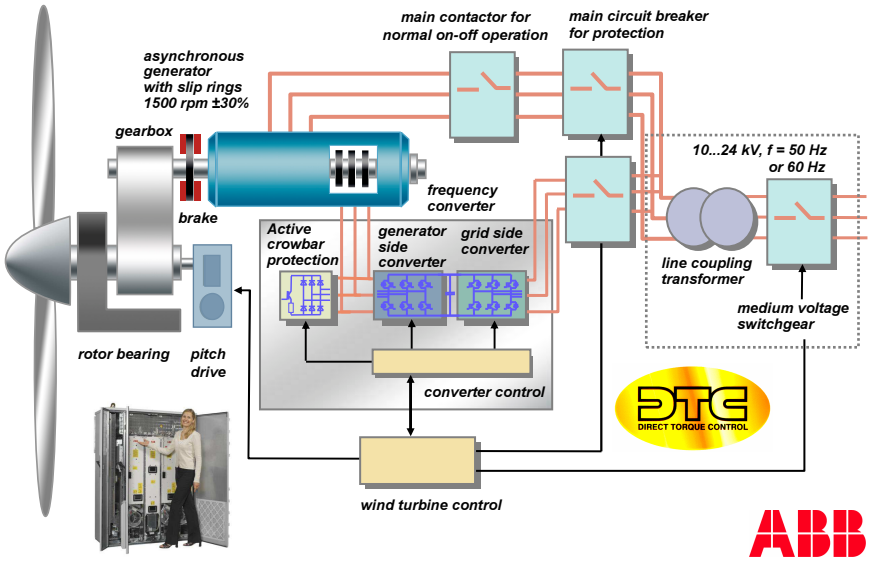


- Average power is 1.5 MW in 2007
- 6 MW turbine prototypes exist

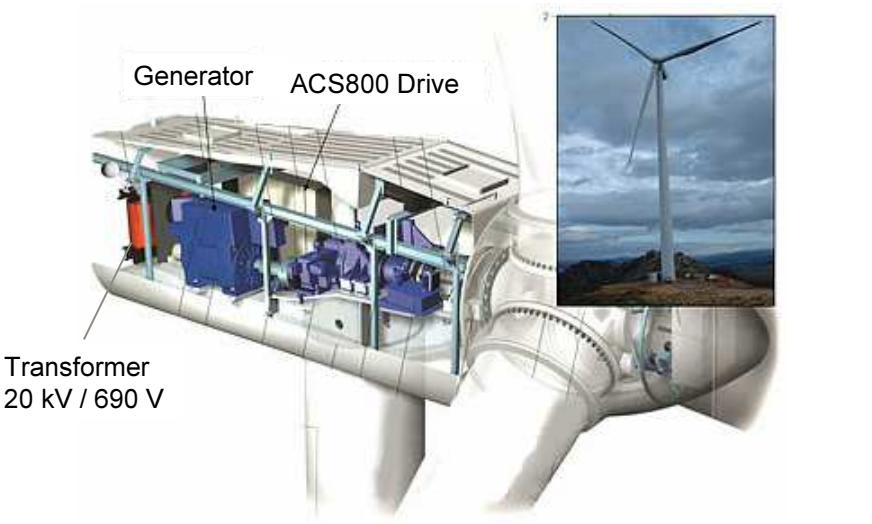
Variable Speed Wind Turbine trends

- Double fed still going strong
  - Gamesa, Vestas, GE Wind, etc
- Full Power increasing in Europe
  - Permanent magnet generators
  - Induction generators
- Average size increasing steadily
- Frequency converters are in transition from air-cooled to liquid-cooled types
- Chinese OEM's are growing fast
- Grid-codes are demanding
- Variable speed market in 2007
  - Total power about 16 000 MW
  - Equals to 11000 pcs of 1,5 MW turbines

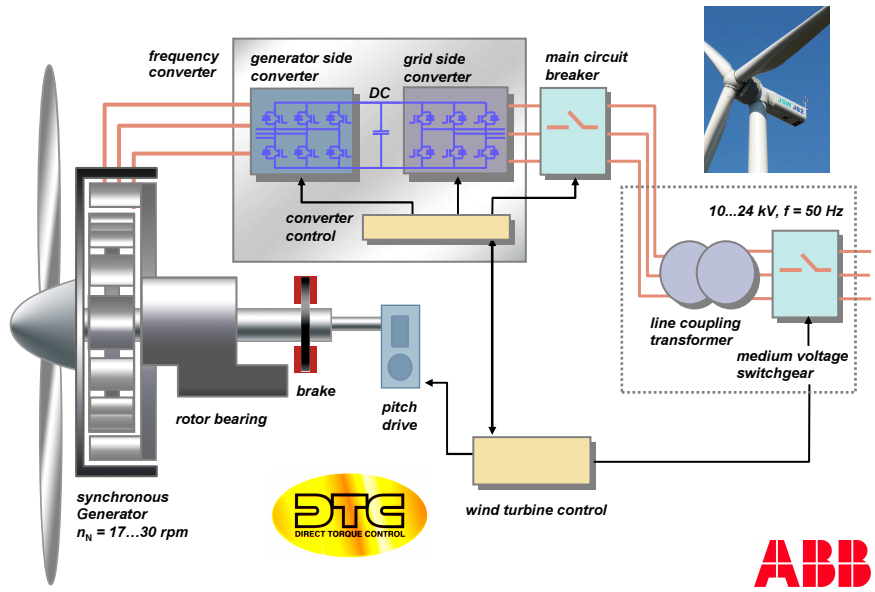
Doubly fed asynchronous generator with slip power recovery



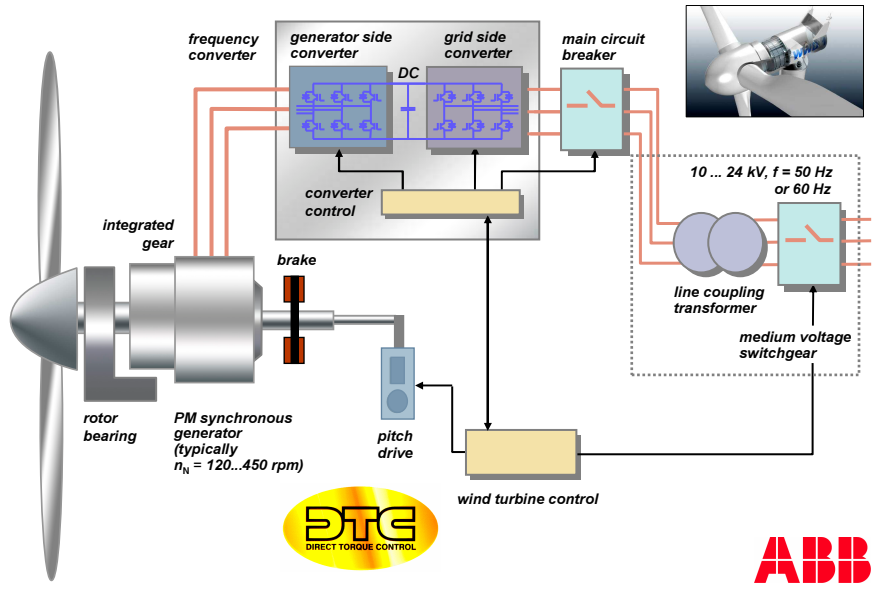
Wind turbine with doubly fed asynchronous generator



Gearless permanent magnet synchronous generator



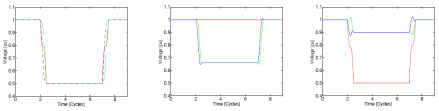
PM generator with integrated low speed gear



Grid Code Evolution

Voltage dips

- Wind turbines' share of electricity production has been increasing rapidly.
- Thus sudden disconnection of large number of wind turbines during grid fault could nowadays cause instability.

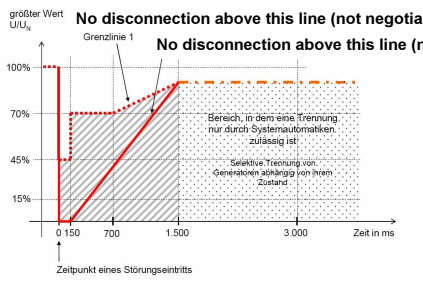


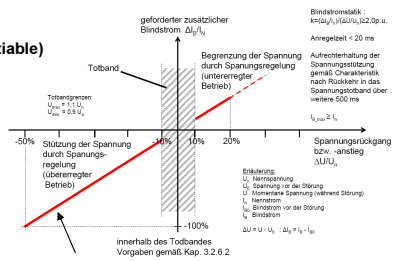
Voltage dip ride through gets tougher

- The grid codes issued by power transmission companies have rapidly become more demanding:
  - 2000: Voltage dip ride through without disconnection
  - 2003: Reactive current support during the dip
  - 2006: Zero voltage ride through, asymmetric dips

Voltage dip ride through gets tougher

- Example 1: US FERC Schedule H, after Dec 31, 2007:
  - three-phase 9 cycle zero voltage ride through, no support
  - single-phase delayed clearing zero voltage ride through, no support
- Example 2: German E-ON 2006:





Reactive current support

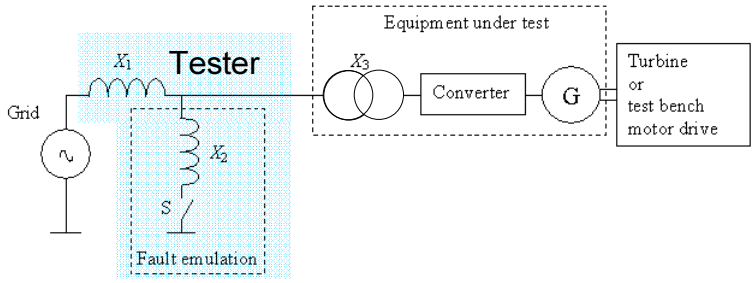
Unsymmetrical dip requirement caused theoretical problem

- Reactive current support has to be verified in tests
- Problem: Many definitions exist for reactive power – and give different results!
  - Aron method
  - Delayed voltage method
  - Instantaneous reactive power method
  - Fundamental component method
- Use of reactive power and current based on the **positive sequence of the fundamental component** is recommended when both the voltages and currents are unsymmetrical (most likely the future 2nd edition of IEC 61400-21 standard will specify this as well)

Zero voltage dip

- Zero voltage dip still a problem – How to define reactive and active current if voltage is zero?

Voltage dip ride through tester

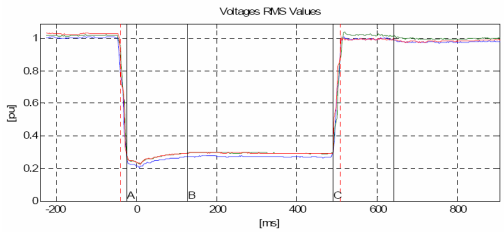


- Example of medium voltage field test equipment in a trailer (max. 5 MW turbine can be tested)

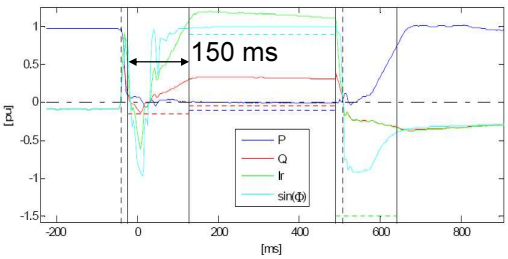
Symmetrical dip with 20 % remaining voltage (field test)

- Doubly fed fault ride through (2006)

RMS voltages
(MV side)



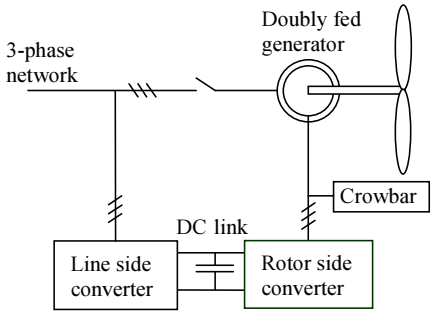
Active power
Reactive power
Reactive current
Power factor

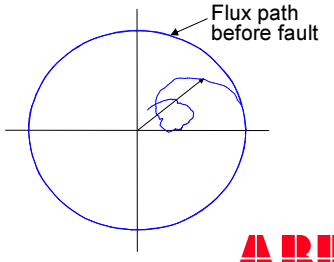


Why crowbar is needed for doubly-fed drives?

- Low converter power rating means high locked rotor voltage (about 3 U_N)
- Voltage dip stops the stator flux vector Ψ_s
- Rotor continues to rotate – thus high slip and high induced voltage
- High induced voltage inside the winding causes high rotor currents
- High voltages and currents can damage the frequency converter
- Crowbar protects the converter by short circuiting the rotor

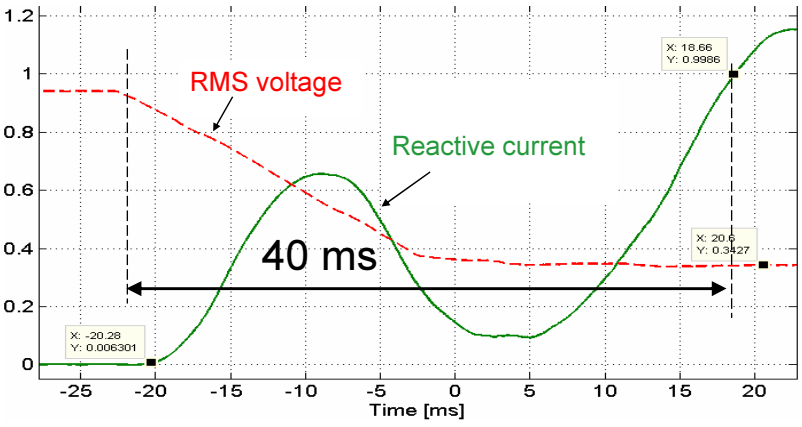
$$\psi_s = \int (u_s - R_s i_s)\, dt$$





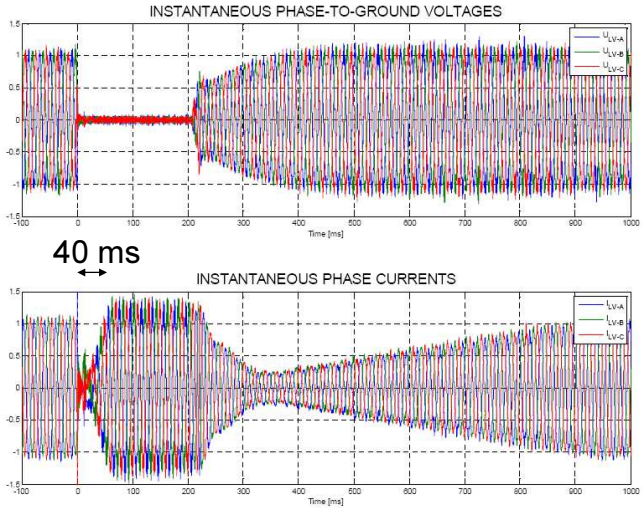
Symmetrical dip with 23 % remaining voltage (factory test)

- Doubly fed fault ride through (2008)



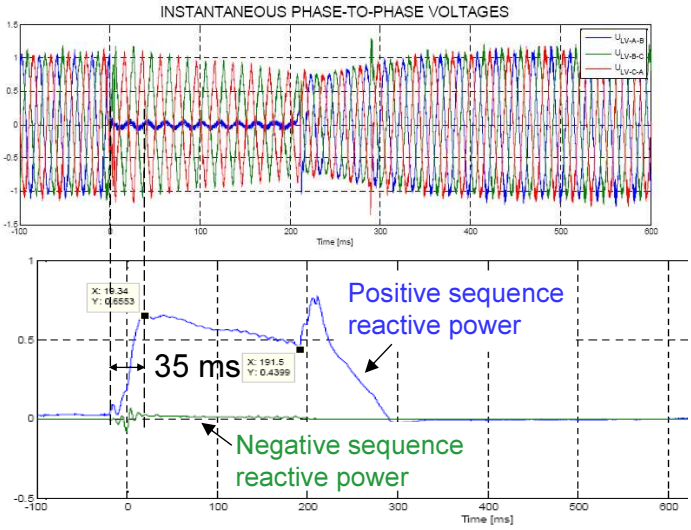
Full-power converter (factory test)

- Zero voltage ride through (2008)



Full-power converter (factory test)

- Zero voltage 2-ph fault ride through (2008)



Future

- Grid codes will continue to evolve
- EWEA is trying to harmonize grid codes
- There are signs that zero voltage dip reactive current support may not be required in the future
- Thus doubly fed concept may continue to stay on market lead
- Full scale converters will, however, gain market share

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