Small is beautiful but big is better: the tale of wind energy technology development

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The Wind Energy Technology Development

• Where it started back in 1980 and key milestones
• Where we are today – onshore and offshore
• The quest for the lowest CoE, onshore and offshore
• Where we are heading tomorrow
• Conclusions and outlook
Different Development Paths -> Different Fates
(small was indeed beautiful)

High-Tech, High Risks, Giant Steps

Evolutionary, low risk & continuous improvement through research

- Vestas V164
- 8MW, Ø 164m
Wind Turbine Development Milestones

Starting point: 50kW, 3 blades, upwind, fixed speed stall regulated

Major milestones that propel the growth of wind turbine size
- Introduction of pitch system for multimegawatt wind turbine
- DFIG concept and variable speed operation Cp-max tracking

Rotor Diameters at Product Introduction
Wind Turbine Product Development

Wind Class

TC III  TC II  TC I

Onshore  Coastal  Offshore

Rotor Diameter

GE 1.5sle
E66 1.5MW

GE 1.5xle
E70 2.0 MW

GE 1.5s
GE 1.5se

Tacke 1.5
(1996)

GE 1.6xle
E92 2.3 MW

GE 1.5sl
GE 1.5sle

GE 1.5

E115 2.5 MW

GE 1.5xle

E82 2.3 MW

3.0 MW

2.3 MW

(1996)
Who has the largest turbine today or mine is bigger than yours

S7.0-171 (Samsung Heavy Industry)
- Power: 7 MW
- Tip height: 193.5 m
- Rotor diameter: 171.2 m
- Tower top mass: unknown

V164 (Vestas Wind Power)
- Power: 8 MW
- Rotor diameter: 164 m
- Tower top mass: ca. 500t
Wind smallest wind turbine

Power: unknown
Rotor diameter: 1.69 mm
On the surface of a smartphone fit ca. 2000 micro turbines

Source: UT Arlington
Cost of Wind Farms and Wind Energy

Onshore cost distribution:
- Wind turbines: 64%
- Foundation: 16%
- Grid connection: 11%
- Planning & miscellaneous: 9%
- O&M: 24%
- Other: 7%

Offshore cost distribution:
- Turbine system: 51%
- Foundation & installation: 27%
- Array cabling: 7%
- Transmission: 13%
- Others: 2%

Source: IRENA, Roland Berger
The Quest for a Lower Cost of Energy Onshore

Annual mean wind speed at hub height (138 Meter): 5.5 m/s
E82: Full load hours 1874h, AEP: 3841 MWh, capacity factor: 21.4%
N117: Full load hours 2631h, AEP: 6314 MWh, capacity factor: 30.0%

- Increase hub height to increase mean wind speed
- Increase rotor diameter to increase power capture at partial load

Nordex N117
Enercon E82
Reduce the uncertainty of the wind resource estimate

- Mobile measurements: UAV - Helicopter and Plane
- Fixed point measurement: metmast 80 meters
- LiDAR measurements: long-range and short-range
LiDAR Feed-forward Controls Field Test

First LiDAR feed-forward controller field tests successfully demonstrated (May 2012)

University of Stuttgart (SWE) LiDAR - CART2
Control: Using Lidar to reduce fatigue loads
NREL Experiment - Results

- reduction in standard deviation of the generator speed of 30% at low frequencies
- but increase of 30% before solving the hard target problem
- similar behavior for the tower base bending moment and other loads
Consider the System Cost: Example of Wind Energy and Combined Storage in Gaildorf

4 x 4.5 MW Wind Turbine
1 x 12 MW Hydro Turbine
160000 m3 Water Storage in the Tower
55 Hours of Power for 12000 Inhabitants
The cost reduction potential of offshore wind energy lies in installation and logistics.
Reliability is another key to the reduction of CoE for offshore wind energy

Normalized failure rate of sub-systems and assemblies for turbines of multiple manufacturers in the database

(Source: Measuring Wind Turbine Reliability – Michael Wilkinson)
Reduction of large array loss through wind farm control

Source: Wake effects at Horns Rev and their influence on energy production

Fig.: Dong energy
Many New Concepts but the Market Hurdle is Very High
Outlook and Conclusions

- The current concept of horizontal axis wind turbine will still dominate the market in the future
- Big is indeed the only way to reduce cost of energy for large scale wind energy generation
- Cost reduction potentials are different for onshore and offshore wind energy
- For large penetration of wind energy and renewable energies in general, it is necessary to consider not only the CoE but the system integration cost
- It is unlikely that the turbine size will grow much larger beyond 10 MW (never say never)
Thanks for your attention

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