Wind Energy: Retrospective, Prospective and the Role of Universities

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Over the last hundred years...

• More people
• More fossil fuel use, more CO$_2$
• Higher temperatures
• More need for renewable energy
  – Solar
  – Wind
  – Marine
  – Hydro
  – Biomass
Where Are We Now?

• Compared to 40 years ago (the beginning of modern wind energy)
  – Wind turbines are far more reliable
  – Wind turbines are larger
  – Cost to produce electricity from wind is much lower
  – Wind supplies ~3% of world’s electricity
  – Climate change recognized as major concern
  – There is still a long way to go!
Evolution of Modern Wind Turbines

- US, Denmark, Germany
- Initially characterized by range of concepts, small size, low availability, high cost of energy
- Now: highly engineered and improved devices

First wind farm: US Windpower 50 kW turbines, New Hampshire, 1980
Contemporary Large Turbine

REpower 5M, model for NREL 5MW
Growth in Wind Energy Capacity

- World capacity as of 2014: 270,000 MW
- Rapid growth since 1990
How Did This Happen?

- Experience
- Data
- Analysis
- Modeling
- Design standards

Universities played a major role:
- Vision
- Direct research
- Educating the participants
Challenges for the Future

• Wind could produce much more of the world’s electricity

• But:
  – We will need many more turbines
    • Lower cost
    • More reliable
    • Easier to service
  – We must integrate them with the energy supply
    • Public acceptance
    • Electrical load management
    • Energy storage
    • Fuel production

More vision and research and more educated people will be needed!
DOE’s A2E Research Framework

• Change the research paradigm from individual wind turbines to entire wind plant cost and performance optimization

• Engage the national labs, universities, and industry in a collaborative consortia...
Resource Characterization

• Forecasting
• Complex terrain (hills and mountains)
• Weather fronts and turbulence
• Long term measurements
• Wind + waves (for offshore)

Excellent topics for universities, research institutes and industrial collaborations!
Wind Plant Technology

- Wind plant and array aerodynamics
- Fluid structure interaction
- Advanced controls
- Component R&D
- Wind plant reliability
- Design & systems engineering tools

Excellent topics for universities, research institutes and industrial collaborations!
Wind Integration

• Issues are related to the desired penetration level (average wind power/average load)
• At low levels (<20%), issues are minimal
• At moderate levels (<40%), coordinated dispatch of other generators is usually sufficient
• At high levels (>50%), more sophisticated load management, energy storage, fuel production may be useful

Excellent topics for universities, research institutes and industrial collaborations!
Some Examples
Flow in Wind Farms is Complex!
Two-Bladed Rotors Again?
Challenge of Fabricating Large Blades

http://www.technologyreview.com/sites/default/files/images/blade.innovationsx519.jpg
Floating Offshore Turbines
Multiple Rotors?

• A new life for an old idea?

Thomas, 1940

Heronemus, 1972
Hybrid Power Systems

• Models for the future?

Diesel plant and wind turbines in Alaska
Wind + Water

• Using wind avoids use of water for cooling thermal power plants
• Wind can supply energy for sea water desalination by reverse osmosis
• Variability of wind provides an interesting opportunity and impetus for innovation
• Storage of water simpler and cheaper than storing electricity
Envision the Future: Wind for Fuel

Precedent: \(H_2\) powered buses in Iceland; “Prof. Hydrogen” at Univ. Reykjavik
Deniers and Skeptics

• Climate change deniers and wind power skeptics often have a vested industry in delaying the transition
• Cogent rebuttals often required
Conclusion

• Great progress in wind technology so far
• Wind at very high penetration is possible and desirable but also challenging
• Many opportunities for innovation
• Concerted, multidisciplinary action will be needed
• Need for scientists, engineers and educated people of all types!