Wind Power Grid Interconnection:

Overview for the Massachusetts Wind Working Group

Sally Wright, PE

Research Fellow, Renewable Energy Research Laboratory, University of Massachusetts

Wind on the Wires - Beyond intermittency

- Wind: an energy resource
  - Not a capacity resource
- Addressing Issues:
  - Policymakers, System operators, Regulators, Equipment Mfrs. …

Want more info? Try
http://www.uwig.org/UWIGWindIntegration052006.pdf
or www.nyserda.org/publications/wind_integration_report.pdf

Wind Power Grid Interconnection: *Today's focus*

- New, Full-scale wind turbines
  - Not small inverter-based
  - Not net metered
  - Not historical designs
- In Massachusetts
- 1- 20 MW projects
- Presumably on distribution lines (possibly transmission)
  - Mostly not on municipal electric lines

Hull Wind 2

Rising Penetration of Wind on the Grid

- Recent US Studies of Operating Impacts
  - New York: 10 %
    - 3.3 GW (nameplate capacity) wind in 33 GW peak load system
  - Minnesota: 15 %
  - Colorado: 10 - 15 %
  - California: 4 %
- Recent European Studies:
  - Denmark: 100 %
  - Portugal: 50 %
  - Germany: 45 %
  - Ireland: 45 %

Source: www.ieawind.org/AnnexXXV/Task25_Publications.html

Higher Penetration ⇨ New Demands on WTG's

- Increasing demand to "look like" a thermal plant
- "Grid Codes" / Interconnection Requirements
  - *Be visible:* SCADA (data & control) to the ISO
  - *Keep going:* ride through system faults
  - *Control Real & Reactive power*

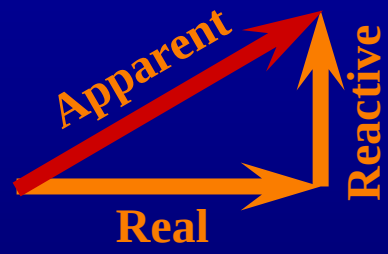
Source: Garrad Hassan

- Parties
  - FERC
  - ISO
  - T&D companies

FERC = Federal Energy Regulatory Commission. ISO = Independent System Operator. T&D = Transmission & Distribution.

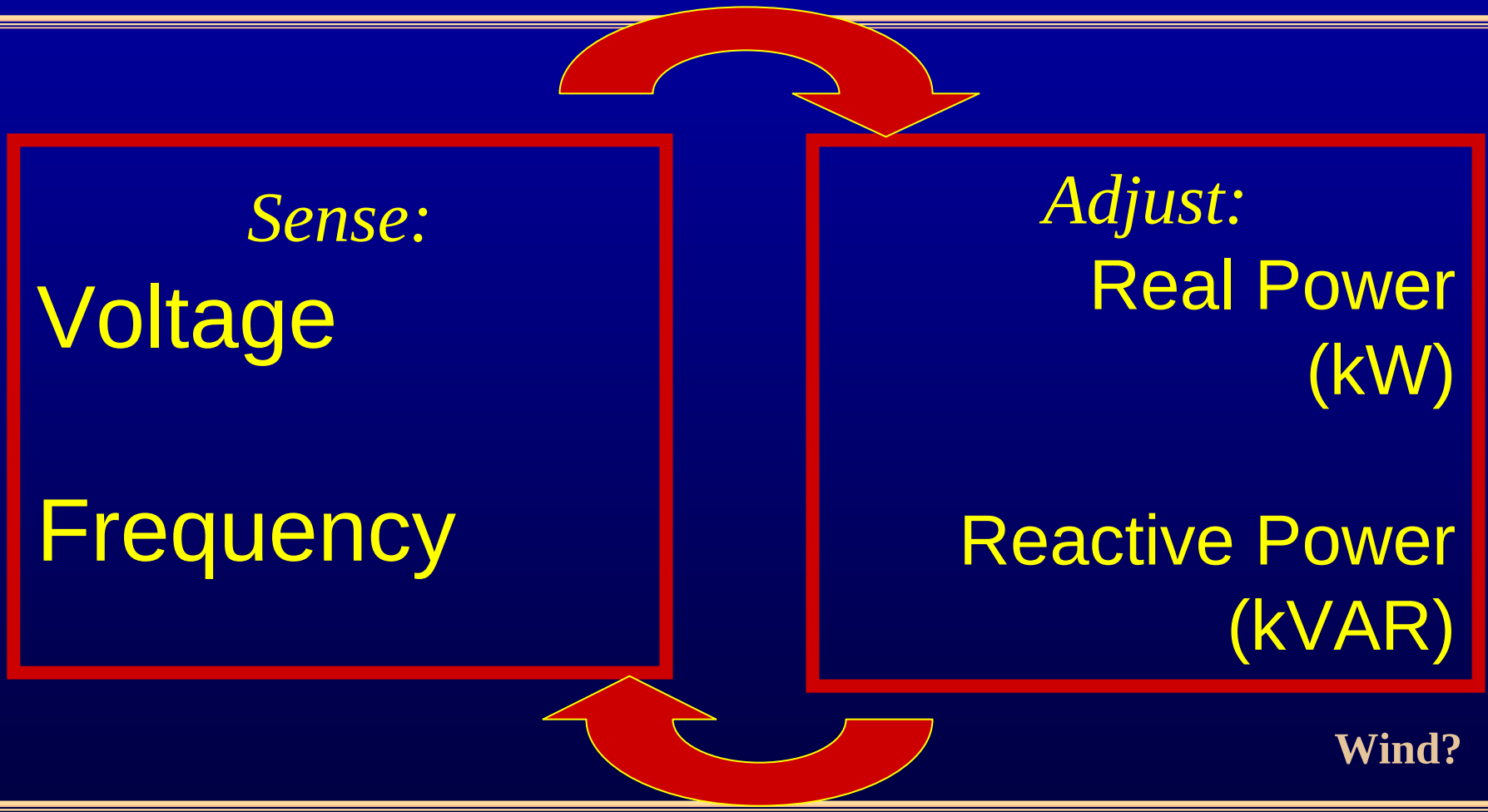
Another Angle on Power: Real vs. Reactive

- Real Power
  - kW
  - Does work, transfers energy
- Reactive Power
  - kVAR
  - No net work. Storage/charging. Capacitive, inductive elements …
- **Both must be balanced**
  - Generation = Load



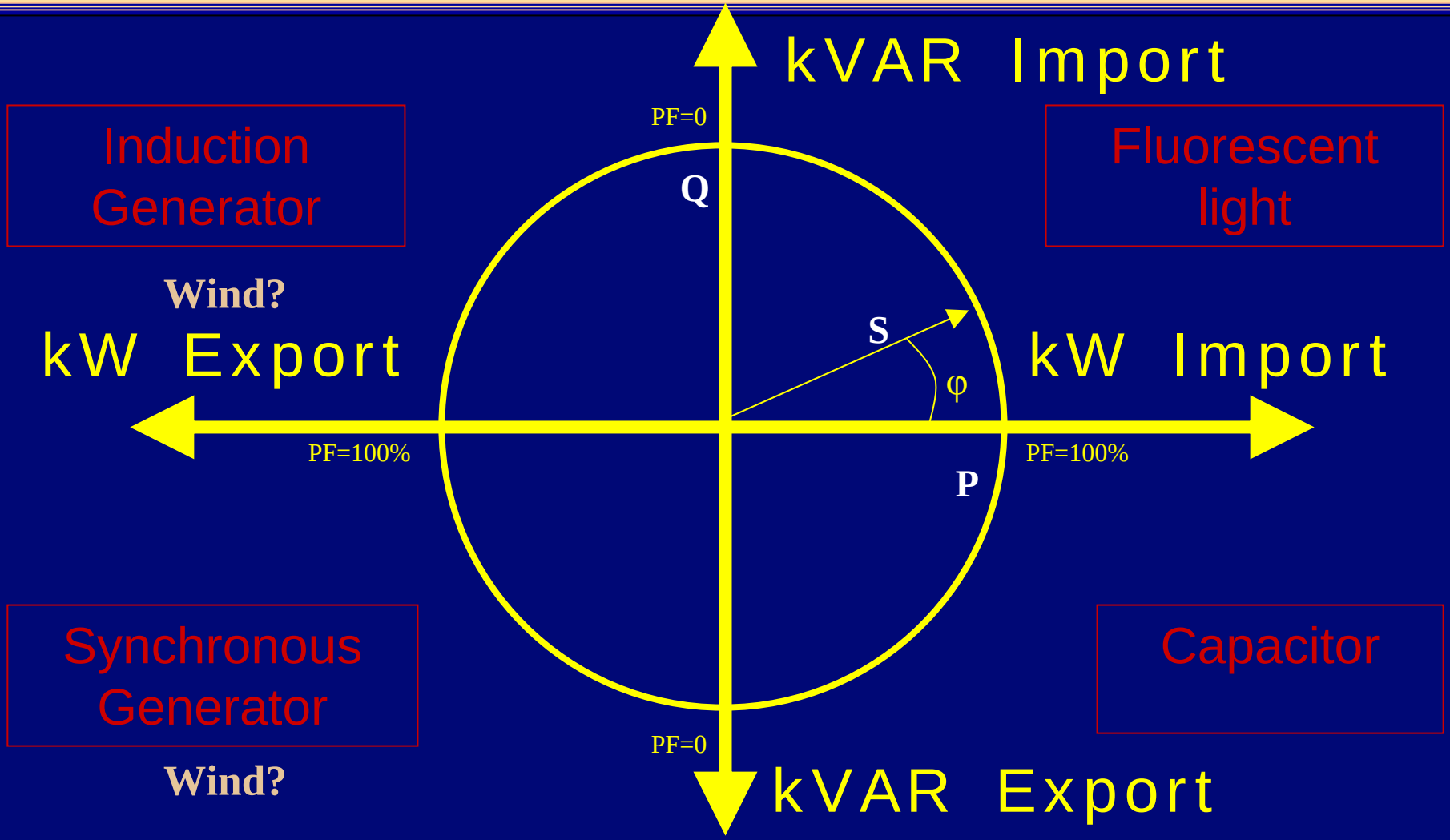
Want more info? Try Wikipedia, *"Reactive Power"*

Basic Generator Controls



Wind?

AC devices Generate or Consume Real AND Reactive Power



Power Factor: PF = kW / kVA = real / apparent = P/S = cos(φ), kVAR = kVA sqrt(1- PF^2)

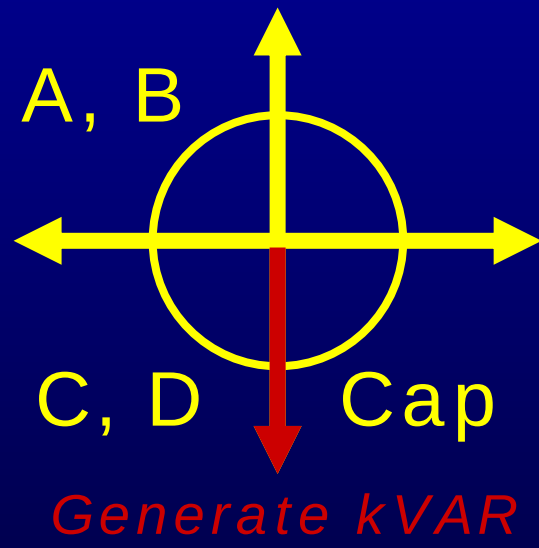
Types of Wind Generators

A: Fixed speed
- Most early designs, robust; consume VAR – add capacitors

B: Limited variable speed
- Vestas' *OptiSlip*. Add cap.s

C: Partial power electronics
- DFIG (doubly fed induction generator)
- E.g. GE 1.5s.
- Most common outside US

D: Full power electronics
- E.g. Clipper *Liberty*



Source: Wind Power in Power Systems,2005, Editor: Thomas Ackermann

How do Wind Turbine Generators participate in the grid?

A: Fixed speed:

- Poor. Requires a stiff grid

B: *Optislip*:

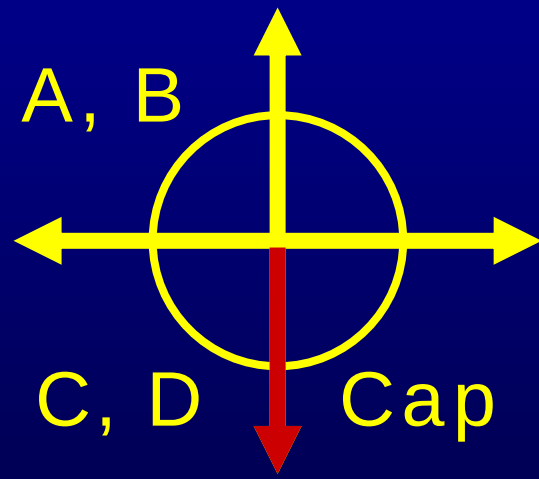
- Improved

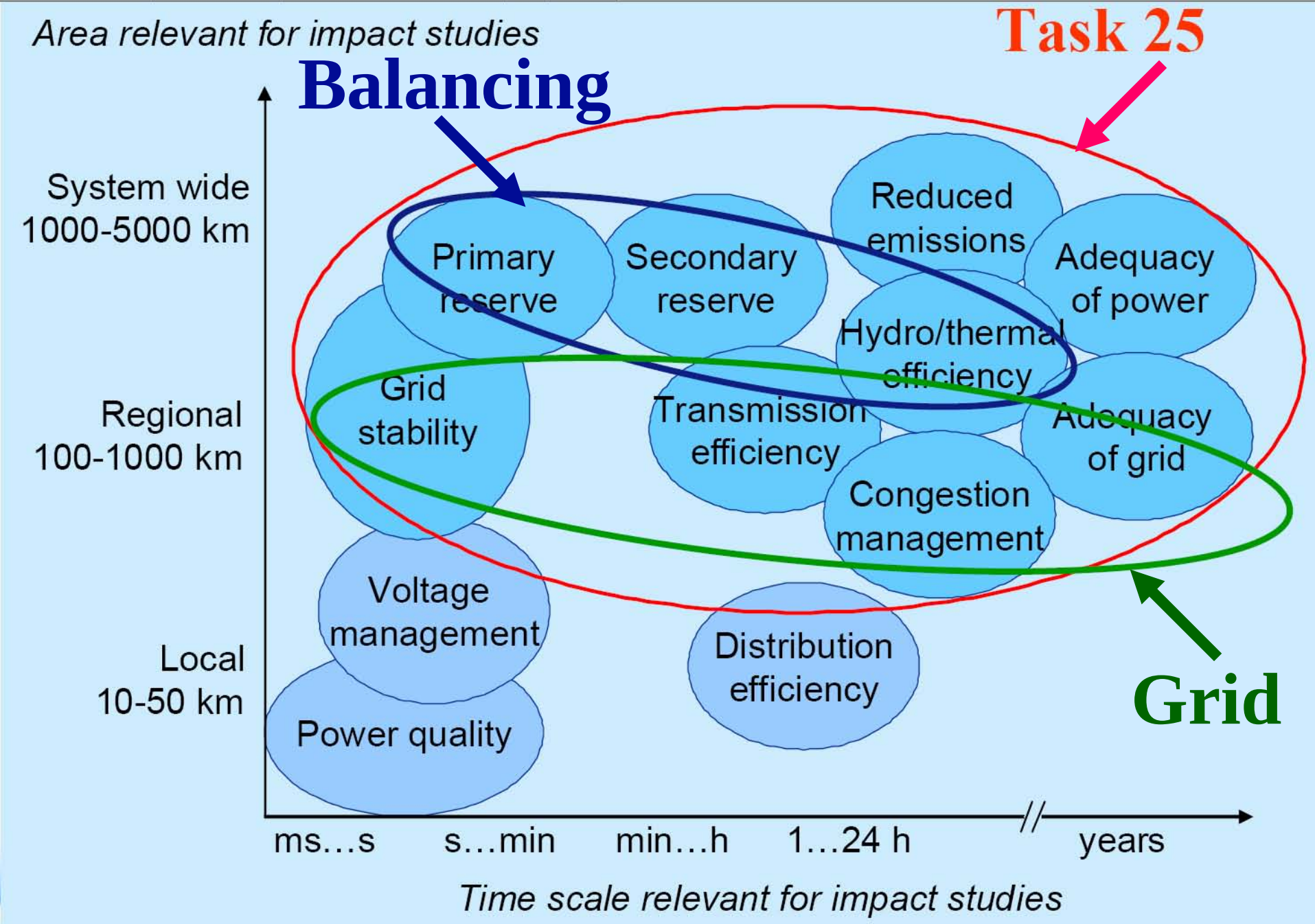
C: DFIG:

- Better grid code compliance

D: Power Electronics

- Best grid code compliance





Source: Int'l Energy Agency "IEA Wind Task 25", Holtinnen. www.ieawind.org/

Wind on the Wires

⇨ wide range of policy & technical issues

- Grid stability & reliability
- Grid Codes
- Market design / rules and tariffs
  - E.g. valuation of Capacity & Ancillary Services
- Long-term transmission planning
- Grid reinforcement needs
  - Cost allocation
- Forecasting
  - Balancing costs, designing imbalance penalties
- At what point does storage make sense? HVDC?

Etc…

"The capacity of the European power systems to absorb significant amount of wind power is determined more by economics and regulatory rules than by technical or practical constraints."

- Corin Millais, EWEA, 2006

Wind Power Grid Interconnection
For More Information

- Utility Wind Interest Group : http://www.uwig.org
  - Utility Wind Integration State of the Art: www.uwig.org/UWIGWindIntegration052006.pdf
- US: Survey of grid impact studies (2003): http://www.nrel.gov/docs/fy03osti/34318.pdf
- NY study: www.nyserda.org/publications/wind_integration_report.pdf
- Europe, Large-scale integration: www.ewea.org/integration/
- FERC order 661: Standard Interconnection Agreements for Wind Energy and Other Alternative Technologies, http://www.ferc.gov/industries/electric/indus-act/gi/wind.asp
- Wind on the Wires www.windonthewires.org/ looks at the implications of transmission planning for wind power in the Midwest

Wind Power Grid Interconnection
Agenda & Panel

- Intro to utility wind interconnect & grid impacts
- Panel: diverse roles in interconnection
  - Fran Cummings, MTC
  - Henri Daher, National Grid, with Edward Kremzier
  - David Forrest, ISO New England
- Interconnection Process:
  - How to file for interconnection of a utility-scale wind turbine
  - Moderated by George Aronson, CommonWealth Resource Management Corp.

These presentations will be posted on the MWWG web page