GARRAD HASSAN

Integrating large quantities of wind in the electricity grid

Paul Gardner

Garrad Hassan and Partners Ltd

paul.gardner@garradhassan.com

Budapest 12 June 2009

Renewable Energy Experts worldwide

Wind Energy the Facts

- Part I: Technology
  - Garrad Hassan (UK), CIEMAT (Spain), EWEA
- **Part II: Grid Integration**
  - Frans van Hulle (EWEA), Paul Gardner (GH)
  - 2. Wind power variability and impacts on power systems
  - 3. Design & operation of European power systems with large amounts of wind power
  - 4. Grid infrastructure upgrade for large scale integration
  - 5. Grid connection requirements
  - 6. Wind power's contribution to system adequacy
  - 7. Economic aspects: integration costs and benefits
- Comments to paul.gardner@garradhassan.com
- This is all about wind energy, but most of the issues are also relevant to other renewables.

Definitions of ‘penetration’

- Wind ***energy*** penetration:
  - Wind energy produced (TWh/y), as a fraction of gross annual electricity demand (TWh/y)
  - Denmark 21%, Spain/Portugal 11%, Ireland 8%
  - EU-27 target 12-14% in 2020
- Wind ***capacity*** penetration:
  - Wind power capacity (MW), as a fraction of peak electricity demand (MW)
  - Western Denmark 66%, Germany 28%, France 2%
- ***Maximum share*** of wind power:
  - Maximum wind power generated (MW), as a fraction of [minimum electricity demand (MW) plus power exchange capacity (MW)]

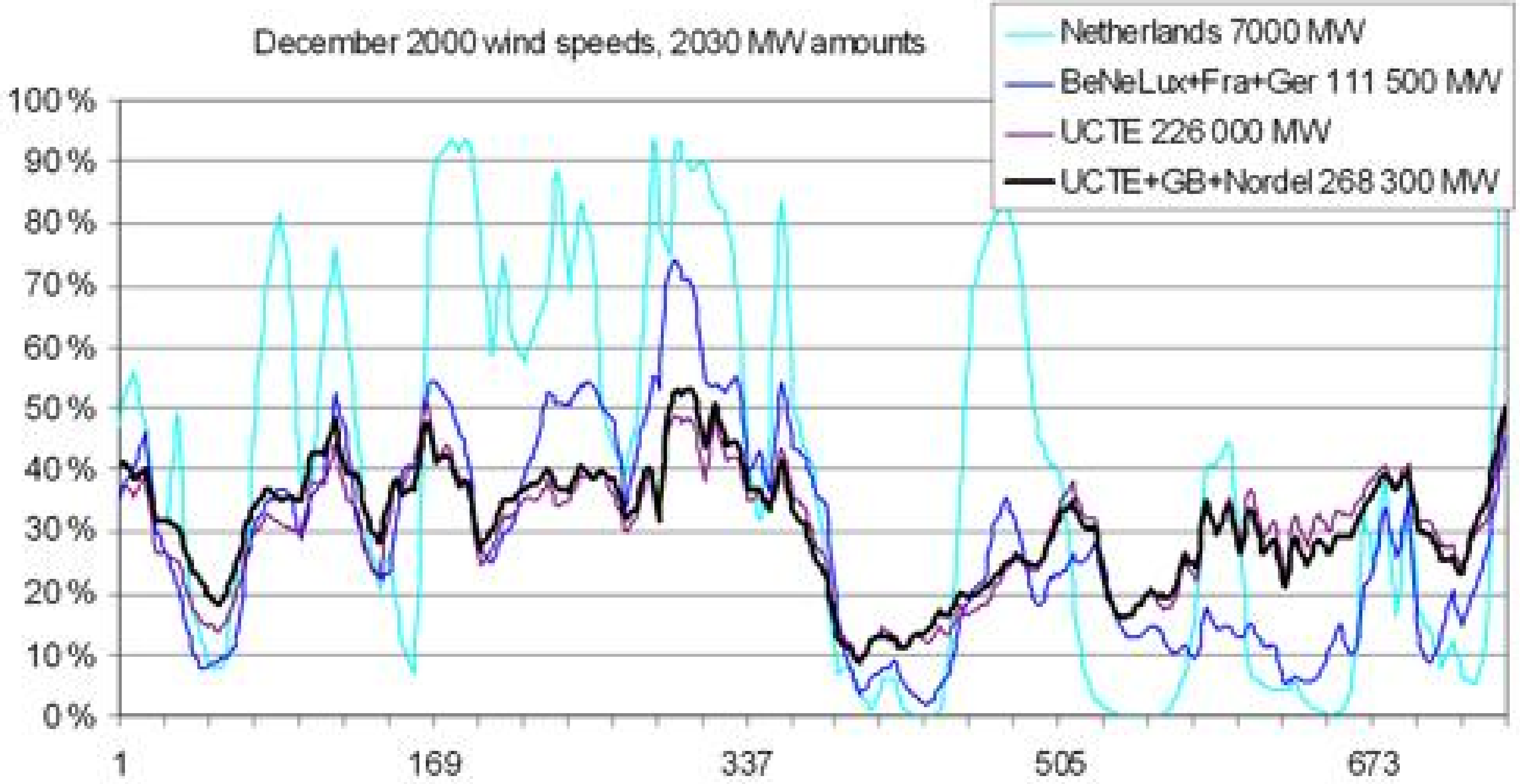
Major issues

- Design & operation of the power system:
  - Reserve capacity, balancing management, short-term forecasting
  - Demand-side management and storage, other flexibility
- Grid infrastructure:
  - Best use of existing infrastructure
  - Reinforcement and extensions, interconnections to other systems
- Grid connection:
  - Grid codes
  - Wind power plant capabilities
- Market issues:
  - Market arrangements
  - Cross-border trading
- Institutional issues:
  - Non-discriminatory grid access
  - Socialisation of costs

Variability

- Variability and predictability are different!
  - Tidal energy is very variable, and very predictable
  - Wind energy is less variable, and less predictable
- Rough approximations:
  - For a single wind turbine, output power can vary on timescales of seconds
  - For a single wind farm (say 10 turbines), output power varies on timescales of minutes
  - For several wind farms spread over a region, output power varies on timescales of 10 minutes
  - For wind farms in a country, output power varies on timescales of 30 minutes upwards
    - 5%/hour normally, 20%/hour maximum

Variability



Predictability

- Forecasting tools have improved significantly
- Accuracy is best for:
  - groups of wind farms;
  - short ‘look-ahead’ times (‘forecast horizon’)
- Is it necessary to forecast the output of each wind farm accurately?
- ‘Look-ahead’ times might be decided by the market structure: is it really necessary to forecast only every 24 or 6 hours?
- Who should do the forecasting?
- Should there be penalties for forecasting errors?

Balancing

- ‘Balancing’ is the short-term control of electricity generators to ensure that demand and supply are in balance, and system frequency is adequately controlled
- System operators need several forms of ‘reserve’, to provide balancing
  - Conventional thermal generation
  - Reservoir hydro
  - Pumped-storage
  - Controllable demand
  - De-rated wind generation
- Wind generation increases the need for reserve capacity, but not much (~5% at 20% wind penetration)
- Cost is ~€1-4 per MWh of wind energy (at 10% wind penetration)

Grid infrastructure

- ‘Soft’ measures:
  - Better use of existing power lines (e.g. temperature monitoring)
  - Improvement of electricity trading and cross-border power flows
  - Control of other generators
  - Curtailment of wind production
- Reinforcement:
  - High-temperature conductors on existing transmission towers
  - Replacement lines
  - New lines
- Other measures:
  - Series reactors, phase-shifting transformers
  - Power electronics, FACTS devices (voltage management)

Grid connection requirements

- Technical requirements for all users of the electricity system must be fair, and clear
- Commonly called ‘Grid Codes’
  - Tolerance: voltage range, frequency range
  - Reactive power control
  - Voltage control
  - Active power control (cap, ramp rate limits etc)
  - Frequency response (‘governor action’)
  - Protection devices
  - Power quality: voltage changes, harmonics
- Harmonisation of grid codes: EWEA working group is attempting ‘structural harmonisation’: to harmonise the definitions, methodologies, units, etc.

Security of supply

- The probability that supply will not be able to meet demand
- Also called ‘system adequacy’ and other terms
- Wind generation makes the calculations harder
- Wind generation does provide some ‘capacity credit’, though there is disagreement on the results and the methodology
- Does it matter, if there is no reward to generators for contributing to security?

Integration costs

- Mainly balancing costs, and transmission reinforcement costs
- Cost depends greatly on the electricity system: size, generation mix (especially hydro generation), market mechanisms, and other factors
- Total costs can be large in total, but very small effect on electricity bills

Summary

- High wind penetrations are technically feasible
- Costs are not high
- Very dependent on the electricity system characteristics

- Therefore we should not ask ‘can it be done?’ Instead we are asking ‘how can we do it cheapest/ fastest/ with least risk?’

GARRAD HASSAN