Business from technology

IEAWIND Task 25
Design and Operation of Power Systems with Large Amounts of Wind Power

Operating Agent
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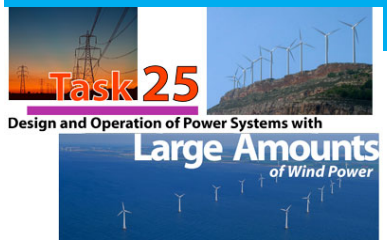

Challenges to power systems with large share of wind power

- Variability and prediction errors of wind power production
  - Currently variable load –more predictable patterns
  - Variability and uncertainty from single turbine and wind power plant is large, but will smooth out when distributed wind power plants
- Grid to connect and transfer the power
  - Currently the grid transferring power from existing units
- Impacts will depend on the share of wind power and power system:
  - The variability of load
  - The flexibility of power generation fleet
  - Possibilities to increase flexible production and consumption
  - The adequacy of grid (wind resource versus load centers)

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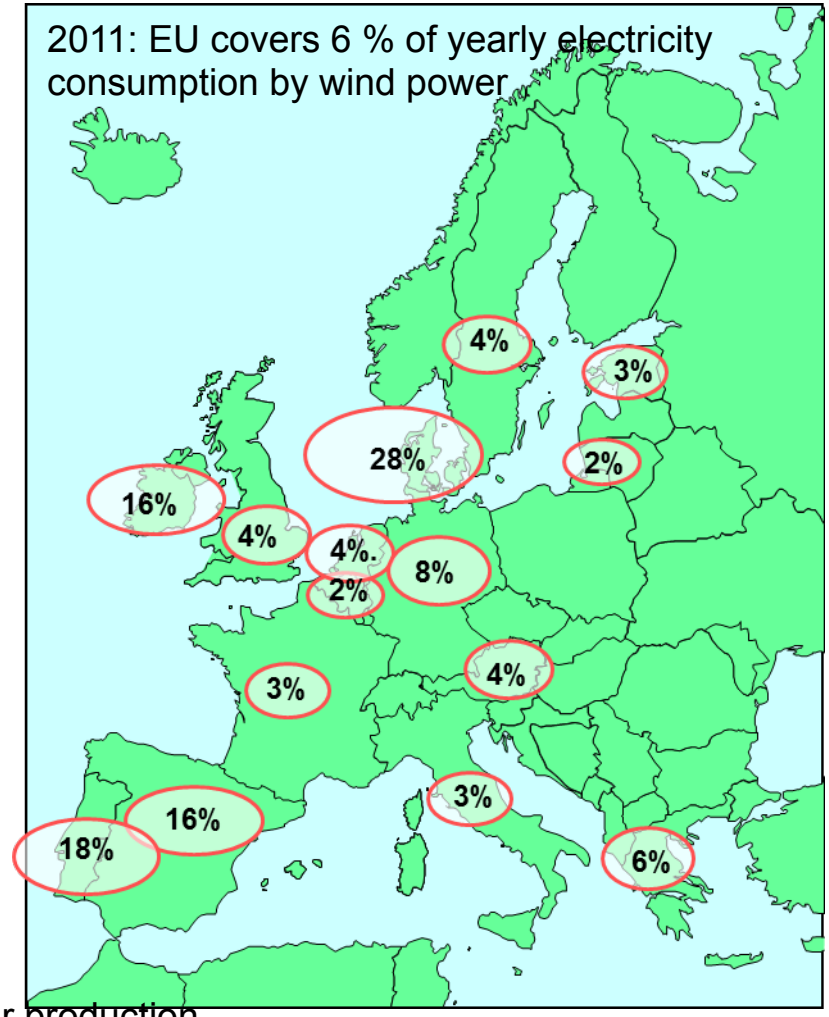
Experience from wind power integration is growing

- There is already experience from several countries in Europe integrating 15-28 % of their electricity consumption from wind energy
- In US: states in Mid West and Texas have > 10 % penetration levels
- There are targets to reach 40-50 % in one country (Ireland and Denmark) and 14 % EU wide in 2020



Penetration level: share of electricity consumption by wind power production

Wind integration today

- TSOs use updated information of on-line production and forecasts as well as possibility to curtail in critical situations
- TSOs see increase in use of short term reserve/load following
- Technical capabilities of wind power plants used more, and evolving

- Existing constraints to reinforce the transmission network can delay reaching 20% wind penetration on the European/North American scale
- Operation strategies to cope with wind generation from a high to a very high level (>20 %) are still being developed. New tools are needed.

TSO: Transmission System Operator

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Wind Integration Studies

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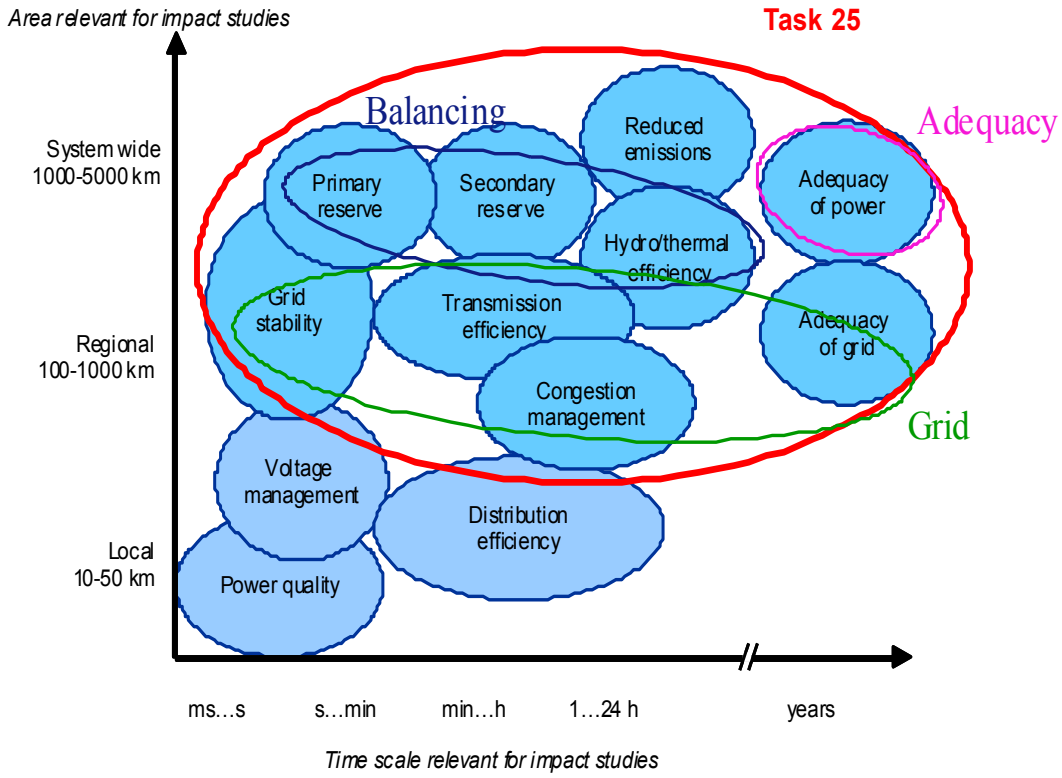
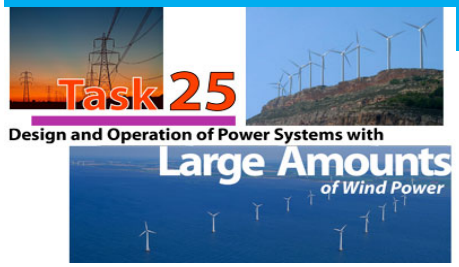
- Integration studies are made for various reasons. System impact studies are often first steps towards defining wind penetration targets
- Wind integration study results and methodologies used vary
- IEA WIND Task 25 is working on providing best available information on how to perform a wind integration study: for research institutes, consultants and system operators





IEA WIND Task 25

OBJECTIVE:
to analyse and further develop the methodology to assess the impact of wind on power systems

1st phase 2006-08, 11 countries + EWEA participate

2nd phase 2009-11, 14 countries + EWEA participate

3rd phase 2012-14, 15 countries + EWEA participate.

- Provide an international forum for exchange of knowledge
- State-of-the-art: review and analyse the studies and results so far
  - methodologies and input data, system operation practices
  - **Final report 2006-08 in July 2009, 2009-11 in November 2012**
- Formulate guidelines:
  - recommended methodologies and input data when estimating impacts and costs of wind power integration
- Quantify the impacts of wind power on power systems
  - range of impacts/costs; rules of thumb

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Design and operation of power systems with large amounts of wind power

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	Country	Institution
	Canada	Hydro Quebec (André Robitaille); Manitoba Hydro (Tom Molinski);
	China	SGERI (Bai Jianhua, Hu Bo)
	Denmark	Risø-DTU (Poul Sørensen); Energinet.dk (Antje Orths)
	EWEA	European Wind Energy Association (Frans van Hulle)
	Finland **OA**	VTT (Hannele Holttinen, Juha Kiviluoma)
	Germany	ISET (Bernhard Lange); TSO Amprion (A.Gesino)
	Ireland	ECAR/UCD (Mark O'Malley); TSO EirGrid
	Italy	TSO Terna (Enrico Maria Carlini, Chiara Vergine)
	Japan	AIST (Junji Kondoh); University of Kansai (Yoh Yasuda)
	Norway	SINTEF (John Olav Tande, Atle Rygg Årdal)
	Netherlands	we@sea, ECN (Jan Pierik); TUDelft (M. Gibescu)
	Portugal	LNEG (Ana Estanquiero); TSO REN (Jose Osario); INESC-Porto (J. Pecas Lopes); UTL-IST (Ferreira Jesus)
	Spain	University of Castilla La Mancha (Emilio Gomez Lazaro)
	Sweden	KTH (Lennart Söder)
	UK	DG&SEE (Goran Strbac)
	USA	NREL (Michael Milligan); UVIG (Charles Smith)

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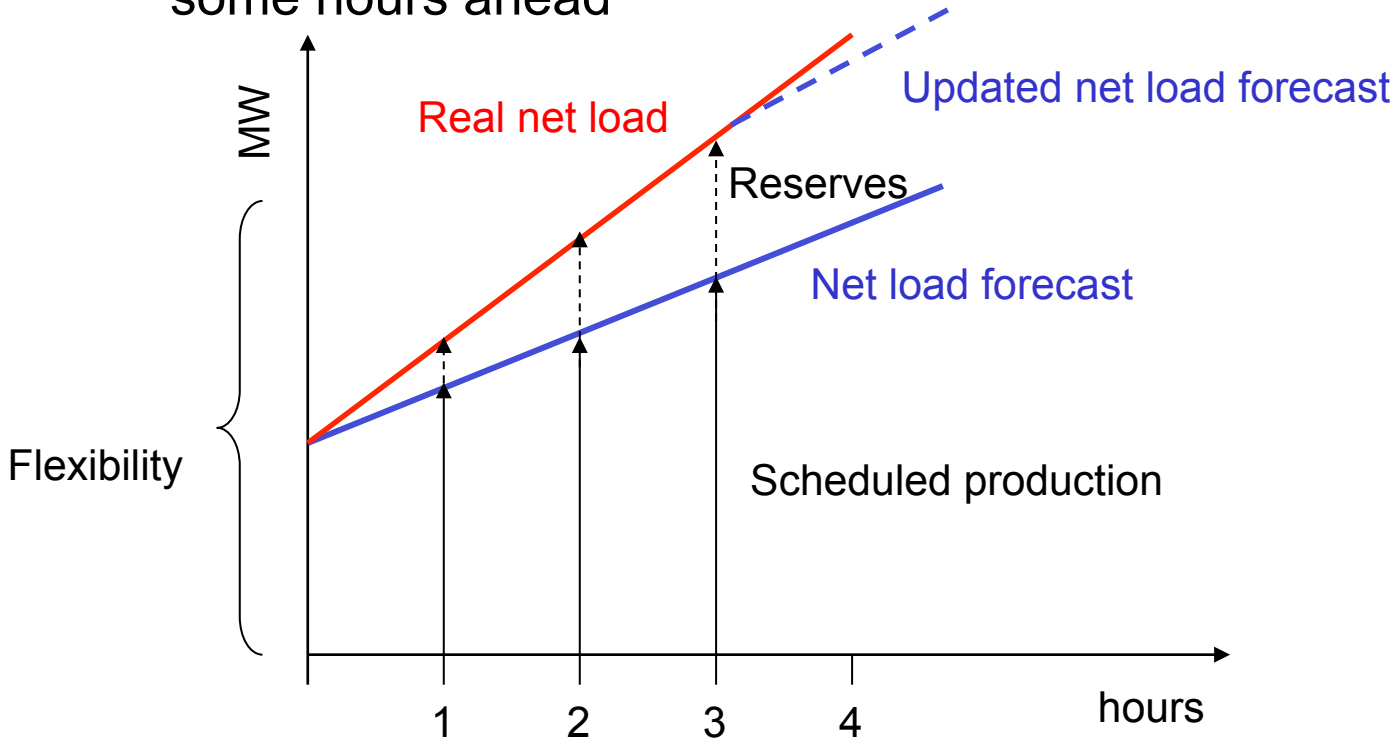
Flexibility and reserves

- Different time scale impacts of wind power
- Wind power impacts flexibility of conventional production units a lot at longer time scales (4…12…24 hours)
- Reserves are operated during the operating hour, can be allocated some hours ahead



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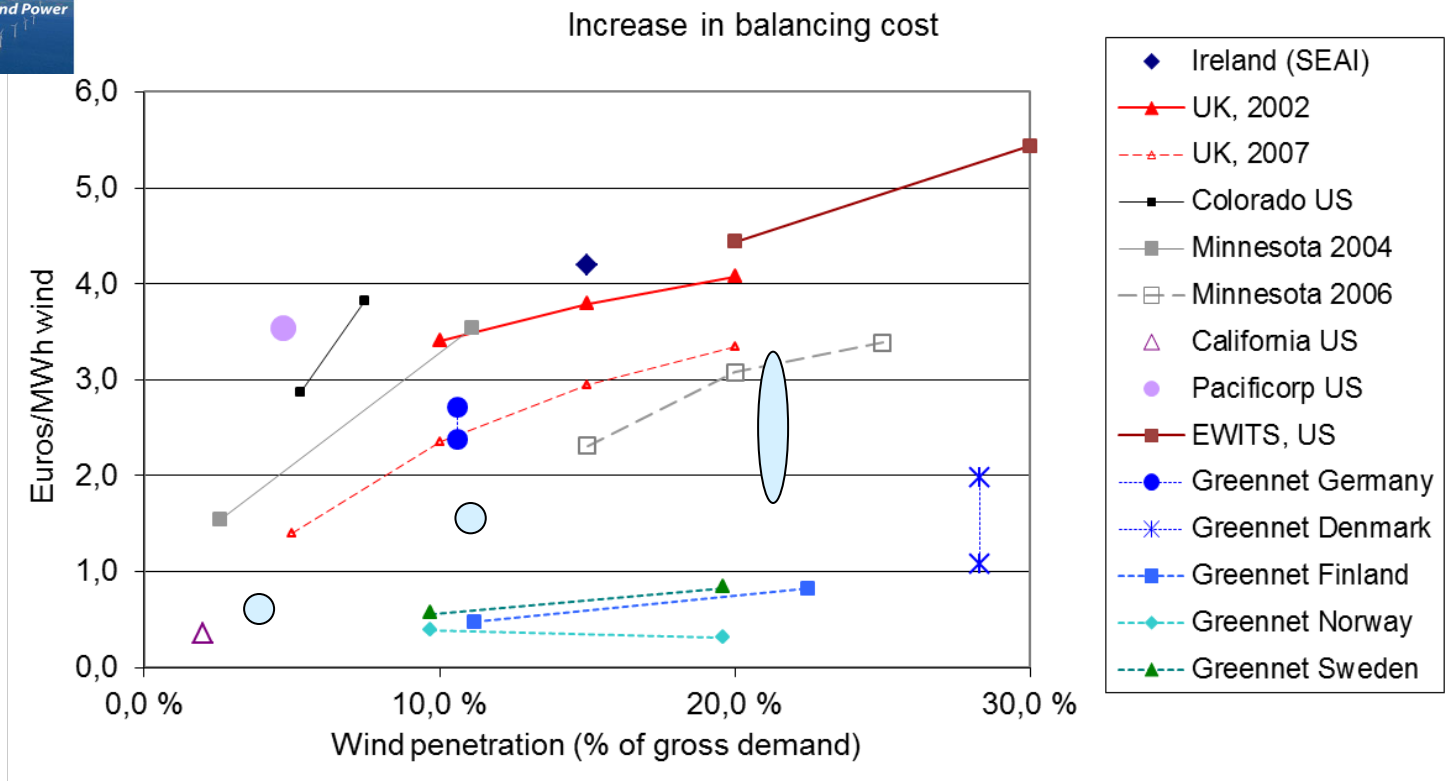
Summary balancing costs



§ Integration costs 0.5 – 4.5 €/MWh up to 20 % penetration level

§ Integration costs are challenging to estimate for a single part

Experience from Denmark/Spain/NL, cost of balancing from electricity markets for wind power producers

allocating investment for new reserve; interconnection taken into account or not; assumptions on thermal power costs

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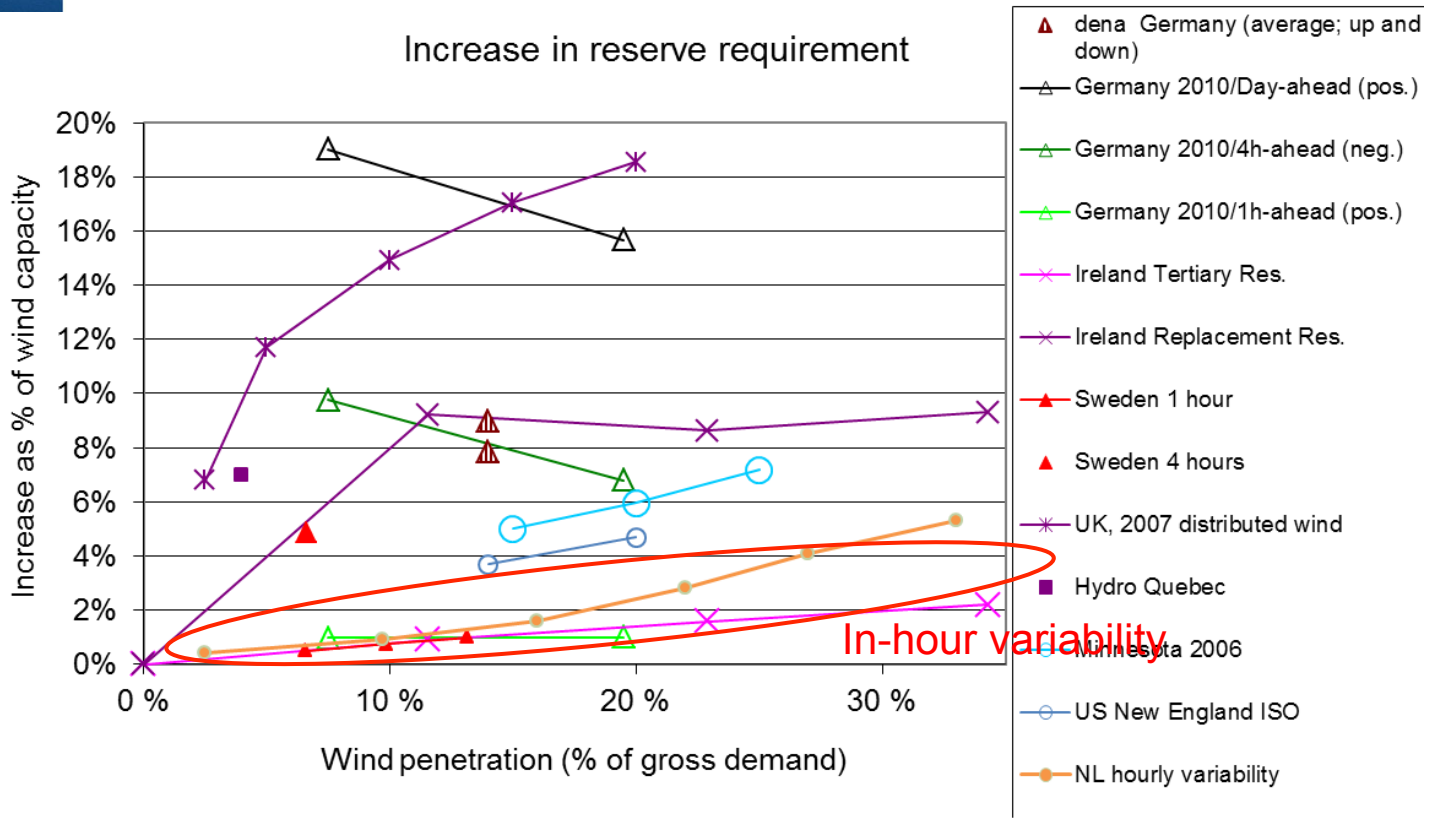
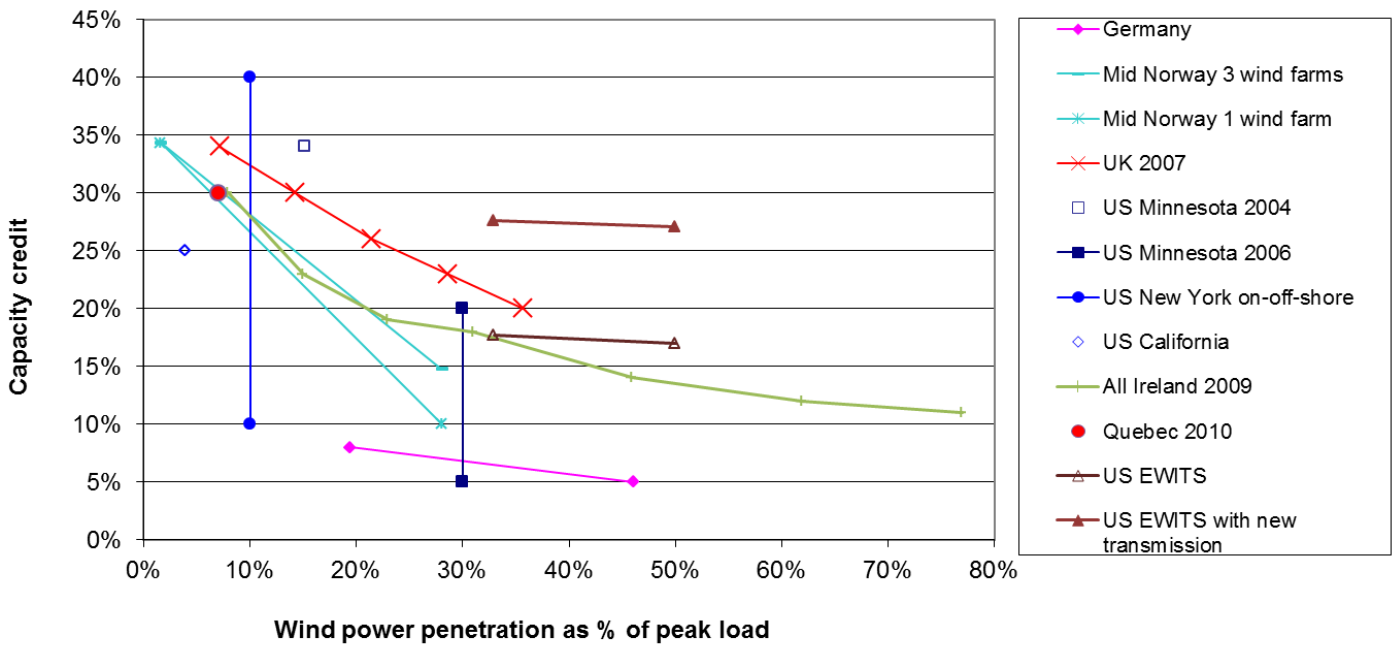
Summary short term reserve requirements



- Based on increase to load variability/uncertainty due to wind power – increasing impact at increasing penetration level
- Sub-hourly variability impacts on reserve requirements small: 1 % of installed wind capacity at 10 %, 2-5 % at 30 % penetration level. Different time scales for estimating the reserve requirement for others - 4 hours ahead, day-ahead

Capacity value of wind power - key points

- Wind power has a considerable impact on generation adequacy – reducing value as penetration increases
- Larger areas – more value - highlights the need for transmission
- Full LOLP calculations needed - approximations not wise
- Data needed
  - Synchronised
  - Multi year
  - High resolution



LOLP – Loss of Load Probability

Impacts to transmission network

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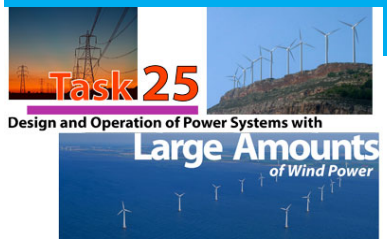
- Wind capabilities evolving to give support to grid
  - Requiring FRT capability is an industry standard, however, many different grid codes; voltage and frequency support
- Transmission has is a key enabler to reach renewable energy and carbon reduction goals, and to help manage variability
  - Wind energy different from conventional energy and requires different approach to transmission planning – and transnational efforts (interconnection-wide transmission planning)
  - Building grid for the total wind power amount more cost effective than upgrading bit by bit
  - Can be very difficult/lengthy to get building permits for lines improving the existing network utilization can help for short term:
    - Using online monitoring (temperature,..); upgrading degraded components and introducing FACTS and phase shift transformers;
    - Accepting occasional wind curtailements



Summary

- Power systems face new challenges when integrating wind power
  - Larger areas help smoothing variability and uncertainty
- Experience from wind integration has shown the problems can be overcome to reach 20 % shares of wind power (of yearly energy)
  - New tools will be needed to achieve higher targets
- Keys to wind integration
  - Transmission planning and operational methods
    - Larger balancing areas to decrease the uncertainty challenge
  - Flexibility needs to be enhanced
    - Future power plants need to be designed to be flexible
    - Other means to increase flexibility from demand side and storages may also be needed in future