Integration of wind power plant in the smart transmission network

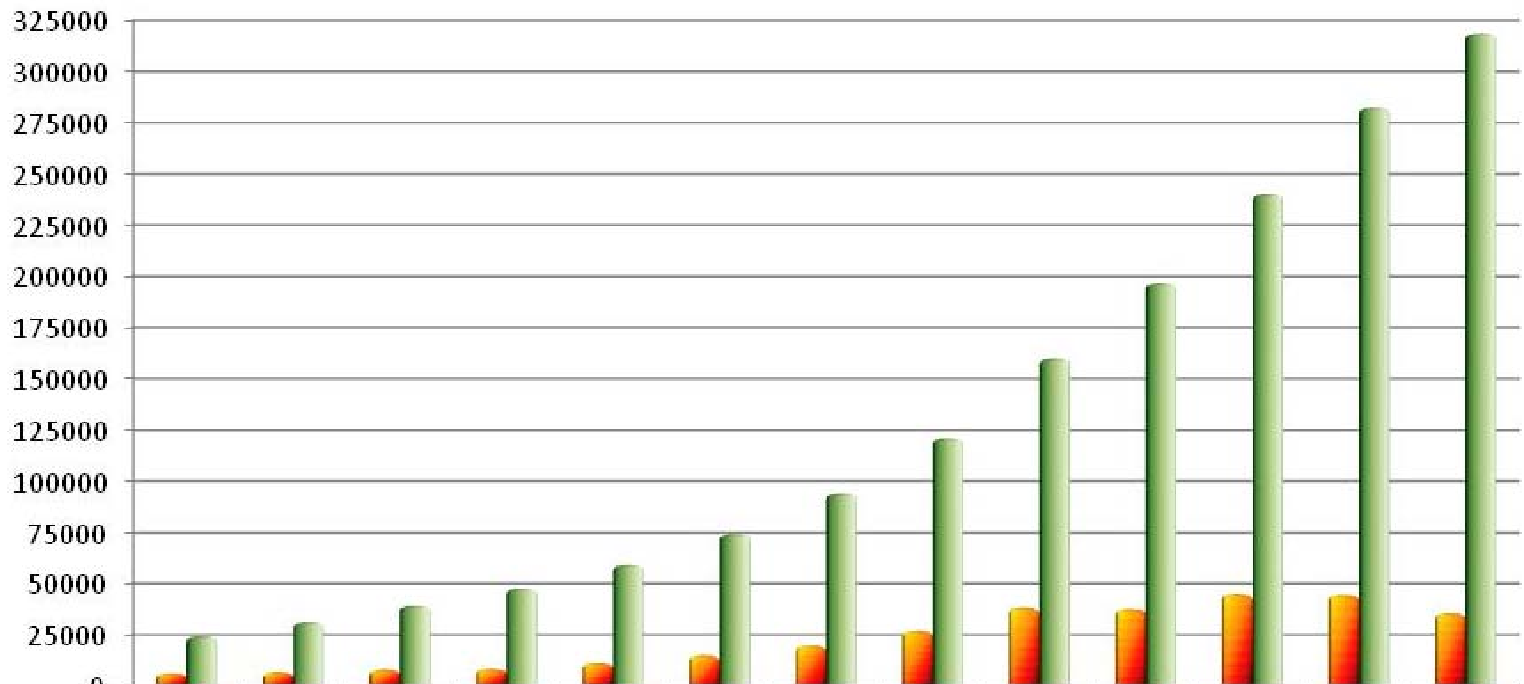
Professor Igor Kuzle

Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

World total installed capacity

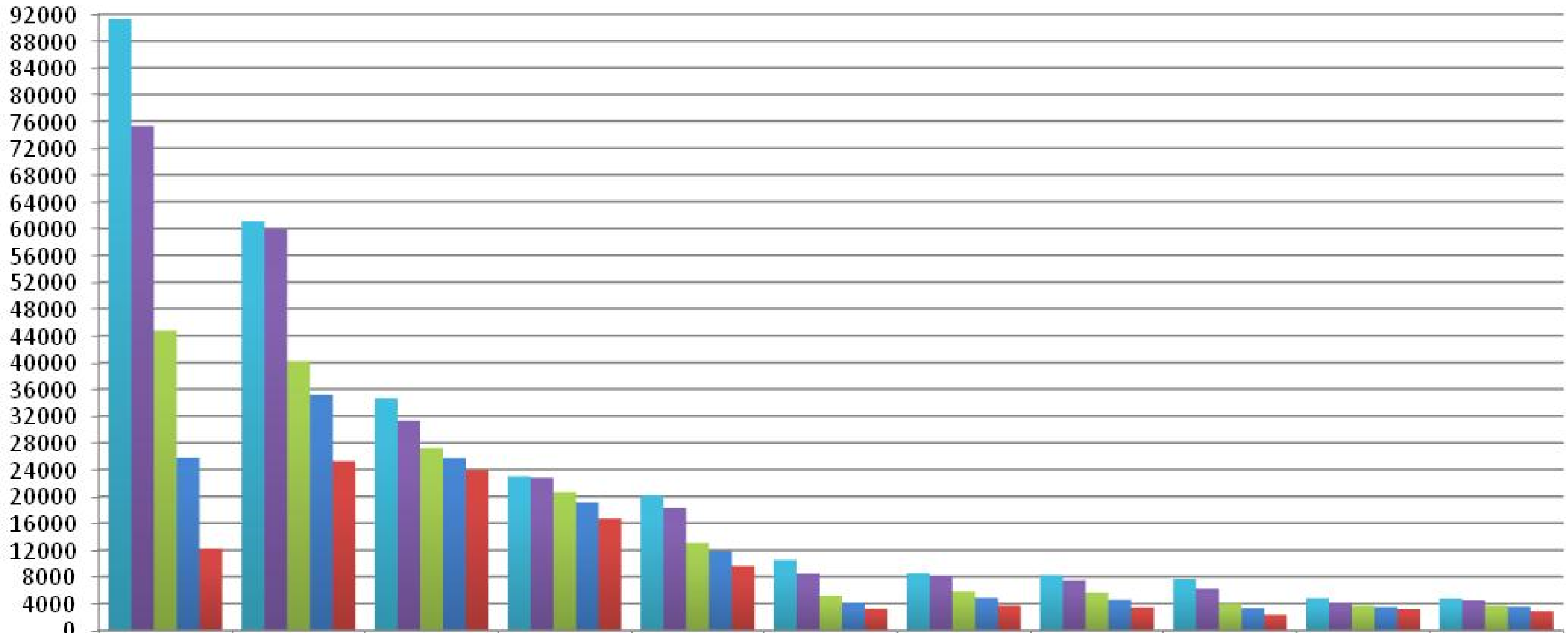
The penetration level of wind power into the power system over the world has been increasing very fast.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
New wind capacity (MW)	6282	6859	8114	8386	11331	15111	19808	26972	38312	37642	45000	44609	35550
Total wind capacity (MW)	24322	31181	39295	47693	59024	74122	93927	120903	159776	196630	240000	282275	318529

Source: www.wwindea.org

Top 10 countries in using wind power



	Kina	SAD	Njemačka	Španjolska	Indija	Velika Britanija	Italija	Francuska	Kanada	Danska	Portugal
2013.	91324	61108	34660	22959	20150	10531	8551	8254	7698	4772	4724
2012.	75324	59882	31315	22796	18321	8445	8144	7499,8	6201	4162	4525
2011.	44733	40180	27215	20676	13065,8	5203,8	5797	5628,7	4008	3734	3702
2010.	25810	35159	25777	19149	11807	4092	4850	4574	3319	3465	3535
2009.	12210	25237	23897	16689	9587	3195	3736	3404	2369	3163	2862

Source: www.wwindea.org

WPP in Croatia (339,45 MW)

Transmission grid

- Bubrig, Crni Vrh i Velika Glava (43 MW)
- Jelinak (30 MW)
- Ponikve (34 MW)
- ST1-1 Voštane (20 MW)
- ST1-2 Kamensko (20 MW)
- Vrataruša (42 MW)
- ZD2 (18 MW)
- ZD3 (18 MW)
- Zelengrad – Obrovac (42 MW)

UKUPNO 267 MW

Distribution grid

- Crno Brdo (10 MW)
- Orlice (9,6 MW)
- Pometeno brdo (17,5 MW)
- Ravne (5,95 MW)
- Trtar Krtolin (11,2 MW)
- ZD4-1 (9,2 MW)
- ZD6-1 (9 MW)

UKUPNO 72,45 MW

Electric power system is changing

Basic terms

WIND ENERGY PENETRATION (%) =

$$\frac{\text{Total amount of wind energy produced (annually) (TWh)}}{\text{Gross annual electricity demand (TWh)}}$$

WIND POWER CAPACITY PENETRATION (%) =

$$\frac{\text{Installed wind power capacity (MW)}}{\text{Peak load (MW)}}$$

MAXIMUM SHARE OF WIND POWER (%) =

$$\frac{\text{Maximum wind power generated (MW)}}{\text{Minimum load (MW) + power exchange capacity (MW)}}$$

Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

Wind Grid Codes

- **Tehnical Requirements for Wind Power Plants regarding:**
  - Connection
  - Operation
- **Variety of requirements between electricity systems**
- **Pan-european grid codes unification**

Grid connection aspects

- **Type of grid:**
  - Transmission
  - Distribution
- **Type of connection**
  - Connection to the node (radial)
  - Connection to the line (in-out)
- **Covering of grid reinforcement costs**
  - Deep method
  - Shallow method
  - Mixed method

Type of grid

- **Transmission grid**
  - Highly meshed
  - Higher installation capacity
  - System impact: voltage support, frequency support, dynamical behaviour
  - Local impact: Loading of lines, short-circuit level, energy quality, protection coordination
- **Distribution grid**
  - Radial
  - Lower installation capacity
  - System impact: low
  - Local impact: Loading of lines, end voltage, energy quality, protection selectivity, short-circuit level, impact to the end customers

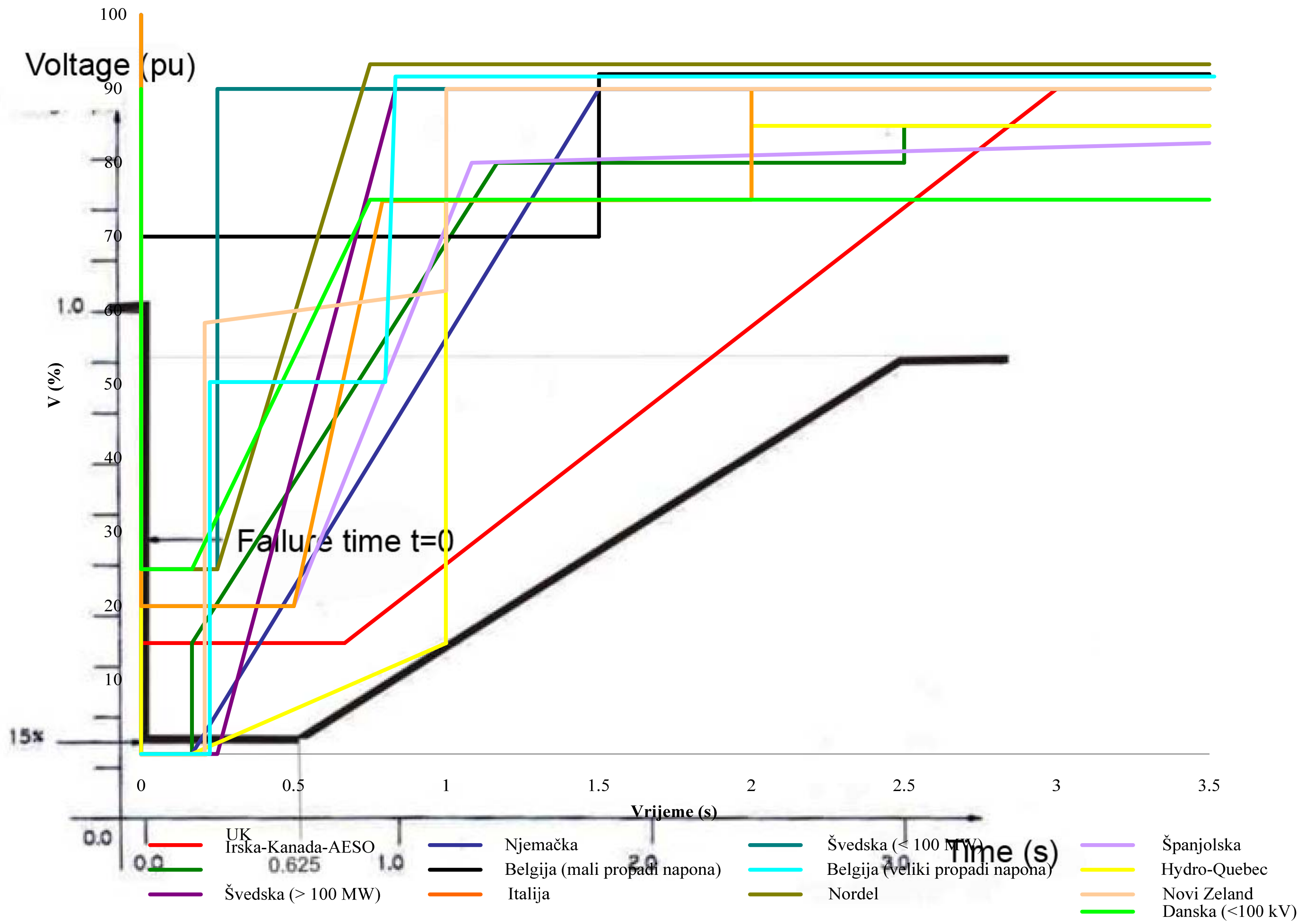
Covering of grid reinforcement costs

- **Network development plans – approved by Energy Regulator**
- **Shallow connection charging**
  - minimizes the costs for producers
  - grid operators pay any costs for reinforcement
- **Deep connection charging**
  - higher costs on producers
  - producers pay for the equipment costs, plus all the cost of any network reinforcement necessary to connect their plant
- **Mixed or shallower connection charging**

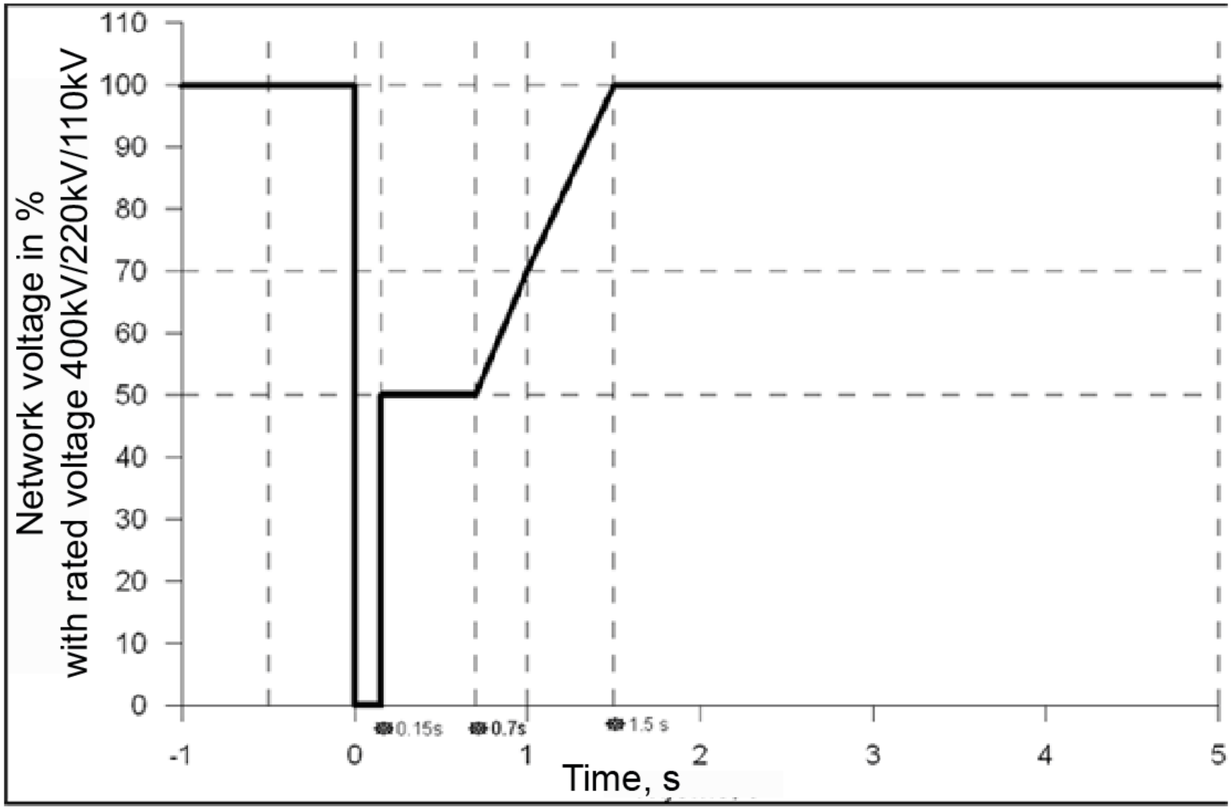
Operational Requirements for Wind Power Plants

- Tolerance - the range of conditions on the electricity system for which wind farms must continue to operate
- Control of voltage / reactive power
- Control of frequency / active power
- Protective devices
- Power quality

Fault ride through capability

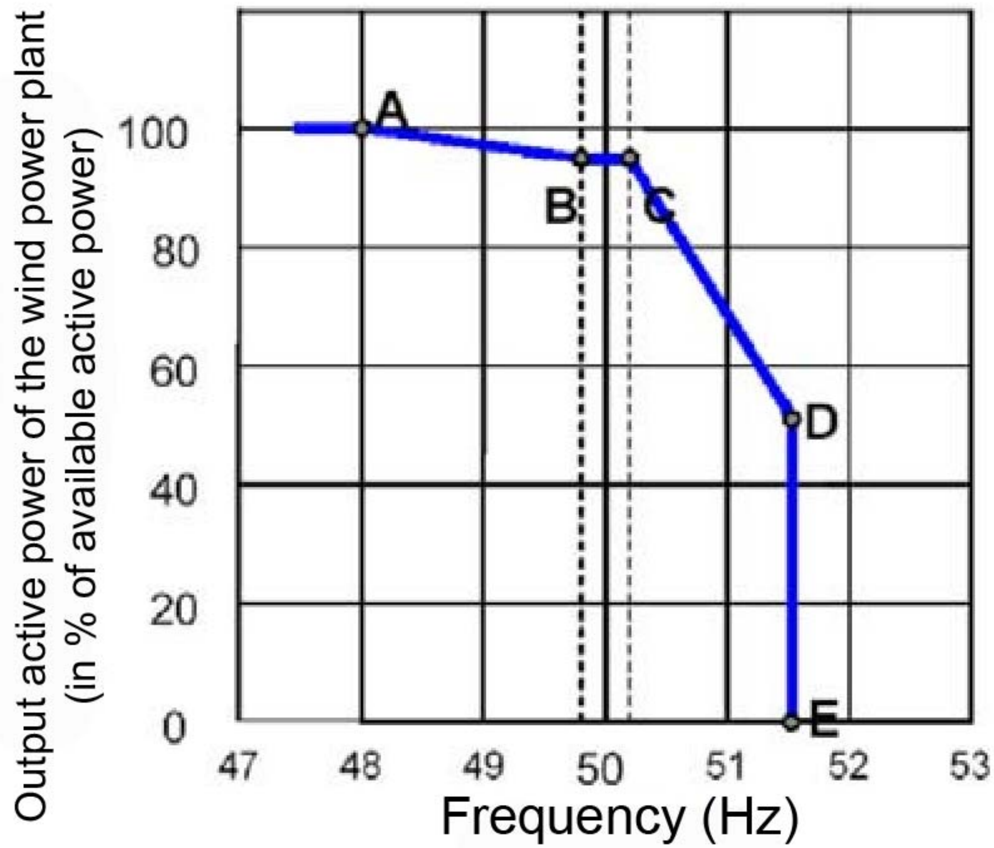


Control of voltage / reactive power



Allowed transmission grid voltage at the high-voltage side of the block-transformer

Control of frequency / active power



Characteristic of the power response to the change of frequency

Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

Impact of wind farms on power system operation

- **Power system stability**
  - Dynamic stability
  - Frequency control
  - Voltage control
- **Power system operation and planning**
  - Power system balancing
  - Power system control reserves (secondary/tertiary reserve)
  - Network congestion / Redispatching

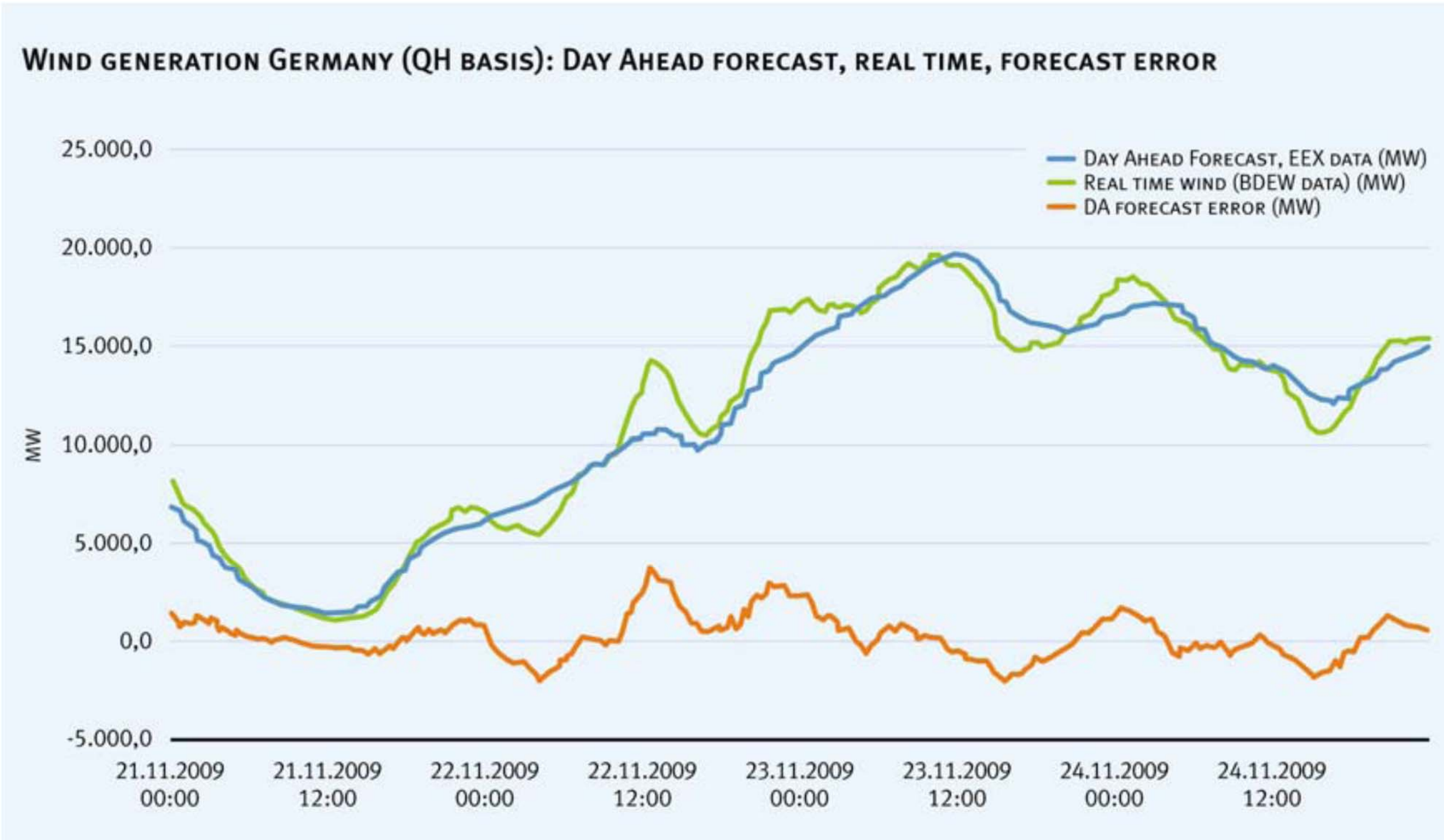
Unit commitment

- Daily and hourly production scheduling
- Economic dispatch
- Usually hydro/thermal production mix
- Unit commitment – tehnical and economical constraints
- Fitting of wind power into daily production schedules – need for backing up of conventional power sources
- Large variations of wind power production – need for extra balancing and control reserve

Forecasting of wind power

- Based on numerical weather prediction model (NWPM)
- Wind intermittence requires complex prediction tools
- Shorter forecast times lead to better results
- Combination of different NWPMs – recent trend

Forecasting of wind power



Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

Centre of Research Excellence for Advanced Cooperative Systems

ACROSS

Wind power economics

- Investment costs (development, building, grid connection)
- Operation and maintenance costs
- Electricity production
- Balancing costs
- Turbine lifetime
- Discount rate

Wind power support mechanisms

- Regulatory price-driven strategies
- Regulatory quantity-driven strategies
- Voluntary approaches
- Indirect strategies

Wind power economics

Source: C.W.Gellings (EPRI): „Impact on the Power System Economics“, CIGRE Opening Panel Aug.2008.

Study	Penetration Level (%)	Regulation	Intra-Hour Load Following	Inter-Hour Load Following	Scheduling/ Unit Commitment	Total
NYSERDA-NYISO	10	--	--	--	--	
Xcel-280	0.3	--	0.41	1.44		1.85
Xcel-1500	15	0.23	0.00	4.37		4.60
AESO	13	7.37	--	3.64	--	11.01
BPA	11	0.19	0.28	--	1.00	1.47
SPS	20	1.00 - 2.25	0.01	--	--	1.01 – 2.26
WE	14	1.08	0.14	--	1.61	2.83
GRE	16.6	1.28	0.18	--	3.08	4.54
Pacificorp	20	--	--	2.50	3.00	5.50

Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

Large-scale wind power integration requires

- Efficient, international power markets (day-ahead, Intraday and realtime markets)
- Strong national transmission grid and interconnections
- Domestic flexibility and automatic control for system balancing
- Same connection requirements for wind power as for any other power plant

Challenges

- Sudden drops or rises in electricity network injection
- WPP are not dispatchable
- Large offshore wind penetration could cause congestion in the network
- WPP plants often connected to the distribution grid, TSOs have a poor observability of the resulting power injections with no direct control over them

Challenges

- Increased demand for capacity reserves and ancillary services
- New guidelines for overhead lines and cables may substantially increase network tariffs
- Increasing need for regional planning and coordinated investments
- Activating the local grids
- Possible introduction of negative spot prices

Summary

- Global wind power penetration – an overview
- Grid connection and tehnical requirements
- Operational issues
- Market integration
- Large-scale integration of wind power into power system
- Smart Grids

Centre of Research Excellence for Advanced Cooperative Systems

ACROSS

Smart grids – concept for largescale wind power integration

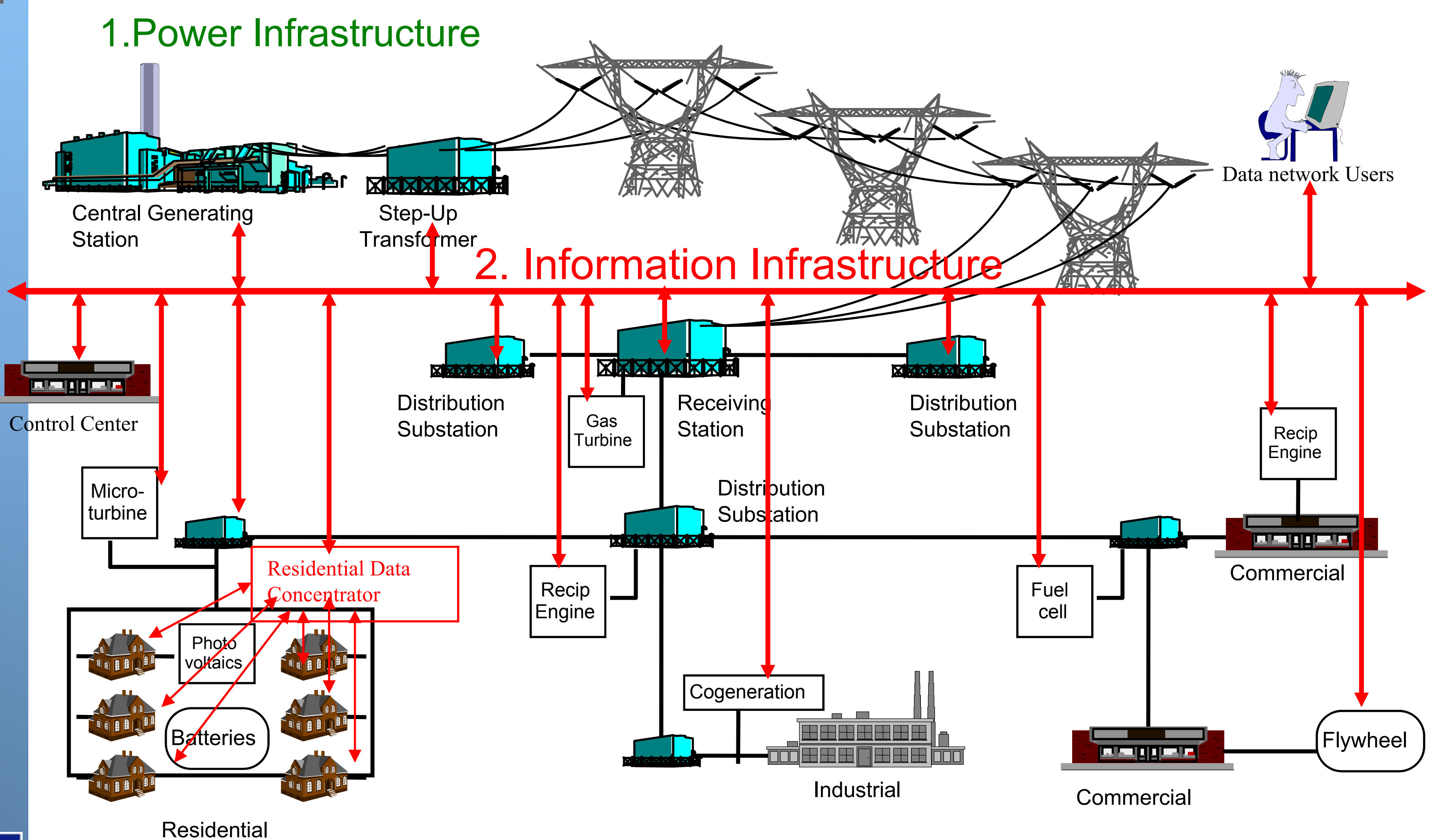
- An intelligent or a smart grid integrates advanced sensing technologies, control methods and integrated communications into the current electricity grid.

Difference Between a Normal Grid and a Smart Grid

Normal Phone

Smart Phone

Electric Power & Communication Infrastructures



Source: EPRI

Trends in transmission system

- **Increasing of transmission capabilities (new technologies and materials)**
- **Electric power system condition monitoring (WAMS)**
  - Secondary equipment (servers, hubs, switches, routers)
  - Intelligent Electronic Devices (Digital Relays, Communication Gateways, Merging Units, Sensors) – IEC 61850
  - Continuously staff education (secondary equipment life time is 14 years, primary equipment is 40 years)

Trends in transmission system

- Long distance electricity transmission (HVDC)
- Control of power flows (FACTS)
- Electricity storage
- Reduction of equipment construction and life time costs
- Enlarge ecological requirements (noise reduction)

Centre of Research Excellence for Advanced Cooperative Systems

Thank you for attention!