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IEEE Transmission and Distribution 2008

Chicago, 23 April 2008

Transmission Expansion Issues for Offshore Wind Farms Integration in Europe

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Summary

- Current and future development of offshore wind in Europe
- Connection solutions for offshore wind farms
  - Solutions adopted for existing offshore wind farms
  - Technical/economic desk analysis for a 100-MW wind farm
  - Description of an under-construction 400-MW wind farm
  - Prospects for large scale application of offshore wind (tens of GW)
- Reinforcement of the European power system
- Options for facilitating transmission investments

Offshore wind in Europe (1)

- **56.5 GW wind capacity (as of end 2007) in EU**
- **1.1 GW offshore wind capacity (as of end 2007) in EU**

CHARACTERISTICS OF OFFSHORE WIND FARMS IN EUROPE, AS OF END 2006

Country	Offshore wind capacity [MW]	Major wind farms, capacity and year of completion
Denmark	427	Horns Rev (160 MW), 2002 Nysted (166 MW), 2004
United Kingdom	304	North Hoyle (60 MW), 2003 Scroby Sands (60 MW), 2004 Kentish Flats (90 MW), 2005 Barrow in Furness (90 MW), 2006
The Netherlands	127	Egmond an Zee (108 MW), 2007
Ireland	25	Arklow Bank (25 MW), 2005
Sweden	23	Utgrunden (11 MW), 2000
Germany	7	Emden (5 MW), 2004
Total	**913**	

Offshore wind in Europe (2)

- **Source: EWEA, "Delivering offshore wind power in Europe", Dec 2007**

Offshore wind in EU: target and scenarios

- **EC: target 20% energy from RES in 2020, 34% electricity from RES, forecasted 128 GW wind capacity**
- **IEA: 150 GW wind in 2020**
- **EWEA: 180 GW wind, of which 35 GW offshore (134 TWh)**

- **Source: EWEA, "Pure Power - Wind Energy Scenarios up to 2030", Mar 2008**

Transmission expansion issues for offshore

- **Connection solutions for offshore wind farms (infrastructures at sea)**
- **Reinforcement of the onshore transmission system for accomodating the power produced by the wind farms**
- **Options for facilitating investments**

Connection solutions for existing wind farms

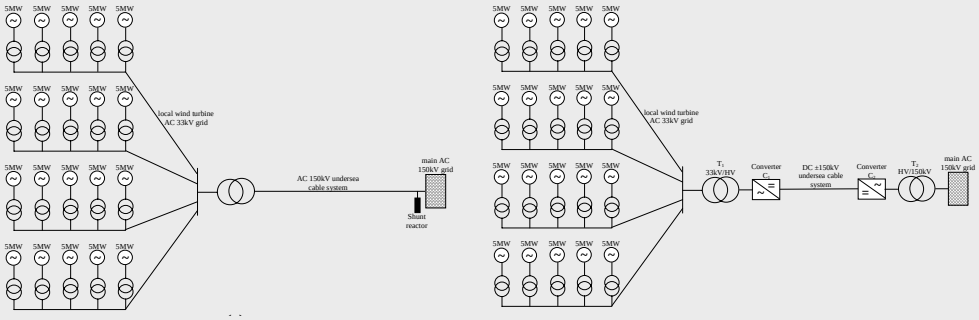
- AC cables at medium voltage (33 kV or similar)
  - UK's North Hoyle (12 km offshore)
  - UK's Kentish Flats (8.5 km offshore), three three-core MV feeder cables
  - UK's Scroby Sands (2.5 km offshore)
  - Netherlands' Egmond aan Zee (10 to 18 km from the coast), three 34-kV power cables
- Offshore transformer substation
  - Horns Rev, 15-km long three-core AC cable, rated voltage of 150 kV
  - Nysted is connected to the shore through an approximately 10 km long, 132-kV rated AC submarine cable
  - Barrow, 33/132 kV substation 7 km from the shore, 132 kV AC cable

100-MW wind farm connection: case study (1)

- 20 x 5 MW offshore wind farm, four strings
- AC connection through a 150 kV cable and VSC-HVDC connection are considered
- Economic assessment based on a 20-years lifetime
  - Investment costs (33 kV AC offshore grid cables and their installation, the HV cables connecting the wind farm to the shore and their installation, transformers, converters, AC switch gear, reactors, the support structure of the offshore platform)
  - Operation and maintenance costs
  - Negative valorization of losses (lost revenues: €97/MWh for the first 5 years since commissioning)
  - Negative valorization of energy not supplied

100-MW wind farm connection: case study (2)

- **Technical assessment**
  - **Evaluation of losses based on a load flow calculations (18-step representation of wind power production)**



- **Source: CESI RICERCA**

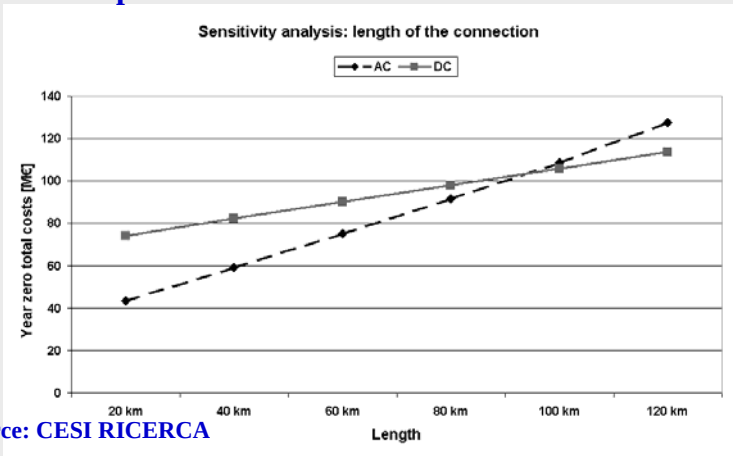
100-MW wind farm connection: case study (3)

- **Higher losses and unavailability for DC solution**
- **Distance: sensitivity analysis (base case: 60 km offshore)**

Case	Type	Investment costs M€	Year zero losses costs M€	Year zero O&M costs M€	Year zero ENS costs M€	Year zero total costs M€
100 MW - 20 km	AC	31.98	6.13	3.71	1.75	43.57
	DC	46.82	16.06	4.46	6.91	74.24
100 MW - 40 km	AC	45.12	7.92	4.37	1.75	59.17
	DC	53.61	16.83	4.80	6.91	82.15
100 MW - 60 km	AC	58.21	10.03	5.03	1.75	75.02
	DC	60.39	17.61	5.14	6.91	90.05
100 MW - 80 km	AC	71.29	12.73	5.69	1.75	91.46
	DC	67.18	18.38	5.48	6.91	97.95
100 MW - 100 km	AC	84.35	16.37	6.34	1.75	108.82
	DC	73.97	19.16	5.82	6.91	105.86
100 MW - 120 km	AC	97.41	21.33	7.00	1.75	127.49
	DC	80.75	19.93	6.16	6.91	113.76

100-MW wind farm connection: case study (4)

- **Break-even point AC vs. DC at 90 km distance offshore**



- **Source: CESI RICERCA**

Connection of a 400-MW wind farm (1)

- **Borkum West II offshore wind farm cluster**
  - **80 x 5 MW, 128 km offshore**
  - **Expected energy yield: 1760 GWh/year**
  - **Expected commissioning: 2010**
- **Connection awarded in September 2007 by E.On Netz (one of the German TSOs), project costs socialized**
  - **Voltage Source Converters (VSC-HVDC) technology**
  - **DC voltage +/- 150 kV**
  - **Submarine cable laying expected in Spring - Summer 2009**
  - **Expected commissioning: September 2009**
  - **Connection to a 380 kV substation (Diele)**
  - **Contract worth more than $400 million**

Connection of a 400-MW wind farm (2): cables

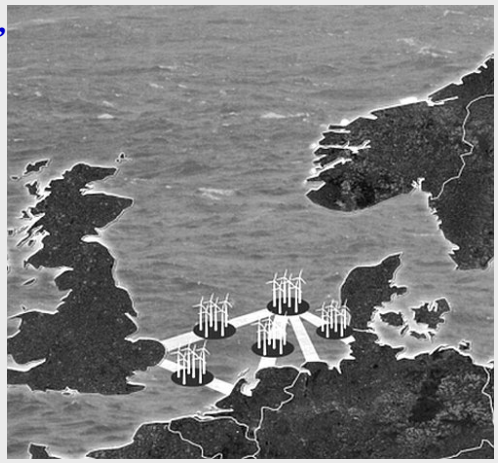
- **Submarine cable (extruded polymer insulated)**
  - **Length 256 km (2x128 km)**
  - **Conductor 1200 mm^2 copper**
  - **Steel armouring**
  - **Diameter 98 mm**
  - **Weight 29 kg/m**
- **Land cable (extruded polymer insulated)**
  - **Length 150 km (2x75 km)**
  - **Conductor 2300 mm^2 aluminum**
  - **Diameter 96 mm**
  - **Weight 11 kg/m**

Large scale application of wind energy at sea (1)

- **Estimated costs of the connection system account some 10% of the capital costs for the realisation of offshore farms (offshore capital costs raised some €2300/kW in 2007 due to small number of manufacturers and low market deployment)**
- **Issue: How to bring onshore the wind energy generated at sea?**
- **Individual connections from the offshore wind farms to the onshore grid (up to a certain distance) ?**
- **Ring structures with substations at sea ?**

Large scale application of wind energy at sea (2)

- "10 GW Foundation Project"
- About 2000 wind turbines
- Off the coasts of:
  - United Kingdom
  - the Netherlands
  - Germany
  - Denmark
- €22000 million capital cost
  - €20000 million generation
  - €2000 million transmission



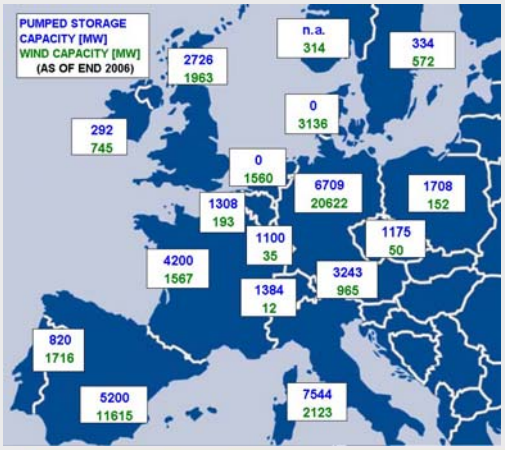
Source: Airtricity

Reinforcement of the European power system (1)

- Main impact: fluctuating feature of wind production
- Storage possibilities are quite small, substantially limited to conversion in the hydro pumped storage plants or to displacement of flows/production of hydro basins
- Issue: how to manage this fluctuating source ?

Reinforcement of the European power system (2)

- **Possible exploitation of wind-hydro combination ?**



Country	Consumption of pumps 2006 [TWh]	Equivalent storage capacity of hydro reservoirs [TWh]
Austria	3.3	3.2
Croatia and Slovenia	0.2	1.8
France	7.4	9.8
Germany	8.9	0.3
Greece	0.6	2.4
Italy	8.6	7.9
Montenegro and Serbia	0.8	2.0
Portugal	0.7	2.6
Spain	5.3	18.4
Switzerland	2.7	8.4
Total UCTE countries	38.5	56.8
Finland	0.0	5.5
Norway	0.5	84.1
Sweden	0.1	33.8
Total NORDEL	0.6	123.4

Source: CESI RICERCA

Reinforcement of the European power system (3)

- **Wind**
  - **Large scale application of offshore wind expected in the Northern Sea**
  - **Significant existing and future projects in Germany, Denmark, the Netherlands**
- **Hydro**
  - **Pumped storage plants are mainly located in Central Europe and in the Alps region (South DE, Austria, Switz, East France, North Italy)**
- **Expected increase of congestion from Northern Germany to the rest of the European System**

Options for facilitating investments (1): definition of priority projects

- Issue: development of infrastructures for connection of offshore wind farms requires massive investments
- EC: definition of wind connection and wind-related grid reinforcement as priority infrastructural energy projects
- The list of projects of common interest in the Trans European Energy Networks (TEN-E) guidelines, adopted in September 2006, includes:
  - wind energy connections in Italy, in Portugal, in the north-east and west of Spain, in Malta, off- and onshore in Germany; upgrade of the onshore 380 kV grid in Germany for connection of offshore wind parks; new offshore wind energy connections in Belgium, including upgrade of 380 kV grid

Options for facilitating investments (2): innovative regulatory framework: United Kingdom

- 6-7 GW of off-shore generation is expected to connect to the transmission network in United Kingdom up to the end of tariff regulatory period April 2007-March 2012
- Expected investments: some €3.5 billion
  - For comparison: allocated investments for other electricity transmission needs amounts some €5.8 billion, which is already the double with respect to the previous regulatory period
- The new regulatory regime to facilitate investments foresees a competitive tendering process to allow developers, called Offshore Transmission Owners (OFTOs), to build offshore transmission assets and to earn a regulated revenue stream from these assets, over a 20 year period

Thank you for your kind attention (1)

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Thank you for your kind attention (2)

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