

RAVE for the Future Integration of Offshore Grids

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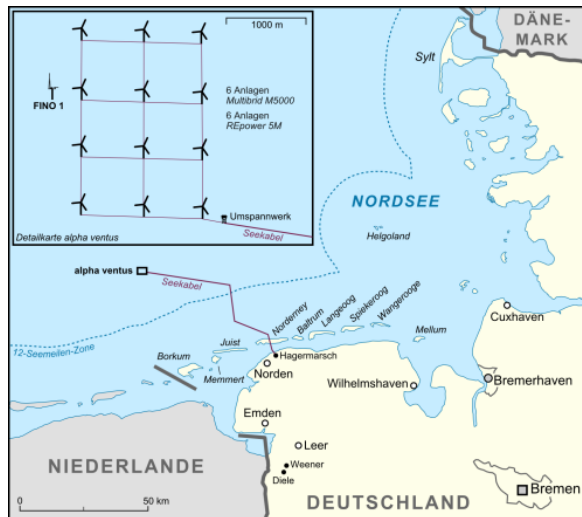
Gefördert auf Grund eines Beschlusses
des Deutschen Bundestages

Projektträger

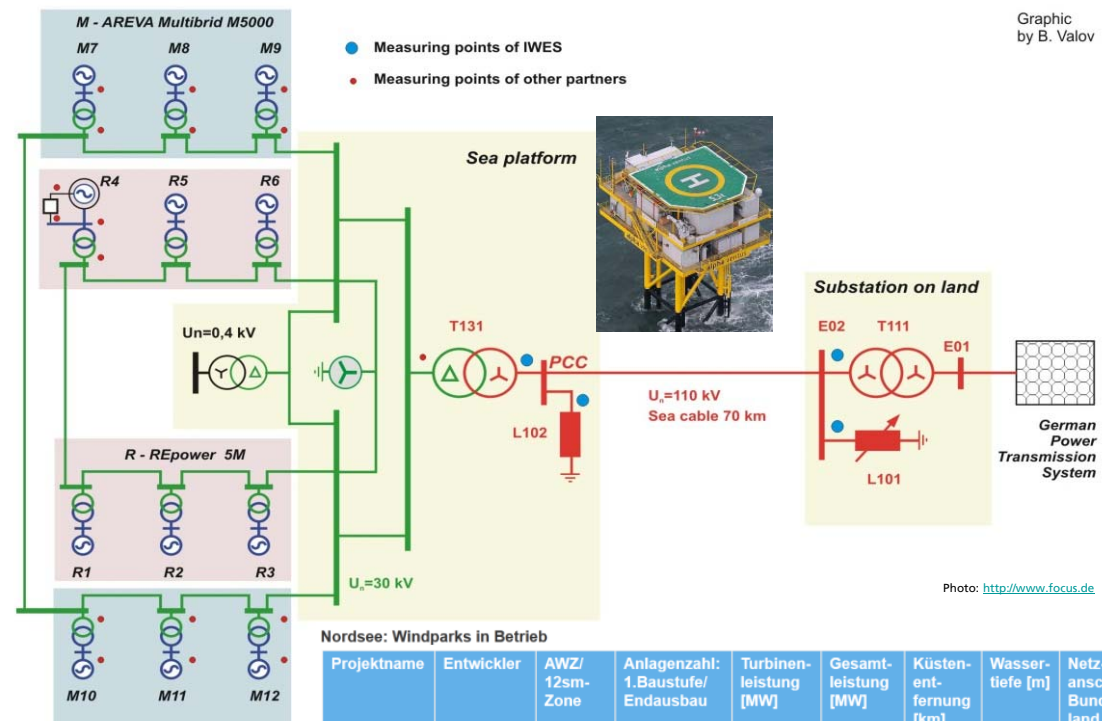
Koordination

Alpha Ventus – Textbook about Wind Farms

Project start - 1999



Graphic: http://de.wikipedia.org/wiki/Datei:Windpark_alpha_ventus_Lagekarte.png



Characteristica:

- Distance - **70 km Sea Cable**
- Power: **60 MW start / 1040 MW final**
- Transmission System - **110 kV AC**
- Reactive Power Compensation - **Inductive Coils**
- Operation: **2 different generator systems parallel:**
 - **Synchronous permanent magnet full size converter** AREVA Multibrid M5000
 - **Double feed induction machine** Repower 5 M
- P, U, I etc. from **many measuring points**

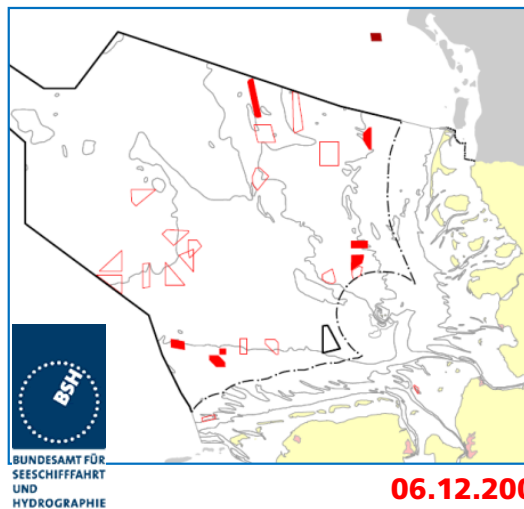
Nordsee: Windparks in Betrieb

| Projektname | Entwickler | AWZ/ 12sm- Zone | Anlagenzahl: 1.Baustufe/ Endausbau | Turbinen- leistung [MW] | Gesamt- leistung [MW] | Küsten- ent- fernung [km] | Wasser- tiefe [m] | Netz- anschluss, Bundes- land |
|--|--------------------|-----------------------|--|-------------------------------|-----------------------------|------------------------------------|----------------------|--|
| Alpha Ventus (Offshore-Testfeld "Borkum West") | DOTI GmbH & Co. KG | AWZ | 12/208 | 3,5 - 5 | 60/1040 | 45 | 30 | NI (Emden/ Borkum) |

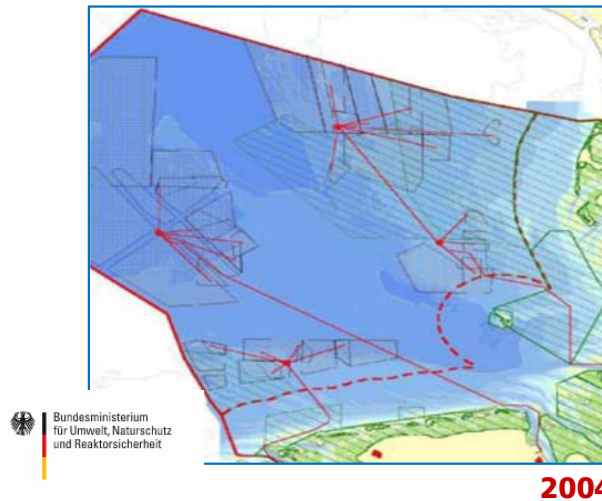
Daten: <http://www.offshore-wind.de/page/index.php?id=4761>



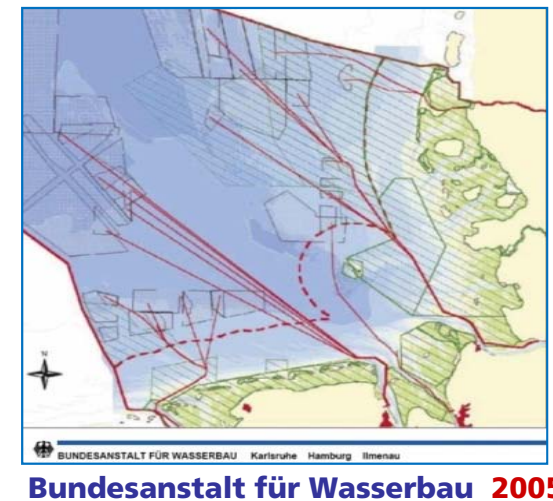
History of Offshore Power Transmission Systems in the North Sea



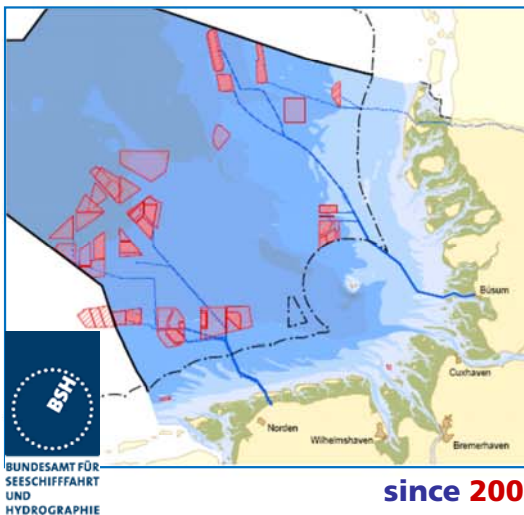
06.12.2004



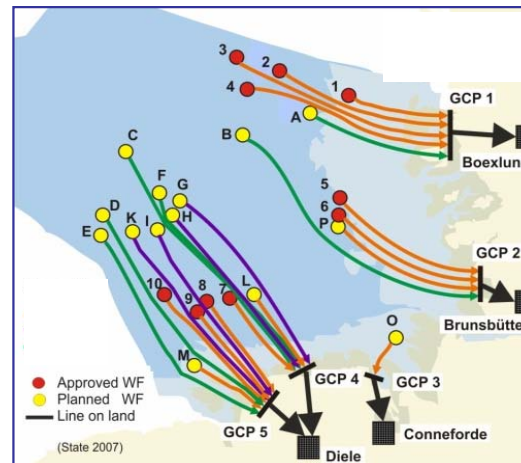
2004



Bundesanstalt für Wasserbau 2005

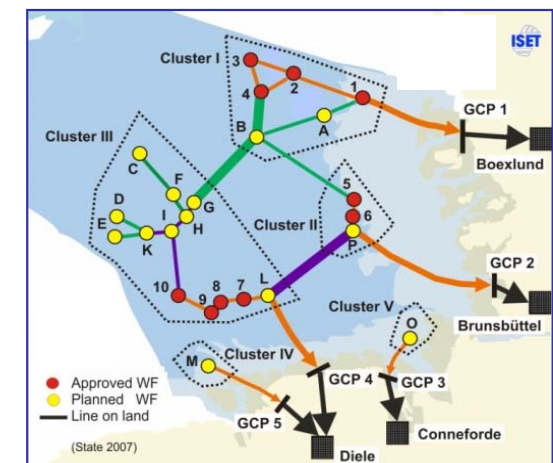


since 2006



Concept of separate connection 2004-2006
(many publications)

Maps from BSH
Graphics of grids by B. Valov



Wind farms 23
WTG a 5 MW 5219
Power total GW 26

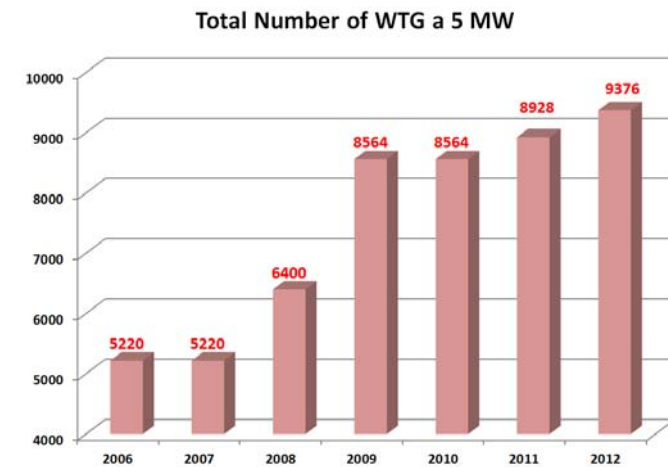
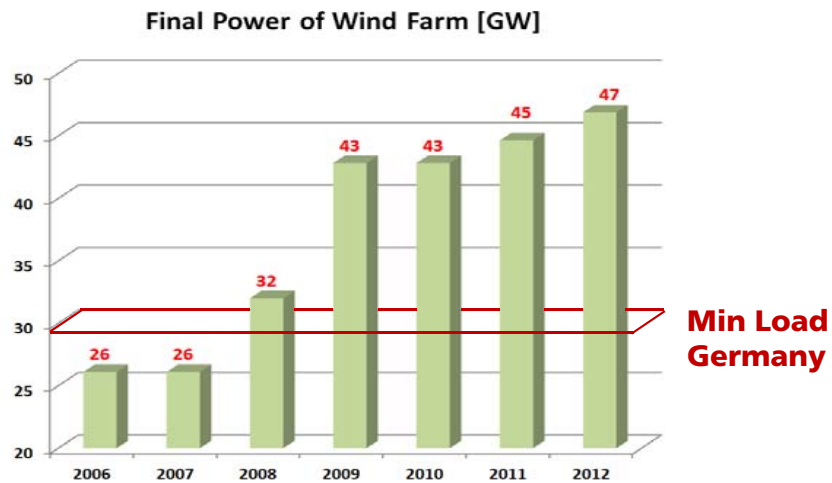
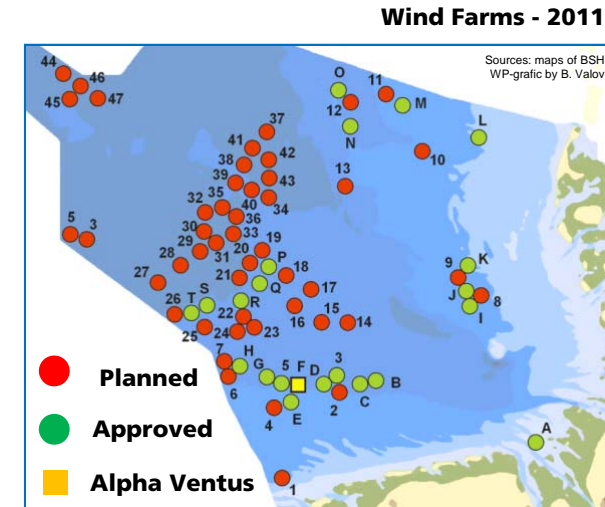
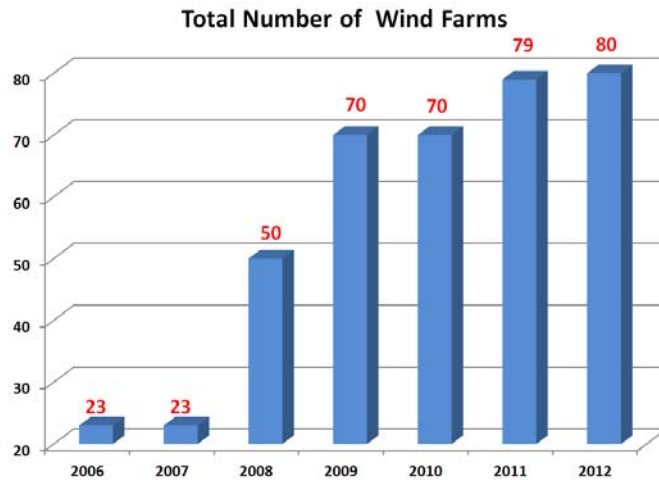
Since 2006
ISET's-Concept

Sources: All maps of BSH and BAW



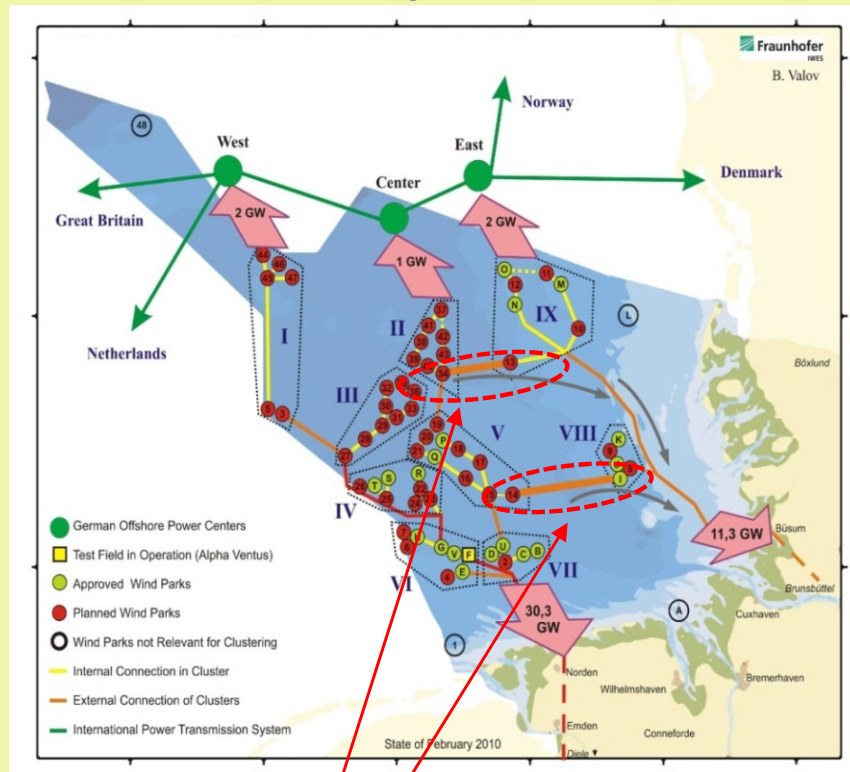
History of Offshore Power Transmission Systems in the North Sea

Statistics by B. Valov, February 2012, Data source: <http://www.offshore-wind.de>



Outlook for Offshore Power Transmission Systems in the North Sea

IWES's Concept



IWES's -Concept:

- 2 cross connections to improve of operation flexibility of PCCs on shore
- (n-1) requirement full filled
- Interconnection to the Super Grid

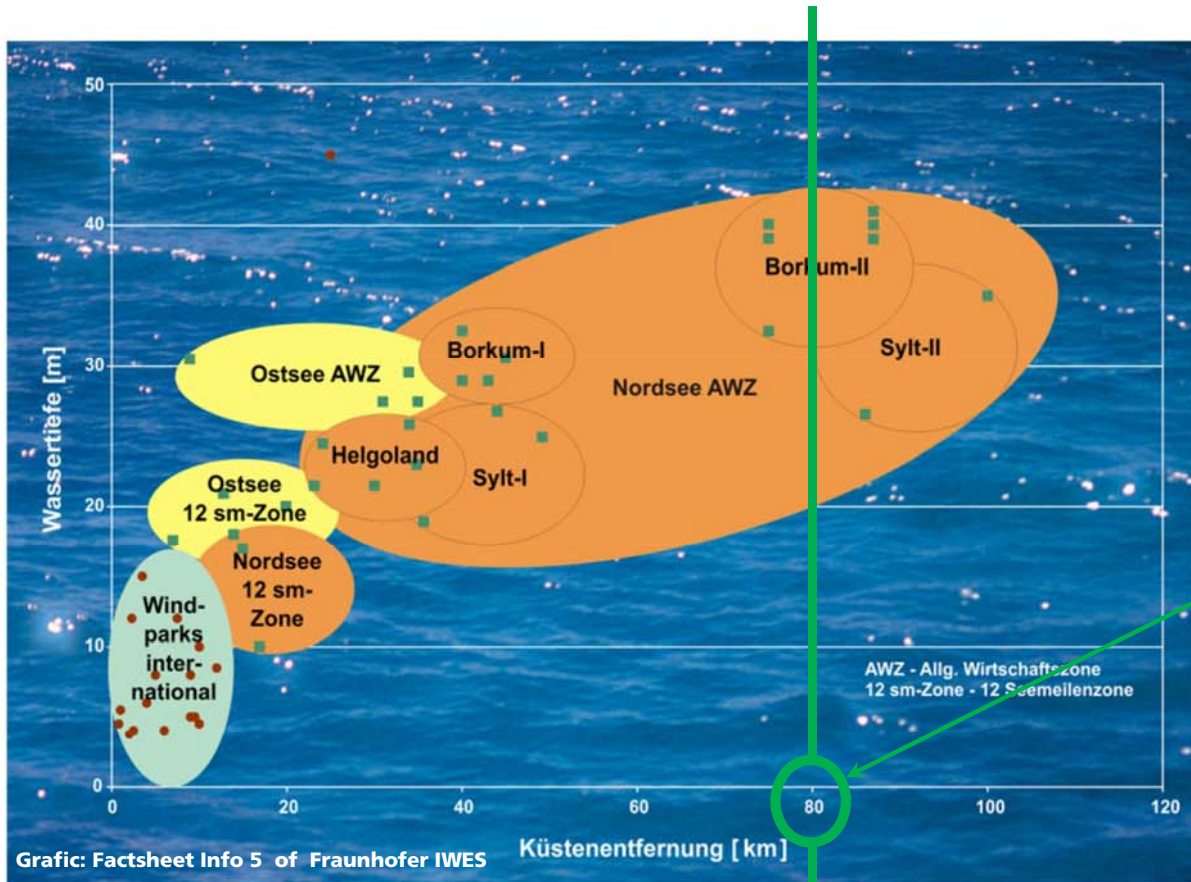
TenneT's Concept



TenneT's Concept:

- (n-1) requirement no full filled
- Advantages/Disadvantage of AC (Alpha Ventus) and DC (BARD Offshore) will be checked due to practice!

Question: AC or DC for Submarine Power Transmission Systems?



Statistics by B. Valov, State 2011
Data source: <http://www.offshore-wind.de>

| Distance until cost line [km] | Number of offshore-wind farms | Number of wind farm and possible system |
|-------------------------------|-------------------------------|---|
| 30 – 50 | 20 | 35 AC |
| 51 – 80 | 15 | |
| 81 – 110 | 20 | 27 DC |
| 111 – 140 | 7 | |

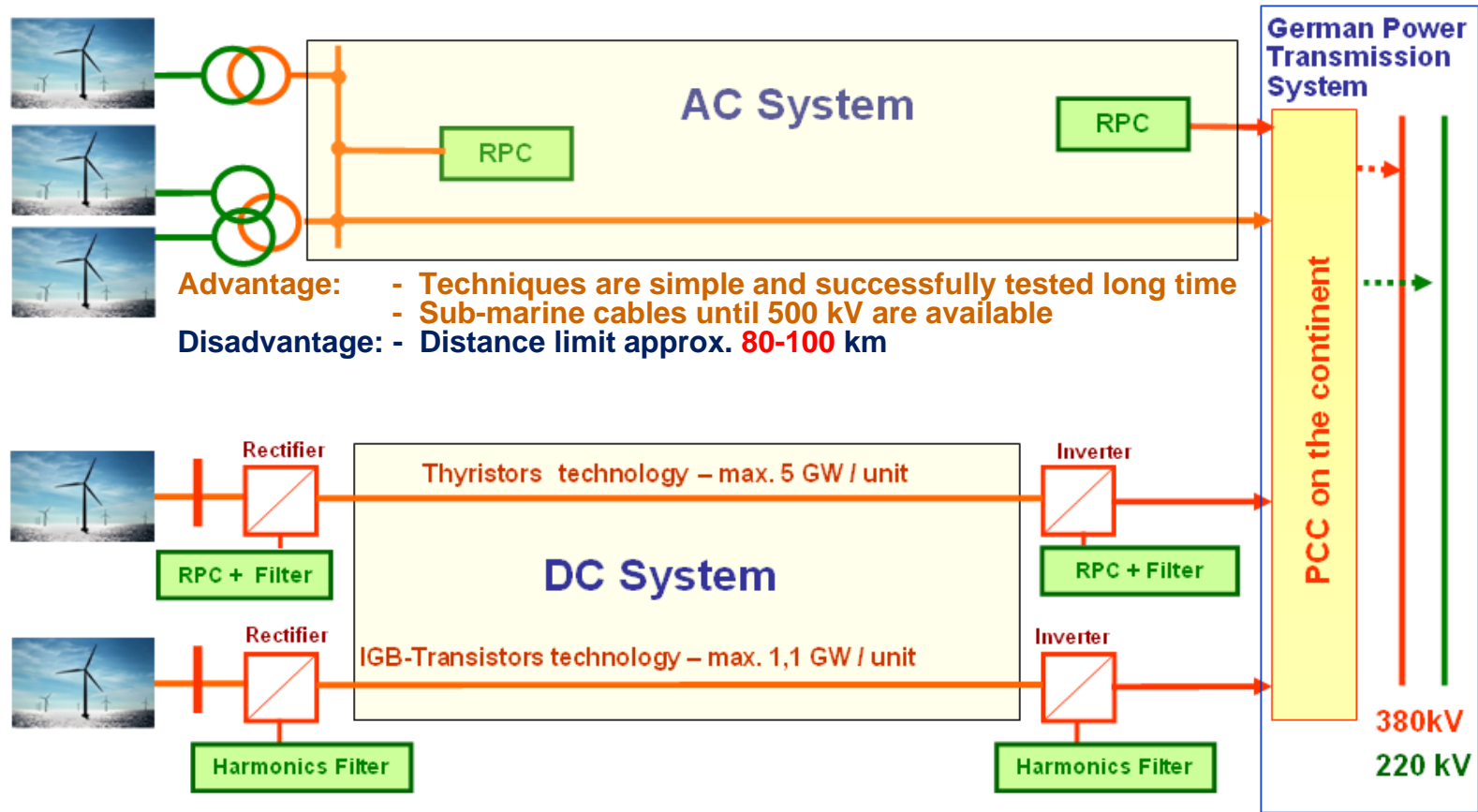
Summary:
35 compared to 27 wind farms could be used **AC system**

35 Wind Farms by AC by 50 Hz

27 Wind Farms by DC



Question: AC or DC for Submarine Power Transmission Systems?



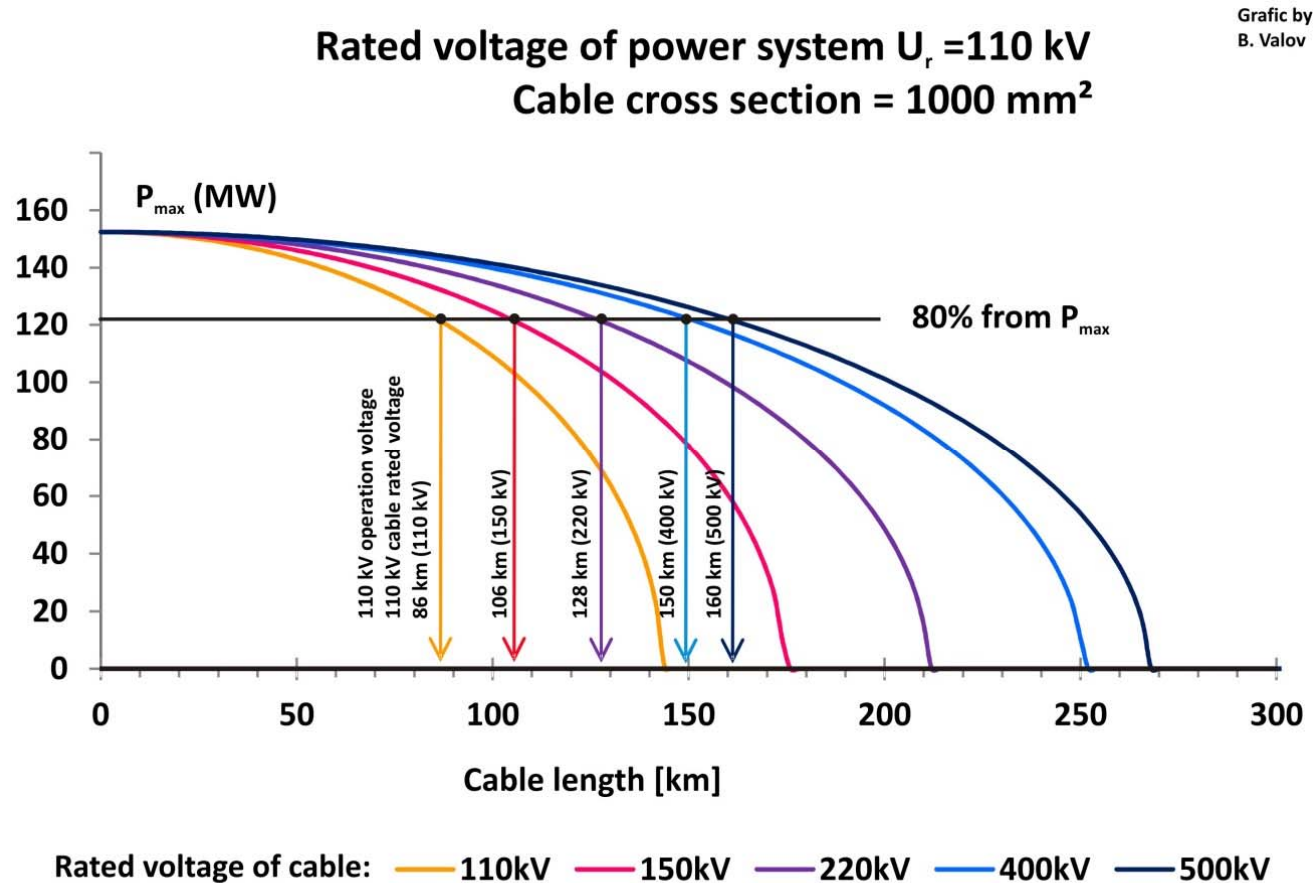
- Advantage:** - No limit for distance
- Disadvantage:** - Harmonics direct feed-in into 110-380 kV German Power Transmission System
- Electro-magnetic decoupling → Dynamic stability: Inertia emulation is necessary
- DC switchers to limit of line power
- No experiences with DC-networks world wide



RPC – Reactive Power Compensator

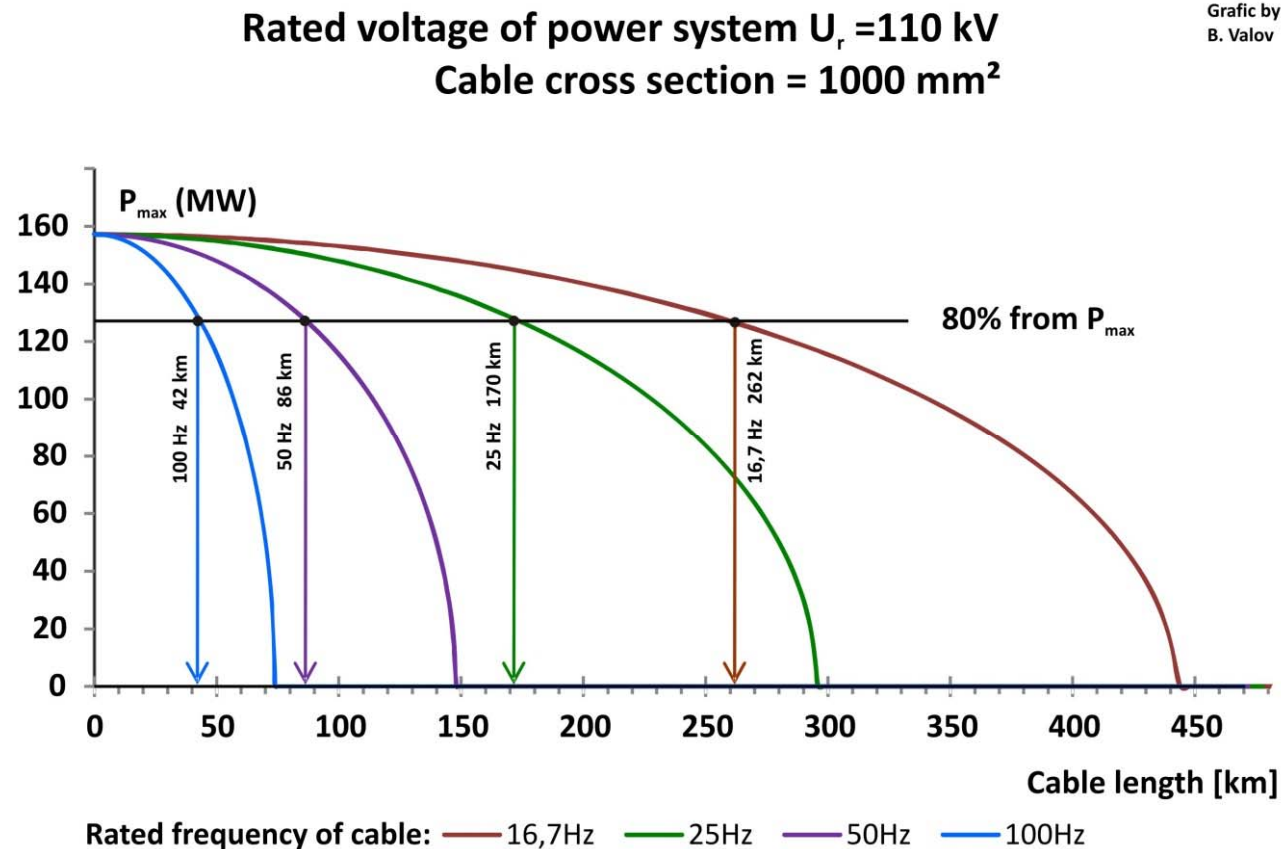
Alternative Design of Offshore Power Transmission Systems

Use of sub-marine cable with higher rated voltage than the rated voltage of offshore power transmission system (coaxial princip)



Alternative Design of Offshore Power Transmission Systems

Use low frequency for offshore power transmission system



Alternative Design of Offshore Power Transmission Systems

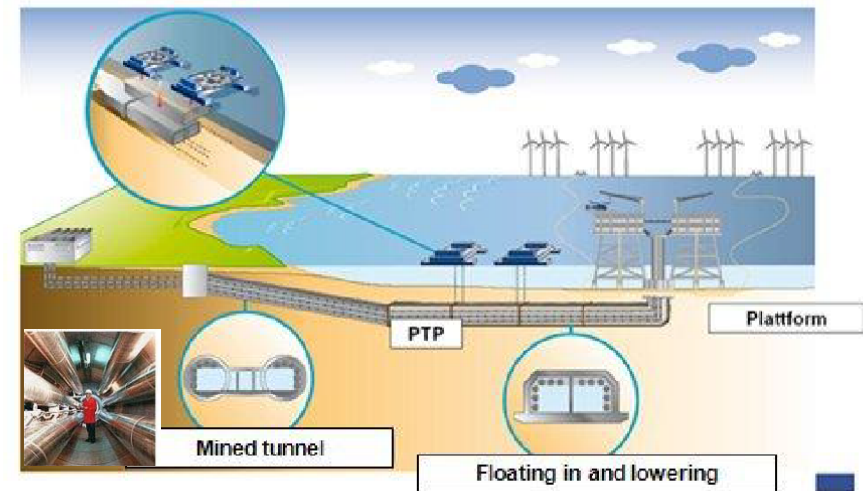
Gas insulated lines for AC - System

Gasisolierte Leitungen für AC-System



Source: K. Köbke (Siemens), HUSUM 2008

Figure 11-28: Schematic overview as combination of drilled tunnel and immersed tunnel



Source: Siemens

Table 11-4: Overview of status and development possibilities of GIL technology for connecting offshore wind farms

| Values per Circuit | Parameter | Unit | 2010 | 2015 | 2020 |
|--------------------|-------------------------------|---------|------|------|------|
| GIL | Year of commissioning | | 2015 | 2020 | 2025 |
| | Un | kV | 400 | 400 | 400 |
| | In | A | 3150 | 3150 | 3150 |
| | Smax (Tunnel) | MVA | 2182 | 2182 | 2182 |
| | tunnel width | m | 12 | 12 | 12 |
| | Number of circuits per tunnel | | 4 | 4 | 4 |
| | Required space offshore | ---, ++ | + | + | + |
| | Max. distance | km | | | |
| | black start capability | yes/no | yes | yes | yes |
| | | | | | |

Source: Manufacturer

Source: dena-study II, p. 253-255



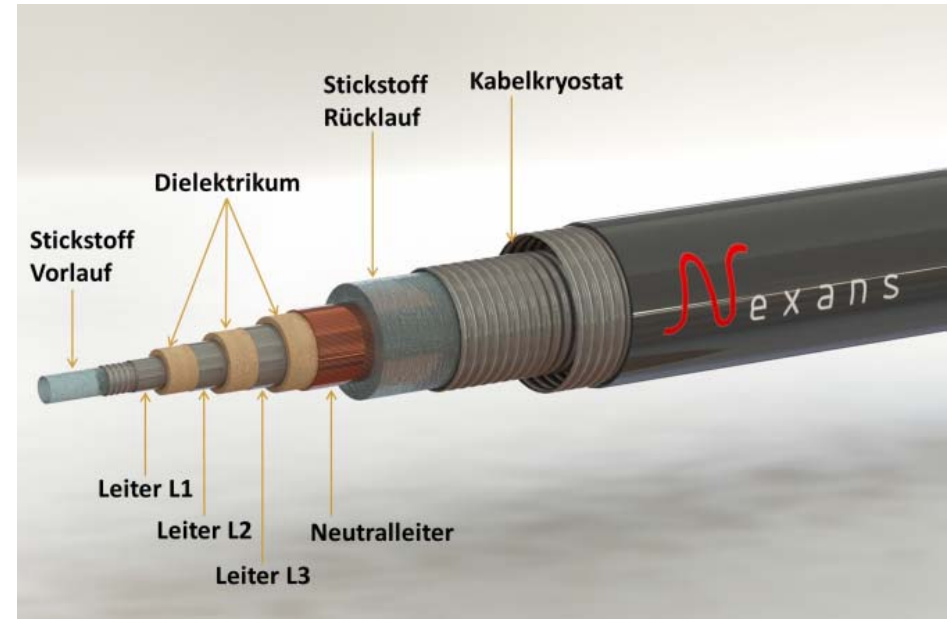
Alternative Design of Offshore Power Transmission Systems

Super conduction cable for AC – System

Supraleitende Kabelsysteme für AC-System



Test cable onshore:
20 kV and 110 MVA



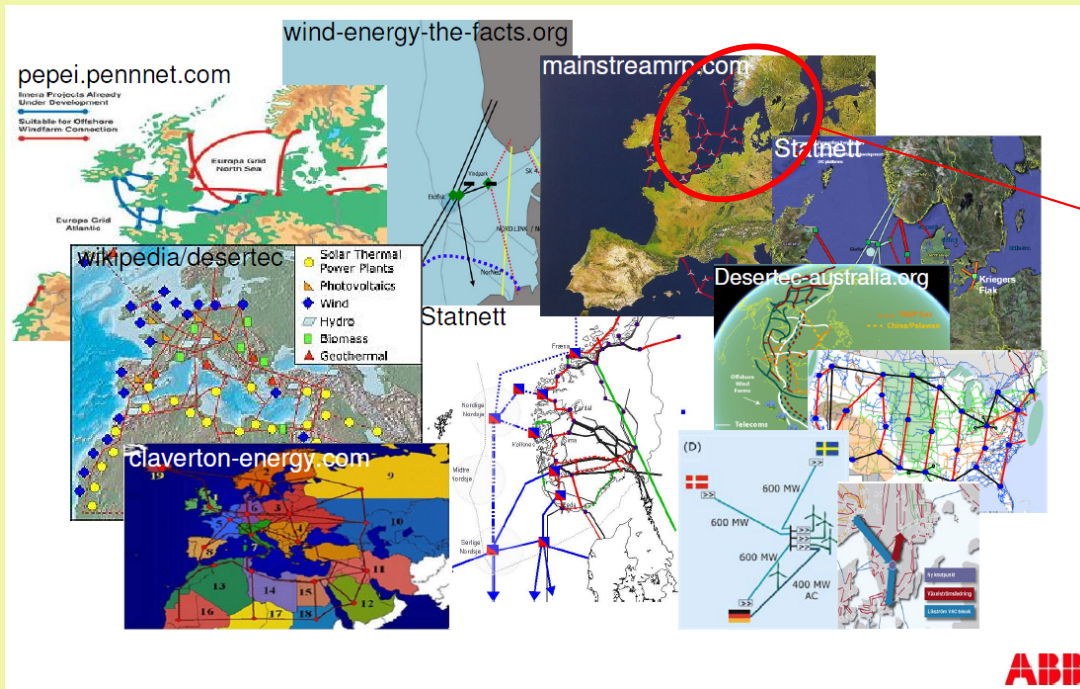
Nexans cable:
10 kV and 40 MW

Source: <http://www.nexans.de>



Alternative Design of Offshore Power Transmission Systems

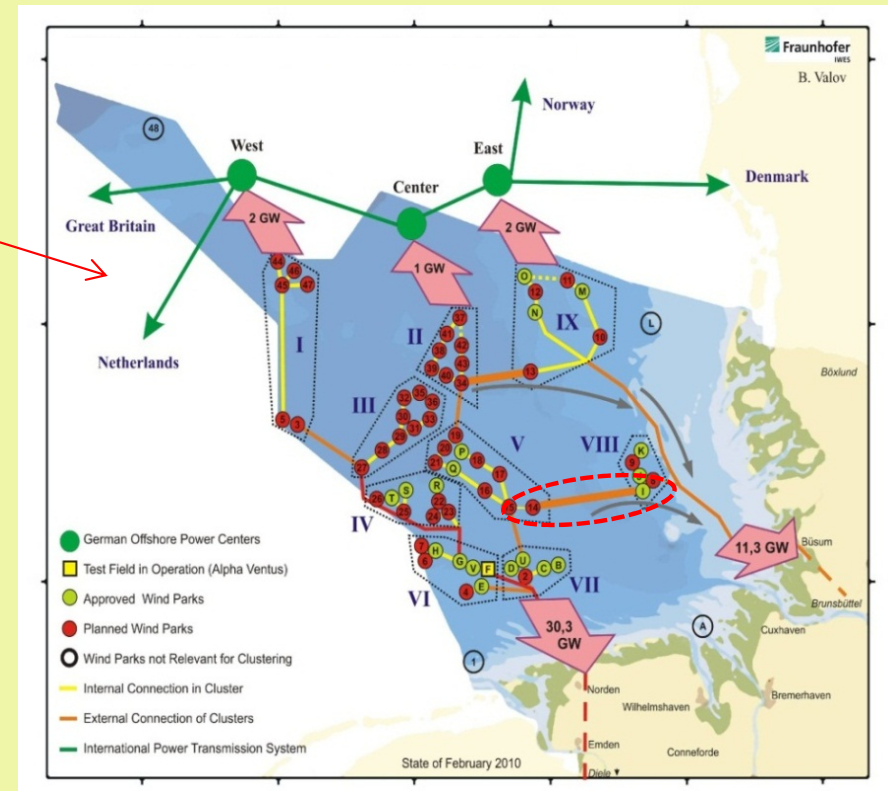
Drafts of Super Grid



Kerstin Linden, ABB, 6 June 2011

What technology is available for HVDC Grid?

German Offshore Grid – the Part of Super Grid



Thank you for your attention



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