OFFSHORE POWER TRANSMISSION SYSTEM 2030 IN THE NORTH SEA

Dr. Boris Valov

Fraunhofer-Institut für Windenergie und Energiesystemtechnik IWES

1. Introduction

The concept envisages the construction of an Offshore Power Transmission System for 70 future wind farms in the North Sea. With a total installed power of approximately 43 GW, this provides a contribution to an optimized development of offshore wind power integration into the German Power Transmission System and into the Trans-European Power Transmission System "Super Grid". The proposed solutions aim to increase the reliability of the Offshore-Power Transmission System and the flexibility of its operation management. They also reduce investment cost in the amount of several billion Euros. The technical feasibility of the concept has been proven by appropriate load flow calculations.

2. Actual plans of future offshore wind farms

According to the „Windenergie-Agentur Bremerhaven" [1] and the German Federal Maritime and Hydrographic Agency [2] the current state regarding quantity and power of the offshore wind farms in the German North Sea equals the following data (table 1) [3, 4]:

Table 1: Status of offshore wind farms in the German North Sea in 2006 and in 2010

Status of offshore wind farms	Quantity of offshore wind farms		Rated power [GW]		Quantity of wind turbines*)	
	2006	**2010**	**2006**	**2010**	**2006**	**2010**
In Operation	0	1	0	1,04	0	208
Approved	15	21	21,96	21,98	4391	4395
Planned	8	48	4,14	19,80	828	3960
Sum	**23**	**70**	**26,10**	**42,82**	**5219**	**8564**

*) equivalent to 5 MW wind turbines

Before reaching any customer, the offshore generated power has to overcome several obstacles:

- Distances from 50 to 100 km, from the wind power plants at sea to the substation on shore,
- Additional distances from up to 50 km from the substation at shore to the main grid connection points,
- Limited absorption capacity of the main grid connection points,
- Transmission through the main transmission- and distribution grid to reach final customers.

3. Concepts for energy transmission

According to the law for "speeding up planning processes of infrastructure projects" [5] the local grid operator has to plan, erect and run connection lines from substations at sea to the most suited main grid connection point in land. This will affect all offshore power plants whose erection started before end of 2015. The amount of offshore wind farms whose erection will be started within this period can hardly be foreseen.

The new developed concept (Fig. 1) is a combination of the "ISET-Concept 2007" and the political attempt of Germany and Europe to connect offshore wind farms to a future Trans-European "Supergrid". Looking at the geographical location of existing and future offshore wind farms, it can be observed that their distribution in space within the Exclusive Economic Zone of Germany (blue box in figure 1) is uneven: the major part is located in the southwest while the minor part is located in the northeast of the zone. This imbalance is also true for the distribution of the total offshore generated (injected?) electric power; 30.3 GW (72.8 %) and 11.3 GW (27.2 %) are to be absorbed by the 2 grid connection points "Diele" and "Büttel". Performed studies show that the minimum requested absorption power, the sub transient three-phase short-circuit apparent power, should be equal to 22 GVA in "Diele" and "16 GVA in "Büttel" to successfully absorb the injected offshore power. Otherwise offshore generated power has to be limited.

As an alternative to the costly and time-consuming grid reinforcement measures, a new concept of flexible distribution of the total offshore power between the two approved onshore grid connection points is proposed. It interconnects the offshore transmission system between the wind power plants Aiolos (34) and White Bank (15) and AreaC (14) and Sea Wind (I) (see Fig 1). Again the performed load flow calculations show the feasibility of the balanced power flow of offshore interconnections between the onshore grid connection points. Additional flexibility can be achieved by connection of the offshore transmission system into a future offshore Trans-European "Supergrid".

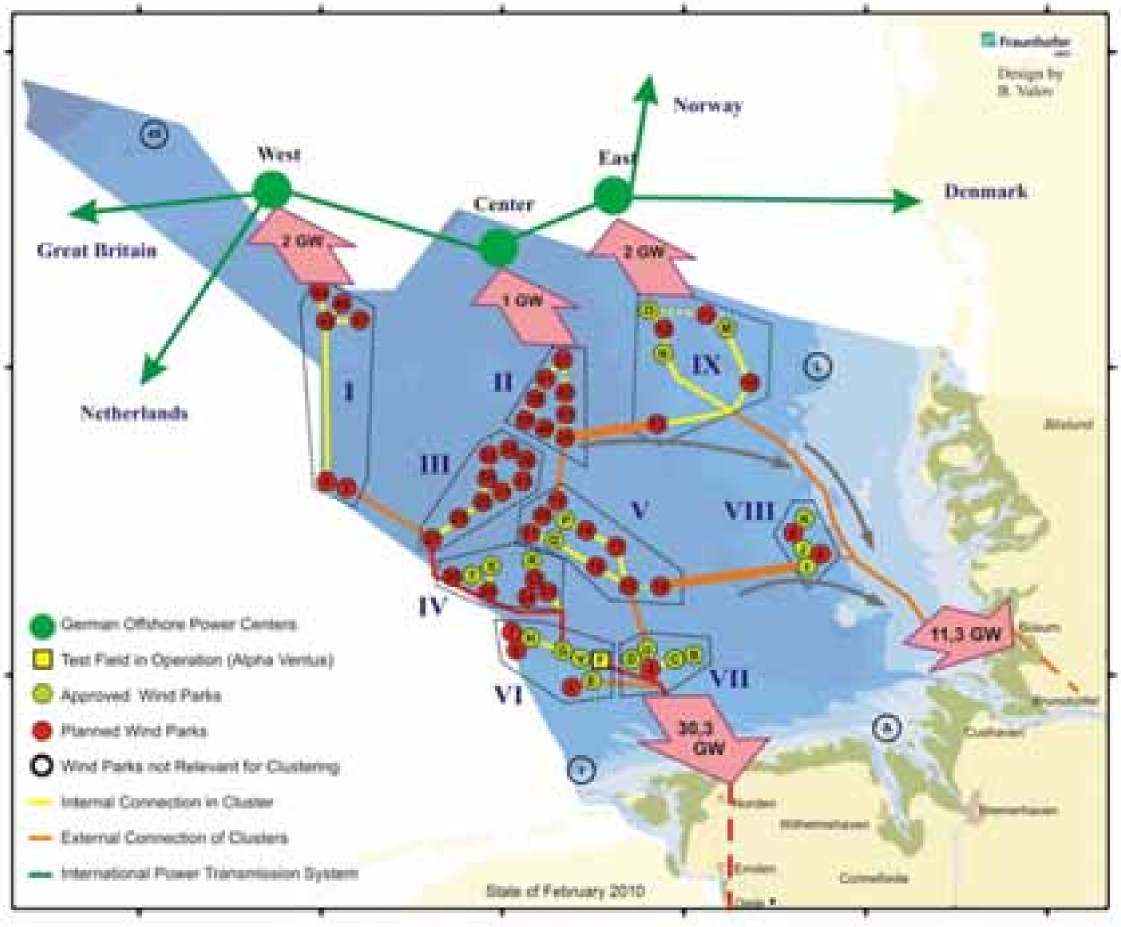

Fig. 1: The developed concept of offsore power transmission system 2030 in the Nord Sea with example of integration into Trans-Europain „Super Grid"

Legend: A - Nordergründe; B - Godewind II; C - Godewind; D - OWP Delta Nordsee I; E - Borkum Riffgrund; F - alpha ventus (Borkum West); G - Borkum West II; H - Borkum Riffgrund West; I - Meerwind; J - Nordsee Ost („Amrumbank"); K - Amrumbank West; L - Butendiek; M - Dan Tysk; N - Nördlicher Grund; O - Sandbank 24; P - Global Tech I; Q - Hochsee-Windpark Nordsee; R - „He Dreiht"; S

- BARD Offshore I; T - Veja Mate; U - OWP Delta Nordsee II; V - MEG Offshore I; 1 - Borkum Riffgat; 2 - Innogy Nordsee 1; 3 - Diamant; 4 - Borkum Riffgrund II; 5 - Euklas; 6 - Borkum Riffgrund West II; 7 - OWP West; 8 - Kaskasi; 9 - Hochsee Testfeld Helgoland; 10 - Uthland; 11 - Nordpassage; 12 - Sandbank 24 ext.; 13 - Weiße Bank; 14 - AreaC III; 15 - AreaC II; 16 - AreaC I; 17 - Skua; 18 - Sea Wind I; 19 - Albatros; 20 - Notos; 21 - Sea Wind II; 22 - He dreiht II; 23 - Bight Power II; 24 - Bight Power I; 25 - Aquamarin; 26 - OWP „Deutsche Bucht"; 27 OWP - „Austerngrund"; 28 - Bernstein; 29 - Citrin; 30 - Sea Storm; 31 - Sea Storm II; 32 - VentoTec Nord I; 33 - VentoTec Nord II; 34 - Aiolos; 35 - Sea Wind III; 36 - Kaikas; 37 - GAIA I; 38 - GAIA II; 39 - GAIA III; 40 GAIA IV; 41 - Horizont I; 42 - Horizont II; 43 - Horizont III; 44 - NSWP 4; 45 - NSWP 5; 46 - NSWP 6; 47 - NSWP 7; 48 - H2-20

Such integration could result in the following benefits:

- Required grid reinforcements reduced to a minimum because excessive power can be absorbed by the "Supergrid",
- Possibility to use the great amount of hydro storage capacity in other countries, .e.g. Norway,
- Participation in international electricity markets, which could result in reduced overcharges of the German electricity grid,
- Improvement of the reliability of the offshore transmission system,
- Flexibility in grid operation management.

Some studies considering the design of a future "Supergrid" are already at hand [6, 7, 8]. However they mainly cover the economic value of interconnection to a future "Supergrid". A technical feasibility of an electric realization remains uncertain until today [9].

In the introduced concept 3 converter sea substations are proposed: "West", "Center" and "East". Presence of the applied 2 grid connection points, 3 converter sea substations for a connection to a future "Supergrid" and 2 interconnections between the grid connection points has highly increased the flexibility and reliability of the offshore transmission system 2030 in the North Sea.

4. Summary

The developed concept of an offshore power transmission system 2030 supports the actual plans for electricity transmission in the German North Sea. It provides a contribution to an optimized development of offshore wind power integration into the German Power Transmission System and a Trans-European "Supergrid". The proposed solutions aim to increase the reliability of the German Power Transmission System and the flexibility in operation management of the offshore transmission system and to reduce investment cost in the amount of several million euros. Feasibility of the concept has been proven by appropriate load flow calculations.

5. Acknowledgement

Parts of this article have been developed in scope of the project "Windenergieforschung am Offshore-Testfeld" (FKZ 0325002). The author thanks the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Project Management Jülich for their support. Responsibility for this article is with the author.

6. Contact

Dr./OAK Moskau Boris Valov, Fraunhofer Institut für Windenergie und Energiesystemtechnik IWES, FuE Bereich Anlagentechnik und Netzintegration / R&D Division Engineering and Network Integration, Gruppe Elektrische Netze / Group Electricity Grids, Koenigstor 59, D-34119 Kassel, Germany. Tel.: +49 561 7294-125, Fax: +49 561 7294-400. Mail: boris.valov@iwes.fraunhofer.de; http://www.iwes.fraunhofer.de

7. References

[1] Offshore Windenergie. Das Magazin der Windenergie-Agentur Bremerhaven/Bremen e.V. (WAB). Juni 2007.

[2] Offshore-Windparks (Pilotgebiete). Bundesamt für Seeschifffahrt und Hydrographie (BSH). Dokument im Internet http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/index.jsp.

[3] Windparks. Bundesamt für Seeschifffahrt und Hydrographie (BSH). Dokument im Internet, 2009. http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/index.jsp.

[4] Windparks in der Nordsee. Dokument im Internet, 2009. http://www.offshore-wind.de/page/index.php?id=4761.

[5] Gesetz zur Beschleunigung von Planungsverfahren für Infrastrukturvorhaben (InfraStrPlanVBeschlG) . Geltung ab 17.12.2006 G. v. 09.12.2006 BGBl. I S. 2833, 2007 I S. 691.

[6] Oceans of Opportunity. Harnessing Europe´s largest domestic energy resource. A report by the European Wind Energy Association. September 2009

[7] Delivering Offshore Wind Power in Europe. Policy recommendations for large-scale deployment of offshore wind power in Europe by 2020. By the European Wind Energy Association. Published by EWEA, December 2007.

[8] Integrating Wind. Developing Europe´s power market for the large-scale integration of wind power. European Wind Energy Association. February 2009.

[9] Ein Super-Netz für die Windkraft auf hoher See. Handelsplatt. Dokument im Internet http://www.handelsblatt.com/politik/international/erneuerbare-energie-ein-super-netz-fuer-die-windkraft-auf-hoher-see;2508101