Future North Sea Infrastructure based on Dogger Bank modular island

Enabling the change

Prof. M.A.M.M. van der Meijden
Delft University of Technology
Delft, Netherlands
and TenneT TSO BV
Arnhem, Netherlands
mart.vander.meijden@tennet.eu

***Abstract*— In Europe, the North Sea has the best potential for large-scale development of offshore wind. This paper describes a compelling view on a future North Sea Infrastructure. The proposed North Sea Infrastructure is based on the development of multi-national offshore interconnectors in combination with an island in shallow waters. Because the island can be constructed in stages it will enhance optimal planning of the system rollout.**

Keywords-component; offshore, wind, energy, interconnection, infrastructure, modular, island

I. Introduction

During the 2015 climate conference in Paris, Europe committed itself to a carbon emission reduction of 80%-95% by 2050 compared to emission levels in 1990. Measures required to help achieve these ambitious targets will include the large-scale implementation of renewable energy. Europe has various potential renewable energy clusters, including solar, wind, hydropower and biomass clusters [1]. Price and other developments in the solar PV sector show that this technology is clearly developing into a mature energy source in terms of pricing and functionality. It would now be possible to create a stable energy system by combining it with wind – complementary to solar PV. Making the EU's power consumption entirely sustainable would require vast volumes of solar PV and wind energy, for example around 600 [1] GW of onshore and offshore wind, power and around 2,000[2] GW of solar PV. It would be very difficult for individual member states to accomplish volumes in this order of magnitude on their own. It is going to take European cooperation. In Europe, the North Sea has by far the best potential for large-scale development of offshore wind and this potential could contribute significantly to the volumes required. In that scenario, national energy policies, regulatory frameworks, government grant systems and use of space on the North Sea would have to be aligned/harmonized between member states [2], [3], [4]. The Political Declaration on energy cooperation between the North Sea countries is a significant step in that direction. TenneT's vision builds on that declaration and proposes a coordinated European rollout of North Sea Infrastructure as a basis for the future energy system. A possible location for this infrastructure would be the Dogger Bank. Governments, NGOs, industry and TSOs can work together to find an appropriate balance between social, ecological and economic needs on the North Sea. However, the sustainability objectives of individual member states are an important precondition.

II. North Sea Infrastructure

The future development of a North Sea energy system up to approx. 2050 will require a <u>*rollout, coordinated at European level*</u>, of interlinked offshore interconnectors, i.e. a so-called <u>*interconnection hub, combined with large-scale wind power*</u>. Any surplus wind power could be <u>*converted*</u> into other forms of energy, or <u>*stored*</u>. Situating this interconnection hub on a <u>*modularly constructed island*</u> in a <u>*relatively shallow part of the North Sea*</u> would result in significant cost savings. These are the starting points for a proposed efficient, affordable and reliable energy system on the North Sea, which will contribute to European objectives being met. This vision does not preclude the option of providing renewably generated power from the wind farms to nearby oil and gas platforms to reduce Europe's CO_2 emissions.

Cost-saving aspects of developing large-scale wind power are:

- Scale: a large-scale coordinated rollout would result in significant economies of scale compared to developments by individual member states

[1] European Wind Energy Association (EWEA)
[2] Delft University of Technology

- Location: a shallow area in the North Sea would reduce the construction costs of the energy system
- Efficiency: connecting wind farms to an interconnector hub would result in far more efficient utilisation of infrastructure and would make any future point-to-point connections unnecessary
- Technology: construction of a work platform would allow wind farms to be connected using near shore (e.g. AC) technology instead of DC technology, which is significantly more expensive
- Logistics: constructing a work platform would enable optimisation of logistical processes by organising (human) resources and operational activities on the platform itself
- Storage and conversion: any surplus power can be converted into e.g. gas or stored in water reservoirs
- Modular: owing to its modular nature, the system can be created using a step-by-step approach, which has benefits including lower financial risks and the ability to set up a stable pipeline.

A. Interconnection hub linked to large-scale wind power

The proposed North Sea Infrastructure is based on the development of offshore interconnectors (figure 1) as opposed to a redundant offshore grid. Offshore, there is no energy consumption with a similar social impact as onshore, which means a redundant grid will not be necessary [5], [6], [7]. The impact of failures differs:

- Cost of onshore failure is approx. 200 x cost of electricity not delivered,
- Cost of offshore failure is around 1 x cost of electricity not delivered.

In addition to transmitting wind power, the interconnectors will also serve to create links between energy markets during still spells, as the interconnection capacity could then be used for the international electricity market to reduce price differences between countries. This will benefit energy consumers [8]. Using the flexibility provided by Norwegian and Scottish hydropower (rainwater/ storage reservoirs), the efficiency of the system can be enhanced even further. If the interconnectors are linked to onshore grids as close to load centers as possible, there would be no need for large-scale extension of onshore grids, which is associated with considerable costs.

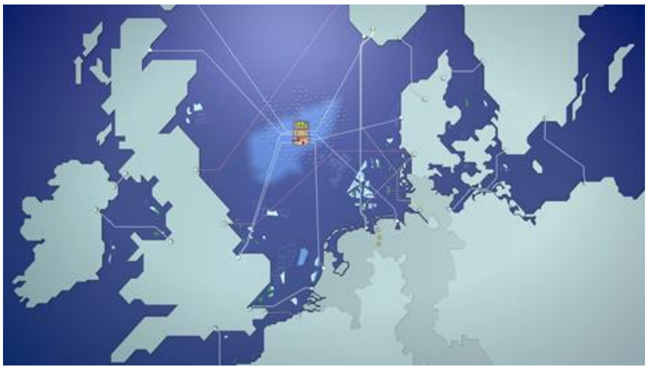

Figure 1. Offshore interconnection hub

B. Modular island

Using a modular work island would allow an efficient logistics chain to be set up. Staff, components and assembly workshops could be stationed on the island and operate based on intelligent organizational plans. By creating docking facilities on the island, all necessary components can be shipped there from different European ports. Staff stationed on the island can travel by boat, aircraft or helicopter. Because the concept involves large-scale generation sites, staff would be permanently deployed for wind farm construction and maintenance. Furthermore, a work island would allow the most cost-effective technology to be used. Although wind farms are at fare shore sites, the fact they are connected directly to the island means that far cheaper connection technologies can be used. At a later stage, a work island could also be used to facilitate power conversion stations, e.g. power-to-gas plants in order to improve the operational efficiency of the power transmission system and becomes an energy island. Existing infrastructure can be used to transport the converted gas to shore for consumption. This could potentially make the use of gas-fired plants needed to balance the system more sustainable.

Figure 2. Island

Because the island can be constructed in stages, instead of constructing it full-scale right away, it will be possible to optimally plan the rollout of the system and safeguard the reliability and stability of the power system [9]. This flexibility will afford member states the option of upwardly adjusting their ambitions over time.

III. STEP-BY-STEP ROLLOUT

Designing and developing a North Sea Infrastructure could realistically be effected between 2030 and 2050. Before that time, a number of significant steps will have to be taken closer to shore to help promote structural reductions in the costs of offshore wind. A number of North Sea countries are already making great strides individually in developing offshore wind, thereby building the necessary knowledge and experience for a large-scale offshore rollout. Because investments have an average lifecycle of 20 to 60 years and plan development, obtaining permits and actualising projects can take a very long time, it is important to set things in motion now.

A. IJmuiden Ver – after 2020

The next step in offshore developments in the Netherlands for the period after 2020 concerns the designated area *IJmuiden Ver*. Here, important principles can be developed that are required for a rollout at an even larger scale, such as combining wind parks with interconnectors, the potential use of a small work platform and researching a connection between *IJmuiden Ver* and the East Anglia wind farm in the UK. By that time, a start will also have to be made with resolving the regulatory challenges between the participating countries.

B. Dogger Bank – after 2030

A logical choice for a very large-scale rollout of North Sea Infrastructure is an area where national borders meet, with space for the required scale, where the sea is relatively shallow and where wind conditions are optimal. Further out at sea, wind conditions are better, which would partly compensate for the additional costs of bridging the corresponding distance. A possible site that meets all environmental conditions is the Dogger Bank. The Dogger Bank is a sand bank in a shallow part of the North Sea measuring around 17,600 km². Its depth ranges from 15 to 36 meters. The surface area required for developing the energy system will depend on the ambitions. If 70 GW were opted for, the project would extend across approx. 40% to 50% of the Dogger Bank. However, the Dogger Bank is a Natura 2000 conservation area, characterized by its specific soil composition and the ecology it supports. In our view, any development of the Dogger Bank can only come about if NGOs, governments, industry and TSOs engage in wide-ranging exploratory research.

IV. CLOSING REMARKS

As grid operator in the Netherlands and Germany, TenneT has accrued extensive experience in building infrastructure on the North Sea. The ongoing learning effects gained from this have been translated into a stable supply chain, realistic planning methods, possibilities for standardization, cost reductions and a reduced ecological and environmental impact by bundling infrastructure. Based on this experience and its role as TSO, TenneT has developed a vision in consultation with various expert organizations to help shape the European energy transition. TenneT invites the North Sea countries to discuss and further develop this vision to work towards a coordinated approach.

REFERENCES

[1] M. A. M. M. van der Meijden, A sustainable and reliable electricity system. Inescapable and challenging, inaugural address, TUDelft, Mekelweg 4, Delft, the Netherlands, 10 February 2012 http://resolver.tudelft.nl/uuid:3d04f70f-38a1-47f4-898e-0330f528ad47

[2] Shariat Torbaghan, S. , Müller, H., Gibescu, M., van der Meijden, M., Roggenkamp, M. (2014, July). Impact of wind energy support schemes on the development of an offshore grid in the North Sea. In PES GM—Conference & Exposition, 2014 IEEE (pp.1-5).

[3] H. Müller, S. S. Torbaghan, M. Gibescu, M. Roggenkamp, M. van der Meijden, The need for a common standard for voltage levels of HVDC VSC technology, Energy Policy 63 (2013) 244–251.

[4] Shariat Torbaghan, S., Müller, H., Gibescu, M., Roggenkamp, M. van der Meijden, M. (2015). The legal and economic impacts of implementing a joint feed-in premium support scheme on the development of an offshore grid. Renewable and Sustainable Energy Reviews, 45 (2015)

[5] B.W. Tuinema, M.Gibescu,W.L. Kling, "Availability Evaluation of OffshoreWind EnergyNetworks within the Dutch Power System", in Proc. IEEE Joint IAS/PELS/PES Benelux Chapter, Young Researchers Symposium: Smart Sustainable Power Delivery (YRS2010), Leuven, Belgium, March, 2010.

[6] B.W. Tuinema, J.L. Rueda, M.A.M.M. van der Meijden, "Network Redundancy versus Generation Reserve in Combined Onshore-Offshore Transmission Networks", in Proc. PowerTech2015, Eindhoven, the Netherlands, June, 2015.

[7] Reinout E. Getreuer, Bart W. Tuinema, José L. Rueda, Mart A.M.M. van der Meijden, "Multi-Parameter Approach for the Selection of preferred offshore Power Grids for Wind Energy", Energycon, 4-6 April 2016

[8] Shahab Shariat Torbaghan, Madeleine Gibescu, Barry G. Rawn, and Mart van der Meijden. "A Market-Based Transmission Planning for HVDC GridCase Study of the North Sea." IEEE Transactions on Power Systems 2012.

[9] M. Ndreko, A. A. van der Meer, M. Gibescu, M. A. M. M. van der Meijden, J. A. Bos, and K. P. J. Jansen, "Transient stability analysis of an onshore power system with multi-terminal offshore VSC-HVDC transmission: A case study for the netherlands," in Power and Energy Society General Meeting, Vancouver, Canada, Jul., 21–25, 2013.