TenneT: Offshore wind energy in North Sea to play key role in European energy

20/10/2018

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Abstract

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54 ZEE N°4/2018 EOLIENNES OFFSHORE DOSSIER 1 Back to the future It is the year 2050. At a central location in the North Sea, where the Exclusive Economic Zones of Denmark, Germany, the United Kingdom and the Netherlands meet, there is a brand-new artificial island measuring some eight square kilometers. It has a high-tech multifunctional maintenance and distribution centre, with its own hydrogen plant, and connects large-scale offshore wind energy capacity to direct-current electricity infrastructure and gas pipes. The artificial island is the result of an exceptional feat of engineering and international collaboration. At present this artificial far shore island exists only on paper, under the TenneT: Offshore wind energy in North Sea to play key role in European energy transition Marco Kuijpers TenneT Senior Manager Offshore Netherlands TenneT is Europe’s first cross-border Transmission Operator (TSO) and manages the high-voltage electricity grid in the Netherlands and a large part of Germany. In both countries, the government has also designated TenneT as the developer and operator of the offshore grid. This paper describes the main offshore wind farm projects developed by TenneT, in the Netherlands and in Germany. It underlines the differences in technology. Finally, it gives a long term perspective of what the future may look like. ABSTRACT TenneT est le
The ambitious plan is the brainchild of TenneT, Europe’s first and largest cross-border Transmission System Operator (TSO) (see Box 1: TenneT’s profile). The Dutch-German TSO has already formed a consortium with its Danish counterpart Energinet, Dutch gas grid operator Gasunie and the Port of Rotterdam Authority in order to explore the concept. According to TenneT, large-scale development of offshore wind energy is essential to ensure that the EU’s CO2 emissions reduction objectives can be realized without sky-rocketing costs. Combining offshore wind energy with the development of “green hydrogen” and the electrification of industry completes TenneT’s vision of the energy transition. The NSWPH can make an important contribution to the EU objectives for market integration and development of renewable energy sources. Thanks to this Power Hub, North Sea wind energy could meet the energy needs of 70 to 100 million people by 2050. This is not fiction, but a feasible plan. However, it does require a strong, joint and coordinated commitment from the participating countries, and places heavy demands on the offshore expertise of the collaborating TSOs and industries.

Energy transition in Germany Although Germany and the Netherlands have both endorsed the Paris Agreement on climate change, the two countries have adopted very different sustainability roadmaps and timeframes. As early as 2010, the German government decided that by 2050 greenhouse gas emissions must be reduced by 80 to 95% compared to 1990 levels, and that renewable energy must account for at least 60% of the energy supply. In addition, increased use of these renewable sources must end Germany's dependence on nuclear power by as soon as 2022. The March 2011 disaster at the Fukushima nuclear power plant in Japan added further urgency to the achievement of this aim. Germany has become renowned for its focus and speed in implementing the Energiewende – the massive pro-ject aimed at shifting to a sustainable energy supply. In addition to solar energy and offshore wind, this is also a key pillar of that transition. Back in 2006, Germany already anticipated that by 2020 it would need a high-voltage electricity infrastructure with a large number of converter platforms in the North Sea, in order to “harvest” wind energy genera-ted far out at sea and bring it to shore. In that year, the German government officially designated the German TSO Transpower (which was later acquired by TenneT) as the country’s offshore grid operator. TenneT’s Offshore division was established in early 2007. Germany’s Energiewende therefore established the foundation for TenneT’s expertise and capabilities in the field of offshore electricity transmission. Offshore capacity equivalent to 15 power plants Since its acquisition of Transpower in 2010, TenneT has worked hard on the construction and management of Germany’s offshore power grid. Ten off-shore grid connections are already operational, and that number will only increase in the coming years (see Box 2: Offshore grid connections in Germany). As a result, we have already achieved 82% of the development target defined by the German government: connecting 6.5 GW of offshore wind energy capacity to the grid by 2020. This figure is to be further increased to 15 GW by 2030, a total corresponding to the capacity of approx. 15 large conventional power plants. The energy transition in the Netherlands is proceeding more gradually. Box 1: TenneT’s profile. Box 1: TenneT’s profile TenneT is Europe’s first cross-border Transmission System Operator (TSO) and manages the high-voltage electricity grid in the Netherlands and a large part of Germany. In both countries, the government has also designated TenneT as the developer and operator of the offshore grid. The company has set up an offshore division for this purpose. TenneT provides transmission services and system services and facilitates the energy market. These key tasks have been assigned to the TSO in the Dutch Electricity Act (Elektriciteitswet) and the German Energy Industry Act (Energiewirtschaftsgesetz). TenneT aims to ensure a reliable and uninterrupted supply of electricity to more than 41 million end-users via its high-voltage grids. TenneT’s Offshore division is responsible for the development, construction and management of offshore wind farms in the Netherlands. The joint capacity of the offshore grid connections in Germany is sufficient to supply green electricity to 14 million households. Offshore wind farms in the Netherlands scheduled for construction until 2023, with a joint capacity sufficient to supply green electricity to five million households. Box 3: Offshore wind energy in the Netherlands. B 3 Off h i d i t h N th l d I REE N° 4/2018 Z 57 TenneT: Offshore wind energy in North Sea to play key role in European energy transition Roadmap for Offshore Wind Energy, the Dutch government recently announced its aim of expanding the total offshore wind energy capacity by a further 7 GW in the 2023-2030 period. The resulting total offshore capacity of 11.5 GW will generate sufficient renewable electricity to meet 40% of the current electricity demand in the Netherlands. Box 4: Differences between alternating and direct current. The above diagrams show how electricity transmission...
transmission works in a High-Voltage Direct-Current (HVDC) system and in a High-Voltage Alternating Current (HVAC) system. Direct current for distances of more than 100 km. The generated electricity enters the substation of the wind farm, and is transported via a 155 kV three-phase cable to the converter platform. Transformers increase the voltage level to that of the converter: 320 kV. The converter converts the three-phase alternating current to direct current, also at a voltage level of 320 kV. The two DC cables (positive and negative pole) run across the seabed from the platform to the landing point, i.e. the location where the cable comes ashore. From that point onward, underground cables transport the electricity to the onshore converter, where direct current is converted back into three-phase alternating current and transformed to the required voltage level. The electricity is then fed into TenneT’s 380 kV grid. Alternating current for wind farms located close to shore. Three-phase alternating current is the most economically and technically efficient technology for transmitting electricity across short distances. The electricity is transported from the offshore substation across the seabed, and then via an onshore cable to a substation on land. At this substation, the power is transformed to the right voltage level (380 or 220 kV) and fed into TenneT’s high-voltage grid. HVAC system. The cost reduction of 40% Following its official designation as the Netherlands’ offshore grid operator in 2016, TenneT has taken up the exciting challenge of designing and constructing a power grid at sea. One noteworthy “detail”: in 2013, the parties to the National Energy Agreement also committed to reducing the cost price of offshore wind energy by no less than 40% in ten years’ time, i.e. by 2023. This means that the costs of the off-shore grid under development must be reduced by a corresponding percentage. The tone has been set: the Agreement requires TenneT to apply its creativity and expertise to the fullest in designing and realizing the Dutch offshore grid. DC technology in Germany, AC technology in the Netherlands. Back in 2010, TenneT already demonstrated its ability to develop state-of-the-art technological solutions when the 200-km-long BorWin1 offshore grid connection was completed. Named after the island of Borkum in the German sector of the North Sea, the BorWin1 project is the world’s first direct-current (DC) connection between an offshore wind farm (OWF) and the onshore high-voltage grid. DC electricity transmission has one disadvantage: massive transformers are required at both ends of the cable to convert alternating current (AC) into direct current and vice versa. However, this drawback is more than compensated by the benefits and the resulting cost reduction. A High-Voltage Direct-Current (HVDC) system can transmit significantly larger quantities of electricity over longer distances than a High-Voltage Alternating Current (HVAC) system, and requires two rather than three cables to do so. Depending on the distance, direct current results in fewer losses during transmission than alternating current. Consequently, DC technology is highly suitable for off-shore wind farms (OWFs) located more than 100 km from the shore. The wind farms in the German sector of the North Sea are therefore mainly connected via subsea and onshore cables in a DC system. The first planned offshore wind farm zones in the Netherlands (Borssele, Holland Coast South and Holland Coast North) are located much closer to the coast, and can therefore be connected to the onshore grid using AC technology. The advantage is that costly AC-DC conversion is not required. Based in part on its offshore experiences in Germany, TenneT has designed a smart, scalable and future-proof offshore connection system based on standard components. In the aforementioned wind farm zones, five standard 700 MW offshore transformer platforms will be connected to the onshore grid via two cables per platform. If there are two platforms in a wind farm zone, these are also connected to each other to ensure optimal redundancy. The wind farms are directly connected to a platform and the realization of the offshore grid will be coordinated with the farms’ construction to ensure that the available capacity keeps pace with the demand. The OWFs in the next 7 GW phase (2023-2030) will be partially connected using TenneT’s standard AC concept. However, it will be necessary to adopt DC technology for the IJmuiden Ver wind farm zone (capacity: 4 GW), which is located so far from the coast that a DC system is the only feasible and cost-effective option. In a world first, TenneT’s standardized 700 MW AC concept will be based on 66 kV connections instead of the 33 kV connections that are commonly used for OWFs at present. A higher voltage level will result in lower losses during transmission, require fewer cable connections between wind farms and platforms, and will enable developers to connect wind turbines with greater capacity. A final noteworthy technical detail: TenneT continuously measures the temperature inside the cables. When the temperature permits, the transmission capacity can be increased from 350 MW to 380 MW. This also increases efficiency and thus helps to reduce costs. Rapid cost reduction In March 2016, the then-Minister of Economic Affairs announced that the cost reduction target for the offshore grid would be achieved in five years’ time rather than in ten years. The price is expected to decrease from EUR 0.025 per kilowatt-hour (kWh) in 2014 to EUR 0.014 per kWh in 2019. This decrease is not only caused by the use of standardized components, fewer cables, and smart technological solutions. The official designation of TenneT as the Netherlands’ only offshore grid operator has also resulted in economies of scale, for instance in procurement and design costs. The fact that the costs of constructing and operating OWFs are decreasing significantly was demonstrated by develope producers in March 2018, when Swedish energy company Vattenfall announced that it would build the world’s first non-subsidized OWFs off the Holland coast. Vattenfall was selected as the winning tenderer for the construction of two OWFS in the wind area called Hollandse Kust zuid (1,400 MW) which are scheduled to be taken into operation in 2021. There are the first wind farms in Europe to be realized without government subsidies. Market development and interconnectors Cost reduction through economies of scales and standardized technology is a good example of the way in which TenneT aims to develop the sustainable energy market in Europe. In conjunction with the tendering system adopted by the Dutch government, this approach REE N°4/2018 Z 59 TenneT: Offshore wind energy in North Sea to play key role in European energy transition ensures a level playing field for OWF operators and challenges them to develop increasingly effective installations. As a consequence, the costs for the development of offshore wind energy have decreased dramatically. Wind and solar energy are not continuously, easily controllable energy sources like conventional power plants. In addition, storage systems and load centres are not always located in areas with high average wind speeds. In order to utilize these geographical and meteorological differences as effectively as possible, it is therefore becoming increasingly important to exchange electricity over long distances and across
national borders. Together with its European partners, TenneT is therefore constructing and operating so-called "interconnectors": offshore and onshore electricity connections that link the high-voltage grids of different countries (see Box 5: Interconnectors). Level playing field Interconnectors offer a number of obvious advantages. They make it easier to exchange sustainably generated electricity between countries. This helps to improve the security of supply and makes it easier and less costly to maintain the balance between supply and demand on the grid. However, the secondary effects are just as important: an integrated grid ensures more uniform price levels for customers and suppliers. Internationally, this encourages the development of more effective and efficient solutions for the generation, consumption, and storage of green electricity. This contributes to the energy transition and is good for society at large, because electricity is always made available at the lowest possible price. Coordinated collaboration Nevertheless, interconnectors are just the first step in the ongoing integration of energy systems. TenneT firmly believes that the success of the energy transition in Europe strongly depends on co-ordinated collaboration between the countries involved. The vision of a North Sea Wind Power Hub described at the start of this article is also based on international collaboration and a long-term perspective. The potential of offshore wind energy in the North Sea can be utilized more efficiently and cost-effectively, and in a shorter time frame, by collaborating regionally and ensuring the coordinated development of wind energy capacity and infrastructure in the North Sea, based on a shared vision of the future. An enormous potential it is clear that offshore wind energy offers enormous potential. The consort-um developing the NSWPH concept – consisting of Danish TSO Energinet, Dutch gas grid operator Gasunie, the Port of Rotterdam Authority, TenneT Netherlands and TenneT Germany – has commissioned a study into the potential size of the total offshore wind energy capacity in North-West Europe. This re- sulted in an impressive total of 230 GW. Potential OWF locations include the Irish Sea, the Baltic Sea and the Atlantic coast of France. However, the lion’s share of the required capacity (approx. 180 GW) can be realized in the North Sea, according to the study. Europe must utilize that potential to achieve its CO2 emissions reduction targets. Hydropower, solar energy and onshore wind energy do not provide nearly enough capacity to meet the demand for renewable electricity. It should be noted that the sun and the wind play complementary roles: more solar energy is available from spring to autumn, whereas more wind energy can be generated in the colder winter months. This is beneficial to the stability of the sustainable energy system as a whole. Nevertheless, a great deal of solar and wind energy capacity is needed, and offshore wind energy in the North Sea is simply essential for Europe. Multifunctional artificial island The concept of the North Sea Wind Power Hub has been developed with precisely these considerations in mind. One artificial island in the central North Sea – or more, since the concept is scalable – with a surface area of approx. 8 km² would be able to accommodate several large converter stations. The participating countries would be able to connect large wind farms to the infrastructure on the island. The island’s DC transmission cable to the onshore grid will fulfill a dual purpose. They will also be used as interconnectors and thus facilitate international electricity trading between the Netherlands, Belgium, the UK, Norway, Germany and Denmark. As a result, the efficiency of these connections will increase significantly from 40% to approx. 80%. With personnel, spare parts, a port and maintenance facilities on the island, the generally complex offshore logistics can be organized more efficiently and effectively. The anticipated area is characterized by high average wind speeds, and this will of course contribute to a higher wind farm output. The pro- posed location of the NSWPH is also in a relatively shallow part of the North Sea, reducing the costs of constructing the island and the wind farms. If those combined advantages weren’t enough, the parties involved are exploring one further option: producing green hydrogen on the island using electrolysis generated by the wind farms. This would make it possible to absorb peaks in wind energy production on-site, so that losses during transmission can be minimized. Moreover, hydrogen can be transported over long distances more cost-effectively than electricity. The existing gas infrastructure in the North Sea could be used for this purpose. Importantly, that infrastructure can also be used to store hydrogen. The combination of offshore wind energy and hydrogen production is interesting, since hydrogen can serve as both an energy carrier and as a raw material for industry. Consequently, electrolysis is expected to develop into a mature and economically viable technology by approx. 2030. If the energy-intensive industry switches to hydrogen, (excess) electricity produced by offshore wind farms can also be used for hydrogen production (see Box 6: Hydrogen and offshore wind energy). Hydrogen technology provides a further reason for coordinated collaboration aimed at developing an integrated sustainable energy system. Political support It will come as no surprise that a power hub in the North Sea will not be realized tomorrow, or the day after tomorrow. The five consortium partners have agreed to investigate the possibilities offered by this concept until mid-2019. Concrete analyses will be performed focusing on technical, market-related and environmental aspects. Photo 1 : NSWPH beach view. REE N°4/2018 Z 61 TenneT: Offshore wind energy in North Sea to play key role in European energy transition Regardless of the findings concerning the technical and economic potential of...
the North Sea Wind Power Hub and the possibilities of maintaining the ecological balance, the actual realization of this vision requires broad political support in the participating countries. One step closer… Does all this mean that the North Sea Wind Power Hub should be regarded as a vision for the distant future, or – for the Eurosceptics among us – as an entirely unrealistic plan? Certainly not. In March of this year, the Dutch government presented its roadmap for the further development of offshore wind farm zones in the Dutch sector of the North Sea in the period until 2030. The proposed IJmuiden Ver wind farm zone is located far from the coast, as its name implies (“ver” means ‘far’ in Dutch). It will have to be connected to the onshore grid using DC technology. The ministries involved have now asked TenneT to investigate the possibilities for an artificial island in this zone. This island would have roughly the same multifunctional infrastructure as the originally envisaged North Sea Wind Power Hub, but on a smaller scale. It is currently uncertain if this island in the IJmuiden Ver zone will actually be built, but the ongoing feasibility studies will nevertheless produce valuable knowledge and insights for a larger island further out in the North Sea. Box 6: Hydrogen and offshore wind energy. THE AUTHOR Marco Kuijpers is Senior manager TenneT Offshore Nederland since 2014. He was Eneco Project director from 2012 to 2014 and managing partner at Twynstra Gudde from 2000 to 2014. He holds degrees from Insead, Rotterdam University of Applied Sciences and Fontys. In the Netherlands, the Hydrogen Coalition (an alliance of 23 parties) has called on the government to further develop and implement green hydrogen technology, in order to create long-term energy storage solutions and promote the sustainable development of industry and the transport sector. In order to achieve rapid and cost-effective growth, the Coalition advocates an approach similar to the one applied to offshore wind energy. Large industrial consumers play a key role in designing the electricity systems of the future and developing the required storage capacity. The Dutch aviation, shipping, steel and (petro)chemical industries collectively consume five times more electricity than all Dutch households combined. Hydrogen is a very useful and sustainable alternative to oil and gas, which are currently used as raw materials and fuel by the energy-intensive industry. In the future, it will be possible to produce hydrogen in large quantities and at low cost by means of water electrolysis using renewable electricity. It can be stored and transported using the existing gas infrastructure. Hydrogen can also potentially be stored in the earth’s salt deposits, which are located relatively close to the surface in the Netherlands, Germany and Poland. In the light of these considerations, the Hydrogen Coalition regards the combination of hydrogen (which enables the ‘greening’ of industry and offers storage solutions) and offshore wind energy (offering large-scale production capacity) as a solid foundation for the energy transition. A scenario in which hydrogen is produced on a large scale for industry and the transport sector offers possibilities that radically change our current perception of the energy transition. Hydrogen can be converted to methane and stored in or transported by the existing natural gas infrastructure in the Netherlands and Germany. It can then be used to heat residential and non-residential buildings, but also to produce electricity in a controllable manner.

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