NORTH SEA OFFSHORE GRID DESIGN – AN ENGINEERING-ECONOMIC ANALYSIS FOR MARKET AND WIND INTEGRATION IN THE NORTH AND BALTIC SEA REGION

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Overview

Though the initiation of the ENTSO-E is one step towards the single European electricity market, in reality these markets in the North and Baltic Sea region are highly separated from the United Kingdom, Nordel in Scandinavia and the UCTE in continental Europe. In addition, the European roadmap for the 2020 renewable target demands for large on- and offshore wind capacities in the North and Baltic Sea region which have to be connected to the existing onshore grids. While there is a common understanding that network development is a key issue, there is little academic research on the engineering-economic aspects of network expansion projects for that issue. In particular, this refers to the idea of combining the efforts for market and wind integration jointly for the United Kingdom, Scandinavia and continental Europe by implementing an North and Baltic Sea offshore grid which has to be built from scratch.

In this paper, we provide an engineering-economic scenario analysis for a nodal AC-DC Grid based on a large potential of wind generation. We identify consistent wind expansion scenarios for the European electricity market that include different amounts of on- and offshore wind as well as possible offshore grid designs for market and wind integration. Using a welfare maximising electricity market model, we analyse the market outcomes of these scenarios and test their network implications. We evaluate welfare aspects of different grid realizations and the impact of offshore grid design drivers.

Methods

In a first step, we develop a wind expansion scenario and different offshore grid designs for mainly point to point offshore links and an offshore grid dominated by meshed elements (Oceans of Opportunities 2009, Tradewind 2009).

To analyze the economic implications of these scenarios, we use the electricity market model ELMOD which is described in Leuthold et al. 2008. As an optimization model, ELMOD has a welfare-maximizing objective function. It models the Western and Central European UCTE high voltage transmission network and includes more than 2000 nodes and 3000 transmission lines. As a DC load flow model, ELMOD implements the Kirchhoff laws and allows a realistic representation of physical characteristics of electricity networks like loop flows. In this paper, we expand the model scope to the United Kingdom and the Scandinavian Nordel market. While all countries of the North and Baltic Sea region are implemented on a nodal level the southern European countries are simplified to a single node. We model an offshore HVDC grid for the wind and market integration between the non-synchronized markets of the United Kingdom, Nordel and the UCTE.

In order to capture all relevant system conditions, we model different hours with specific supply and demand characteristics. Model inputs include installed generation capacities of various conventional and renewable technologies, reference demands and prices, and fuel prices as well as short run marginal costs for the reference year of 2009. The generation technologies are expanded with hydro reservoirs allowing for intertemporal optimization for their generation budget within the welfare objective. Model outputs are country-specific electricity market results (prices and generated quantities) and total welfare, which can be used for welfare comparisons. Importantly, the model allows quantifying welfare implications related to the three markets of the UK, Nordel and the UCTE separately as well as congestion rents in the offshore HVDC grid.

Results

Depending on the wind scenario and the chosen offshore grid design, the welfare maximizing market result includes different shares of producer and consumer rent for the different countries. The increasing trade with more HVDC line capacity causes price shifts with higher prices in Nordel and lower prices in the other two market areas. The Scaninavian hydro reservoirs are utilized to smooth the fluctuating character of wind power and electricity demand.

Regarding welfare, we find that the meshed offshore grid design significantly increases welfare compared to scenarios with no additional offshore links or point to point connections but also leads to higher rent shifting between cosumers and producers. However, the modeled congestion rents on the HVDC offshore links are rather small and do not reach the costs for the offshore grid investments.

Conclusions

We compare different offshore grid scenarios for the European electricity sector with offshore wind installations that include market and wind integration in the North and Baltic Sea by HVDC lines. With a welfare-maximizing electricity market model, we show that an offshore grid not only increases welfare, but might also be profitable under certain conditions. However, the congestion rents on the HVDC links are not sufficient for the choosen line capacities that limit the possibilities for large offshore networks financed by merchant transmission investments.

Due to the participation of many states and market designs, large-scale network expansion projects in this region will be difficult to realize in the current market environment. Potential investors face a multitude of market, policy and regulatory risks, technological uncertainties, coordination problems, and other barriers like local resistance. The current lack of business cases for network expansion can only be overcome if a clear and stable long-term policy framework is in place that removes existing barriers. Importantly, welfare benefits of network expansion projects should be distributed in an incentive-compatible way. Hence an institutional analysis will be required to determine opportunities and challenges in the development of such electricity scenarios.

References

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