Energy Policy 101 (2017) 28–41

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Integrated North Sea grids: The costs, the benefits and their distribution between countries

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ARTICLE INFO

Keywords:
Cross-border interconnection
Onshore and offshore transmission investment
Offshore coordination
Net benefit allocation

ABSTRACT

A large number of offshore wind farms and interconnectors are expected to be constructed in the North Sea region over the coming decades, creating substantial opportunities for the deployment of integrated network solutions. Creating interconnected offshore grids that combine cross-border links and connections of offshore plants to shore offers multiple economic and environmental advantages for Europe's energy system. However, despite evidence that integrated solutions can be more beneficial than traditional radial connection practices, no such projects have been deployed yet. In this paper we quantify costs and benefits of integrated projects and investigate to which extent the cost-benefit sharing mechanism between participating countries can impede or encourage the development of integrated projects. Three concrete interconnection case studies in the North Sea area are analysed in detail using a national-level power system model. Model outputs are used to compute the net benefit of all involved stakeholders under different allocation schemes. Given the asymmetric distribution of costs and benefits, we recommend to consistently apply the Positive Net Benefit Differential mechanism as a starting point for negotiations on the financial closure of investments in integrated offshore infrastructure.

1. Introduction

Offshore wind power is envisaged to play a key role in the future European energy system, constituting one of the principal low-carbon alternatives to conventional generation plants. Although currently installed capacity of offshore wind in the region is about 5 GW, deployment is expected to reach several hundred GW in the coming decades. By 2030, up to 150 GW are envisaged to be deployed in Europe, with almost half of this capacity concentrated in the North Sea region. In light of Europe's goal of increased market integration and ambitious offshore wind deployment goals, there is an ongoing debate regarding the future development of offshore grids. Given the large capital investment requirements to enhance cross-border energy transfers as well as accommodate imports from large offshore clusters, there is a significant opportunity for these activities to be combined. The economies of scale of accommodating offshore wind export capability and cross-border trade through a common meshed transmission network promises for substantial cost savings. North Sea is particularly suited to the role of a pilot test-bed for such innovative projects due to the area's large offshore development potential as well as the growing need for interconnection between neighboring countries via undersea cables. However, the business-as-usual approach to the development of transmission infrastructure is currently characterized by limited coordination. Alternative arrangements are required to

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http://dx.doi.org/10.1016/j.enpol.2016.11.024
Received 6 June 2016; Received in revised form 14 November 2016; Accepted 16 November 2016
Available online 23 November 2016

facilitate the coordinated connection of wind farms to shore and their meshing with cross-border interconnectors.

The European Commission has in the past recognized the potential for developing a meshed North Sea offshore grid and set it as one of the main infrastructure priorities for Europe (DG Energy, 2010). In a similar vein and recognizing the large offshore wind potential in Britain, the UK regulator has launched a series of consultations on the design of a novel regulatory framework to facilitate the planning and delivery of coordinated projects (Strbac et al., 2014a). The potential for integrating offshore wind farms within interconnection projects between Scotland, the Republic of Ireland and Northern Ireland have also been extensively investigated in the ISLES project (2012). Coordination at the local cluster and multi-jurisdictional level are shown to entail significant cost savings, while the uncertainty related to the allocation of benefits is recognized as one of the primary barriers to coordinated development. In addition, several independent studies have been carried out in order to quantify the potential benefit of such integration projects at the national and EU level. For example, in (Cole et al., 2014) the authors demonstrate that the annual techno-economic, environmental and strategic benefits enabled through coordinated network development in 2030 will be in the order of EUR 1.5–5.1 billion, depending on the eventual level of offshore wind deployment. In a similar vein, a recent study covering all North Seas Countries' Offshore Grid Initiative (NSCOGI) countries has quantified the benefits stemming from coordination at various levels to be between 8 and 40 billion euros, with offshore-onshore connection coordination being a primary source of capital cost savings (Strbac et al., 2014b). In addition, the strategic flexibility of offshore-offshore links was shown to be substantial due to the ability for reducing the impact of asset stranding in the case of unfavorable deployment scenarios (Strbac et al., 2015). Finally, the OffshoreGrid report published in 2011 confirmed the substantial benefits of integrated solutions. The project results showed that a meshed offshore grid that integrates offshore wind energy and interconnection in a hub-to-hub, tee-in or split arrangement increases social welfare due to reduced investment costs that arise from asset sharing (OffshoreGrid, 2016). The importance of coordinating offshore network development across Europe was also highlighted as key in delivering future-proof energy infrastructure a recent report for the UK's National Infrastructure Commission (Strbac et al., 2016).

Researchers and policy-makers agree that in principle an integrated offshore electricity grid brings both financial and technical benefits to the European power system, probably outweighing the costs of investment. This was clearly expressed in the Memorandum of Understanding signed by the North Sea Countries' Offshore Grid Initiative (NSCOGI), in which all coastal states of the North Sea region declared their will to support the implementation of such an offshore grid. NSCOGI performed a cost-benefit analysis of an offshore grid with more updated scenarios reconfirming and further detailing certain aspects of the OffshoreGrid study (NSCOGI, 2012). However, despite the growing evidence that an integrated offshore grid in the North Sea offers significant benefits, such projects are not commercially pursued. In practice, only direct offshore interconnectors are built and planned, and, apart from the three-leg Kriegers Flak project, initially interconnecting Denmark, Sweden and Germany via a 600 MW offshore wind farm, there are currently no integrated projects under consideration. In light of the potentially substantial benefits of interconnected projects in the North Sea area, the European IEE project NorthSeaGrid (Kreutzkamp et al., 2013; NorthSeaGrid, 2016) was conducted. There are multiple reasons for this lack of commercial initiative. In general, integrated projects entail commitment to anticipatory investment elements which entail some stranding risks if project partners do not eventually go ahead (see Konstantelos (2013) for an overview of anticipatory investment under uncertainty). At the same time, connection of wind farms is in itself a time-sensitive matter; the extra complexity due to coordination does open the possibility for time-consuming delays. These factors can translate to an increased project risk leading to unfavorable financing term; the situation is exacerbated by the limited experience that currently exists with such integrated projects. Finally, the asymmetric distribution of benefits between consumers and producers across countries can result in certain stakeholders being worse off, ultimately leading to barriers towards integrated developments.

The principle aim of the present paper is to further explore the underlying reasons for the observed lack of commercial interest in integration and propose suitable mitigation measures, with a particular focus on the subject of asymmetric benefit allocation. In particular, we aim to answer a number of topical questions:

- How substantial is the benefit of integrated solutions?
- Is it riskier to build integrated networks compared to conventional radial connections?
- What are the regulatory issues that may be currently prohibiting the development of offshore integrated networks?
- To what extent is asymmetric cost/benefit allocation a barrier to the development of integrated projects?
- What modifications can be made to national and EU regulatory practices to enable the emergence of cost-efficient integrated solutions?

These questions are addressed with the aid of concrete case studies focusing on three particular projects that could be potentially developed in the near future. For this purpose, a techno-economic tool modelling North Europe electricity system operation has been developed. The undertaken analysis offers a two-fold contribution on the topic of integrated offshore projects in the North Sea:

- We investigate the costs and benefits of three specific case studies, chosen for their development potential. Focusing on a concrete project enables us to compute an accurate estimate of social welfare benefits, analyse economic impact and commercial viability, and delve into the specific regulatory arrangements that apply to uncover potential gaps and barriers.
- We demonstrate that asymmetric cost-benefit allocation is a problematic issue under the current regulatory regime; although integrated connection architectures are shown to increase social welfare, specific players are found to be in a substantially worse off position, leading to severe difficulties in achieving consensus across all involved parties. The Positive Net Benefit Differential method is proposed as an alternative arrangement that alleviates these effects.

The paper is structured as follows. In Section 2 we present the details of reduced EU system and three interconnection case studies and showcase the cost-benefit calculation and allocation methodologies considered. In Section 3 we present the main study results and examine the materiality of different regulatory barriers identified. In Section 4 we summarize and discuss policy recommendations stemming from the presented analysis.

2. Methods

In this section we outline the model and case studies used to explore integrated connections in the North Sea. We first introduce the EU electricity system model used and proceed with presenting the three case studies in detail. We subsequently showcase the methodology employed for calculating the costs and benefits of each project, identify the regulatory and accounting rules that apply in each case study and finally discuss the different cost-benefit allocation methodologies that were examined.