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Gas generation and wind power: A review of unlikely allies in the United Kingdom and Ireland

Joseph Devlin[a,*], Kang Li[a], Paraic Higgins[b], Aoife Foley[b]

[a] School of Electronics, Electrical Engineering and Computer Science, Queen's University Belfast, United Kingdom
[b] School of Mechanical and Aerospace Engineering, Queen's University Belfast, United Kingdom

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ABSTRACT

No single solution currently exists to achieve the utopian desire of zero fossil fuel electricity generation. Until such time, it is evident that the energy mix will contain a large variation in stochastic and intermittent sources of renewable energy such as wind power. The increasing prominence of wind power in pursuit of legally binding European energy targets enables policy makers and conventional generating companies to plan for the unique challenges such a natural resource presents. This drive for wind has been highly beneficial in terms of security of energy supply and reducing greenhouse gas emissions. However, it has created an unusual ally in natural gas. This paper outlines the suitability and challenges faced by gas generating units in their utilisation as key assets for renewable energy integration and the transition to a low carbon future. The Single Electricity Market of the Republic of Ireland and Northern Ireland and the British Electricity Transmission Trading Agreement Market are the backdrop to this analysis. Both of these energy markets have a reliance on gas generation matching the proliferation of wind power. The unlikely and mostly ignored relationship between natural gas generation and wind power due to policy decisions and market forces is the necessity of gas to act as a bridging fuel. This review finds gas generation to be crucially important to the continued growth of renewable energy. Additionally, it is suggested that power market design should adequately reward the flexibility required to securely operate a power system with high penetrations of renewable energy, which in most cases is provided by gas generation.

1. Introduction

As the public and political conscience continues to focus on greenhouse gas emissions and clean energy, the power sector is enhancing its green credentials in order to achieve the binding European Union (EU) 2020 targets. Increased penetration of renewable energy, particularly wind power, is apparent. Great Britain (GB) has recently emerged as a global leader in offshore wind installation, with over 1200 MW installed by 2012 [1]. In Ireland, the lack of indigenous fossil fuel production, favourable domestic policy landscape and geographical suitability for wind energy have encouraged development [2]. As of 2015, there has been over 2800 MW of wind capacity installed, with a further 2000 MW planned for installation by 2020 [3].

However, both the Single Electricity Market (SEM) of Northern Ireland (NI) the Republic of Ireland (ROI) and the British Electricity Trading and Transmission Arrangements (BETTA) market in Great Britain (GB) have high installed capacities of gas fired generation. Output from these gas units contributed 42% and 30% of total electricity production in 2014 respectively [4,5]. Gas fired generation in the BETTA market has a lower share in overall production than in the SEM since the BETTA is a much larger system with increased scope for inflexible base load coal and nuclear generation. As increasingly stringent European legislation restricting the operation of coal plants comes into force [6], the importance of gas fired generation for system security and integrating renewable energy will continue to increase.

Gas fired power stations are much more adept at adjusting output based on residual demand resulting from wind power variation than more inflexible units such as coal [7], hence the power industry's favouring of the use of natural gas in its electricity generating operations as the penetration of renewable energy continues to increase. This natural gas generation also emits much less Green House Gas (GHG) emissions than coal and oil fired power stations [8]. From the outset it is clear that gas fired generation in the SEM and BETTA can contribute to the savings required to achieve the legally binding 2020 targets [9] on two fronts, by reducing overall emissions and supporting the increase of renewable electricity.

However, the intersection of relatively dependable high installed capacities of gas generators and the stochastic nature of high levels of wind penetration provide an extremely interesting set of issues for system operators and energy market participants. The status of wind

* Corresponding author.
E-mail addresses: jdevlin25@qub.ac.uk (J. Devlin), k.li@qub.ac.uk (K. Li), phiggins14@qub.ac.uk (P. Higgins), a.foley@qub.ac.uk (A. Foley).

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energy and its barriers to market entry in SEM have been well documented by Foley et al. in [10]. The paper concludes that an interaction analysis of the SEM and the BETTA markets is necessary for future development regarding market design, operation and energy mix. Both jurisdictions geographical proximity and interconnection provide a suitable scenario for comparison.

Similarly, both the SEM and BETTA are heavily reliant on imported fossil fuels [11]. Domestic oil and gas production in the United Kingdom Continental Shelf (UKCS) is declining rapidly [12] further increasing the dependence of the UK on energy imports. This has a direct effect on Ireland, since 95% of natural gas demand in 2013/14 was imported via a single interconnection point from the GB system [13]. By harnessing the natural resources which are freely available, both the UK and Ireland can reduce their exposure to volatile international energy markets and the effects of geopolitical events.

Analysis of the relatively unexplored relationship between wind and gas generation [10] in an effort to establish a sustainable energy generating future is the central aim of this paper. Despite numerous other developments in the power system such as decentralisation and the electrification of transport and heating systems, this work focuses on the transition to a time when these technologies are widespread. This bridging period is the backdrop for the analysis and considers the impact wind power has on gas generation and the operation of the conventional power system. Wind energy due to its non-synchronous low inertia characteristics, poses significant challenges to frequency control and overall power system operation [14]. This, coupled with the inherent stochastic nature of the resource, requires conventional generation to satisfy residual demand and provide auxiliary services such as reserves and frequency response regulation [15]. Section 2 documents and analyses current policy decisions and their effects on technology development. The technical impact of integrating large penetrations of renewable energy is discussed in Section 3. Economic factors relating to the change in operational profile of gas units are discussed in Section 4, accompanied by a detailed discussion. Concluding remarks are given in Section 5.

2. Policy impact

Policy decisions are one of the largest contributory factors towards emission reduction [16]. Policy also has the ability to affect energy prices and the distribution of wealth between consumers and generators [17]. The EU 2020 targets and Emissions Trading Scheme (EU ETS) are prime examples of the ability to directly impact the fuel mix. Future commitment to a revamped EU ETS and carbon taxes will constrain base load coal generation, since gas fired units require 50% less allowance [18]. However, the adoption of the initial EU ETS triggered innovation mostly in coal fired power generation via the development of carbon capture and storage [19]. The price of carbon in the first two allocations of credits did not sufficiently penalise the adoption of coal fired generation [20], resulting in no shift in the merit order with respect to gas. The direct capability of policy to affect generation technology must be fully realised. Technology advancement benefits from long term legislative goals, providing the policy decisions are time specific and flexible [21]. It has been found that technology advances relating to climate change mitigation only occur at sufficient levels if there is an incentive to do so, i.e. supported by policy developments [22]. The policy implemented accelerates the rate of development, but it is imperative that policy is clear in direction. Industry is made up of many stakeholders who all interpret decisions differently, limiting the effectiveness of overall change [23]. It is imperative that sensible policy decisions are made in order to drive the future technology required to achieve a high renewable penetration energy system.

In the case of gas generation, increases in efficiency both overall and in cycling operation could mitigate the exposure to fuel price uncertainty. Cementing of plant flexibility from an operational, economic and environmental view point would ensure the support capabilities of gas are fully realised in high wind penetration markets. Supporting policy is integral to these developments, and the European Union has been instrumental in achieving a single internal energy market with sustainability as the overarching aim.

2.1. European drivers

European level legislation is adopted in GB, NI and ROI. From an energy perspective the most notable are the 2020 energy targets and the "Third Energy Package". These two main pillars of energy policy aim to reduce the rate of climate change experienced by member states and encourage the development of a competitive single energy market.

2.1.1. 2020 energy targets

The 2020 targets offer a three pronged, legally binding target scenario which aims to mitigate climate change over the entire EU by the year 2020 [9]:

- A reduction in greenhouse gas emissions by 20% from 1990 levels;
- Total energy demand is to be met with 20% renewable energy;
- An increase of 20% in energy efficiency.

This analysis relates to the first two targets listed above. By increasing the amount of renewable energy, the need for fossil fuel electricity generation shows an overall decline, thereby assisting in the reduction of GHG emissions. In 2011, power generation accounted for 33% of total EU greenhouse gas emissions [24].

Each member state sets out their own national renewable energy action plan (NREAP) detailing the steps they will take in order to achieve the 2020 goals. The individual targets when combined with the remainder of the EU, will achieve the required benchmark. In addition to the mandated NREAP, the UK published "UK Renewable Energy Roadmap" in July 2011, setting a GHG emissions reduction target of 16% and a renewable energy target of 15%. Since Northern Ireland is a devolved local government, there is no defined target at EU level. However, in the UK Energy Roadmap, Northern Ireland committed to a renewable electricity target of 40% and a 10% renewable heat target [25]. The GHG emissions target for Northern Ireland extends to 2025, when a reduction of 35% on 1990 levels is expected [26]. Similarly, ROI set out challenging targets in pursuit of 2020 compliance. The Irish NREAP sets out a target of 16% of energy from renewables [27]. GHG emissions are aimed to be reduced by 20%.

2.1.2. Third energy package

The third package is a collection of legislation which aims to further the progress of creating a single EU wide market for gas and electricity [28]. By fostering a European wide energy network, policy and infrastructure can align across borders enabling significant potential for renewable integration. In the case of wind, the meteorological variability experienced by one area of can be offset by the conditions in another [29].

The main area of legislation in the Third package relates to the unbundling of the supply and transmission businesses for both electricity and gas systems. By ensuring these activities are completely separate, non-discriminatory access to pipelines and interconnectors can be achieved. Separating production and supply activities from transmission operation increases market transparency and removes conflicts of interest in the energy supply chain. Implementation of Directives 2009/72/EC [30] and 2009/72/EC [31] for electricity and gas markets respectively ensures unbundling is a requirement of Member States, and ultimately aims to promote efficient use of European wide energy infrastructure under common market rules. By utilising energy infrastructure across Member States in a more efficient, effective and transparent manner, the formation of a single internal energy market is expected to reduce energy prices for