Energy Policy 36 (2008) 3212–3225

Contents lists available at ScienceDirect

Energy Policy

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

Will British weather provide reliable electricity?

James Oswald *, Mike Raine, Hezlin Ashraf-Ball

Oswald Consultancy Ltd., The TechnoCentre, Coventry University Technology Park, Puma Way, Coventry CV1 2TT, UK

ARTICLE INFO

Article history:
Received 10 August 2007
Accepted 23 April 2008
Available online 20 June 2008

Keywords:
Wind
Electricity
Smoothing

ABSTRACT

There has been much academic debate on the ability of wind to provide a reliable electricity supply. The model presented here calculates the hourly power delivery of 25 GW of wind turbines distributed across Britain's grid, and assesses power delivery volatility and the implications for individual generators on the system. Met Office hourly wind speed data are used to determine power output and are calibrated using Ofgem's published wind output records. There are two main results. First, the model suggests that power swings of 70% within 12 h are to be expected in winter, and will require individual generators to go on or off line frequently, thereby reducing the utilisation and reliability of large centralised plants. These reductions will lead to increases in the cost of electricity and reductions in potential carbon savings. Secondly, it is shown that electricity demand in Britain can reach its annual peak with a simultaneous demise of wind power in Britain and neighbouring countries to very low levels. This significantly undermines the case for connecting the UK transmission grid to neighbouring grids. Recommendations are made for improving 'cost of wind' calculations. The authors are grateful for the sponsorship provided by The Renewable Energy Foundation.

1. Introduction

The government of the United Kingdom aims to achieve high levels of grid connected renewable electricity. This is a policy driven by the twin goals of climate change mitigation and lower dependence on imported fuels. Through the mechanism of the Renewables Obligation, the UK aims to achieve 10% of its supplied electrical energy from renewable resources by 2010, and 15% by 2015, with the further aspiration to generate 20% by 2020. The present administration expects most of this, some 70–80% up to 2010, to come from wind power (BERR, 2007) and much incremental growth in renewable electrical energy after 2010 is foreseen as coming from this technology (NDS, 2007).

A target of "20% renewable electricity" does not mean that 20% of generators could be replaced by renewable plants, with other generators carrying on as before. That would be the case if power were to be delivered consistently from such generators. However, wind in Northern Europe is highly variable, producing volatile power delivery, as reported in Germany (E.ON Netz, 2005) and Denmark (Sharman, 2005). This paper sets out to assess how consistent wind power is likely to be in the UK, and the consequences of any volatility on the control and utilisation of individual generation plant on the grid. It calculates that the likely degree of fluctuation in UK wind power is high. The implications of volatile wind delivery are significant, since such volatility would require other generators, which typically use fossil fuel, to ramp up and down as wind comes and goes, and this would restrict continuous base load operation for these plants.

In discussion, the then DTI stated that they had considered funding a model of the nature presented here but had not yet done so (Armstrong, 2007). National Grid plc is aware of the volatility of wind power delivery, as they monitor live transmission system connected wind farm data at their control centre. They use these data to manage the difference between forecast wind and actual output, as illustrated in Fig. 1 (Ahmed, 2007a). However, much of this transmission system connected wind is concentrated in a relatively small geographical area, and National Grid's concern is the balancing of the grid over the last half hour of generation, not the effect wind volatility might have on other generating plants.

As a contribution towards improving understanding, the present paper sets out to model the dynamic behaviour of 25 GW of wind on the UK grid system, assess the volatility of wind, and considers the implications for individual generating plant. This large capacity would deliver 16% of the UK's electrical energy demand at a wind load factor (LF) of 30% or 18.8% at a LF of 35% (UK total demand in 2005 was 407 TWh). The present analysis has been limited to the month of peak demand, January, for the last 12 years, since this is also the month of highest wind output, and may therefore be the period in which problems, if any, are likely to manifest themselves. An exploratory analysis of wind and demand in July has also been carried out, and confirmed the view that summer months are less likely to produce challenging conditions.

* Corresponding author. Tel.: +44 247 623 6080.
E-mail address: info@oswald.co.uk (J. Oswald).

0301-4215/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2008.04.033

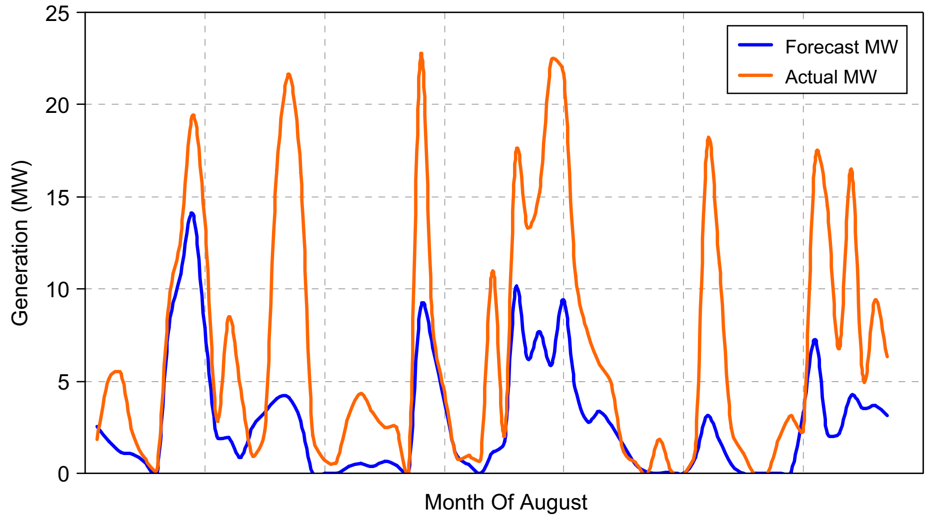

Fig. 1. Forecast and actual wind power generation for a single wind farm.

While this work is in some respects a pilot study the simulations conducted so far allow three main conclusions:

1. Although the aggregate output of a distributed wind carpet in the United Kingdom is smoother than the output of individual wind farms and regions, the power delivered by such an aggregate wind fleet is highly volatile. For example, had 25 GW of wind been installed, with full access to the grid, in January 2005, the residual demand on the supporting plant would have varied over the month between 5.5 and 56 GW.
2. The volatile power swings will require the fossil fuel plant to undergo more frequent loading cycles, thus reducing their reliability and utilisation.
   - Reduced reliability will require more thermal plant to be installed so as to achieve the same level of system reliability. Cost of wind calculations would be more accurate if they included this factor.
   - Reduced utilisation will encourage generators to install lower-cost and lower-efficiency plant rather than high-efficiency base load plant. These have higher CO_2 emissions than high-efficiency plants. Carbon saving calculations would be more accurate if they included this factor.
3. Wind output in Britain can be very low at the moment of maximum annual UK demand (e.g. 2 February 2006); these are times of cold weather and little wind. Simultaneously, the wind output in neighbouring countries can also be very low and this suggests that intercontinental transmission grids to neighbouring countries will be difficult to justify.

2. Previous studies and understanding

There is considerable research literature, and much meteorological science, contributing to the understanding of wind power and its likely variability. The United Kingdom Energy Research Centre (Gross et al., 2006) has collated and summarised the findings of many studies and worked to standardise methods and language and thus facilitate a common understanding of the issues. The present paper sets out to provide complementary findings using data and examples.

Gross et al. (2006) in particular set out an excellent summary of the work to date, and review 200 international studies with the aim of understanding and quantifying the impacts of intermittent generation on the British electricity network, and the assignment of costs. The analyses reviewed are predominantly statistical in nature, and explain the costs arising from increasing levels of intermittency as costs over and above 'those imposed by conventional generation making an equivalent contribution to energy and reliability'. The study separates these costs into two categories: costs arising from (1) '*additional system balancing actions*' and (2) '*the need to install or maintain capacity to ensure reliability of supplies*'. This is a useful framework, and the work presented here is intended to contribute to furthering that understanding. However, where much of the work reviewed by Gross et al. (2006) is statistical in its foundations, the work here relies on the examination of case studies, on a power flow model derived from empirical UK wind speed measurements, and on examples of wind power time series data in Britain and other European countries. This approach provides real and modelled examples of the nature of power changes on the grid and the resulting impact on individual generators. This perspective is adopted since an individual plant does not see the statistical delivery of power but, rather, a specific requirement for power. The examples given lead to suggestions as to how the cost calculations reviewed by UKERC can be improved. The examples studied will also be useful to operators and designers of the generating plant, and to policymakers attempting to understand the practicalities of controlling individual generators once large quantities of wind are embedded in the electricity system. The work supports many of the findings of Gross et al. (2006) and recommends further analysis and adjustments to their analysis so as to take account of costs in the category they define as '*the need to install or maintain capacity to ensure reliability of supplies*'. It provides no particular evidence or relevance to costs described by Gross et al. (2006) under the heading '*additional system balancing actions*'.

This study begins by assessing the volatility of wind using a power flow model derived from Met Office wind speed data and makes comparisons with empirical data for the UK (Ahmed, 2007a, b), Ireland (EirGrid, 2001, 2006), and Germany (E.ON Netz, 2005, 2006). A comparison to Spanish wind data is also made. These comparisons offer validation of the model developed and also provide some indicative information with regard to simultaneous wind output variations across Western Europe. These findings are discussed through comparisons with meteorological expectations and meteorological charts, and then employed in