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Revitalising the wind power induced merit order effect to reduce wholesale and retail electricity prices in Australia

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ABSTRACT

This paper investigates the effect of increasing the number of wind turbine generators on wholesale spot prices in the Australian National Electricity Market's (NEM), given the existing transmission grid, from 2014 to 2025. We use a sensitivity analysis to evaluate the effect of five different levels of wind power penetration on prices, ranging from Scenario A, 'no wind', to Scenario E that includes existing and planned wind power sufficient to meet Australia's original 2020 41TWh Large-scale Renewable Energy Target (LRET). We find divergence in prices between states and similar prices for nodes within states. This supports the Garnaut Climate Change Review assessment on the prevalence of 'gold-plating' the intrastate transmission network and underinvesting in interstate connectivity. We find that increasing wind power penetration decreases wholesale spot prices but that retail prices have increased in deregulated South Australia and Queensland, similarly, in Victoria. We argue that there is a pressing need to split the large generator-retail companies into separate retail and generator companies and to reassess regulatory rules more generally. Interconnector congestion limits the potential for wind power to further reduce wholesale prices across the NEM. So the need for a high capacity transmission backbone in the NEM is becoming clearer and will become pressing when Australia moves beyond its current 2020 LRET.

1. Introduction

In this paper, we investigate causes for the reduction in the merit order effect at higher penetrations of wind power. We suggest ways of removing impediments to the operation of the merit order effect, thus reducing both wholesale and retail electricity prices (Forrest and MacGill, 2013; Ketterer, 2014). These considerations are also pertinent to understanding the dynamics that have underlain the recent retail electricity price rises in South Australia (SA) (ABC, 2016a; Climate Council, 2016). We use simulations from the 'Australian National Electricity Market' (ANEM) model (Wild et al., 2015a, 2015b) to assess the effect of five different levels of wind power penetration on wholesale spot prices. These span Scenario, A which represents 'no wind', to Scenario E that includes all the existing and planned wind power sufficient to meet Australia's original 2020 41TWh LRET.

Fig. 1 shows the topology of the five states comprising the Australian National Electricity Market (NEM): Queensland (QLD), New South Wales (NSW), South Australia (SA), Tasmania (TAS) and Victoria (VIC). The Australian Capital Territory (ACT) is located within NSW. The number of lines between each state indicates the number of interstate interconnectors. Both the Northern Territory (NT) and Western Australia (WA) have their own independent electricity markets and networks unconnected to the NEM and both are relatively small compared to the NEM.

Australia ranks among the top three countries in the world for solar and wind resources (Drew, 2016). The NEM stretches 5000 km from far north QLD to TAS involving a remarkable geographical spread of wind power (AEMO, 2016b). Georgilakis (2008) finds increasing geographic spread increases predictability, reduces variability and minimises near-zero or peak output events. Bell et al. (2015e) have analysed

Abbreviations: AEMO, Australian Energy Market Operator; AGL, Australian Gas Limited; ARENA, Australian Renewable Energy Agency; LRET, Large-scale Renewable Energy Target; NEM, Australian National Electricity Market.

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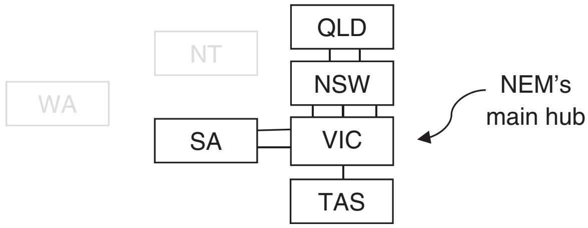

Fig. 1. Topology of the states and interconnectors comprising the National Electricity Market.

wind speed and electricity demand correlation to determine the ability of WTG to meet electricity demand in the NEM without the aid of energy storage. They found that a lack of correlation of wind speeds between the NEM's peripheral states, including QLD, SA and TAS, was advantageous. Additionally, the correlation between electricity demand and wind speed is the strongest between these states. Similarly, they find that the lack of correlation between electricity demands in each of these states yields most advantage.

However, the NEM requires sufficient transmission capacity through VIC and NSW to maximise the benefit of wind power in the peripheral states and the NEM more generally. In this paper we examine price islanding effects that reflect potential transmission constraints through VIC and NSW as well as between other states (Worthington et al., 2005). But overcoming these constraints to provide an optimised network structure for the deployment of wind power faces a major coordination problem as the NEM covers seven jurisdictions and contains 25 network service providers (NSP) (AER, 2016a). These multiple jurisdictions and NSPs serve only 19 million residents (AEMO, 2016b) and present a costly duplication of overheads. In comparison, South Korea has a single combined transmission distribution company serving 51 million residents within a single legislation.

Furthermore, Apergis and Lau (2015) find that there is a high degree of market power exercised by generators in the NEM and this has consequences for prices and mitigating carbon emissions. The Australian generation and retail market is dominated by three privately owned retail-generator companies, AGL, Energy Australia and Origin Energy. These companies are Australia's first, second and third highest emitters of carbon dioxide, respectively (CER, 2016), being the owners of large fossil fuel generation fleets. This presents a potential conflict of interest in both the deployment of wind power generation and the augmentation of interconnectors because both reduce the ability of fossil fuel generators to generate at prices above their marginal cost (Spiecker et al., 2013). From the perspective of electricity consumers, one of the key benefits of increased investment in renewable generation is the potential for reductions in wholesale and retail electricity prices as encapsulated by the merit order effect. Once renewable generation projects such as wind farms have been constructed, they are characterised as having very low marginal costs of generation. In a competitive dispatch process based upon marginal costs, and in the absence of transmission branch congestion, wind farms would be expected to be dispatched ahead of thermal generation with higher marginal costs. This would, in turn, lower wholesale electricity prices and retail electricity prices if passed on. A good discussion and overview of the merit-order effect can be found in Felder (2011). The paper is organised as follows. Section 2 presents a detailed literature survey of investigations of the merit-order effect. Section 3 discusses the methodology for the sensitivity analysis and provides an outline of the ANEM model (Wild et al., 2015a). Section 4 presents the results of the sensitivity analysis. Section 5 discusses the results and Section 6 concludes the paper.

2. Literature survey

In general, detailed assessment of the literature identifies three broad methods that have been used to quantify the merit-order effect. These methods are econometric techniques, power flow/unit commitment techniques and agent-based modelling techniques. Of the three methods, econometric techniques dominate, followed by power flow/unit commitment and then agent-based modelling techniques.

There have been a number of investigations of the merit-order effect in Australia. MacGill (2010) identified the role that wind generation had in reducing wholesale prices in SA. Nelson et al. (2012) also identified a short-run merit order effect although they also pointed out that high direct capital costs of renewable energy investments also needed to be factored into net economic benefit assessments, particularly in relation to feed-in tariff policy design. Forrest and MacGill (2013) confirmed merit-order effects associated with wind generation in SA and VIC over the period March 2009 to February 2011 using econometric techniques. They found wholesale price reductions relative to median prices of −0.069%/MWh and −0.027%/MWh for SA and VIC respectively. Claudius et al. (2014a, 2014b) extended these results to the NEM for years 2011–12 and 2012–13 while ignoring potential inter-regional and interconnection effects but accounting for the impact of the carbon price during 2012–13. They estimated the merit-order effect to be −$2.30/MWh and −$3.29/MWh in 2011–12 and 2012–13 respectively. McConnell et al. (2013) demonstrated a merit-order effect associated with scenarios outlining increased penetration of solar PV within the NEM, using a highly aggregated model of the NEM with no generation or transmission constraints. They found potential values of the merit-order effect as a function of installed solar PV capacity between 1 GW and 5 GW to be between $390m and $1229m in 2009 and between $169m and $628m in 2010. They also argued that these estimates were likely to be conservative.

Given the longer history of investment in renewable energy in both the USA and particularly Europe, there is a more significant literature on merit-order effects in international jurisdictions. Given Germany's leading role in promoting investment in renewable energy, it should not be surprising that the greatest amount of investigation has been applied to this particular country. Sensfuss et al. (2008) employed agent-based modelling to calculate a merit-order effect in 2006 of 7.83 €/MWh in Germany. They also reported significant variation in merit-order effects over daily cycles with greater effects during peak load periods. Weigt (2009) employed mathematical programming techniques to quantify an average merit-order effect of 10 €/MWh associated with German wind power for the period 2006 to the end of June 2008. Keles et al. (2013) investigated the merit-order effect associated with wind power in Germany using a combination of econometric and calibration techniques over the period 2006–2009. They found an average merit-order effect of 5.90 €/MWh associated with an average wind power capacity of 4670 MW's. However, for very high wind power penetrations occurring during high demand periods, the merit-order effect could represent as much as a reduction in wholesale prices of 130 €/MWh.

Mulder and Scholtens (2013) investigated the merit-order effect of Dutch and German wind power on Dutch wholesale electricity prices. They used wind speed data as a measure of wind power. They found that Dutch wholesale electricity prices were affected more by German wind speeds than Dutch wind speeds. For German wind speeds, they estimated a merit-order effect using econometric techniques over the period 2006–2011 of −0.03% associated with a one percent increase in German wind speeds. Tveten et al. (2013) investigated the merit-order effect associated with increased solar PV electricity production in Germany over the period 2006 to 2011 using econometric techniques. They found that the merit-order effect varied on a year-on-year basis, declining from 7.4 €/MWh in 2009 to 3.1 €/MWh in 2011. They also found that the increase in solar PV electricity production also reduced the average price variability albeit at a declining trend over the period 2009–2011. Wurzburg et al. (2013) used econometric methods to estimate a merit-order effect over the period July 2010 to end of June 2012 of 2% of the electricity price associated with the combined impact of wind power in Germany and Austria on day-ahead wholesale electricity prices in Germany and Austria.