Facilitating high wind penetrations within the Australian National Electricity Market – renewable support policies and market design issues and opportunities

I. F. MacGill and H. R. Outhred

Abstract-- **Australia has been an early and enthusiastic adopter of market-based environmental regulation and implemented one of the world's first renewable energy target schemes in 2001. It also has well over a decade's experience of electricity industry restructuring including the creation of a National Electricity Market (NEM) in 1999 based around a gross pool wholesale market that provides significant locational and temporal price signals for market participants. Australia therefore provides an interesting case for assessing different approaches to facilitating the integration of large wind penetrations into the electricity industry. The Australian Government's recently announced intention to expand the present renewable energy target to 20% by 2020 has heightened the practical importance of such assessments. So has the imminent introduction of a centralized wind forecasting system to support security and commercial decision making with the NEM, and a raft of proposed rule changes to more formally integrate wind farms into the market's scheduling processes.**

Wind project developers and financiers in Australia must make investment and operational decisions on the basis of both possible future renewable energy market and energy market income streams. Energy market income depends on the market region within which the wind farm is located and the match of its time varying output with the half hourly market price that exhibits daily, weekly and seasonal patterns and considerable uncertainty. Appropriate locational and temporal price signals can play a key role in driving wind farm investment in a way that maximizes its value to the electricity industry including integration costs and benefits. There are now also formal changes underway to better incorporate wind farms into the market's ongoing operational decision making through greater participation in its scheduling processes, coupled with the intended availability of centralized wind energy forecasts for the system operator and market participants.

This paper outlines experience to date with wind integration in the NEM, and assesses the possible implications of current policy developments. It highlights the potentially favorable outcomes of Australia's particular renewable energy policy support measures and electricity market design for facilitating high wind penetrations.

Index Terms—**Electricity Markets, Wind Integration.**

This work was supported in part by the Australian Greenhouse Office as part of the Federal Government's Wind Energy Forecasting Capability initiative.

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I. INTRODUCTION

Wind energy is an emerging energy resource that is now making a valuable contribution to meeting the pressing greenhouse and energy security challenges facing electricity industries around the world. However, it represents the first intermittent energy source to reach significant penetrations in power systems and has rather different characteristics from conventional generating plant. These characteristics can pose important challenges to existing arrangements for power system operation. Meanwhile, many electricity industries worldwide have themselves been undergoing restructuring over the last two decades towards more commercially competitive, market-based operation and investment.

In its broadest sense, the challenge for wind integration within electricity industries is to facilitate wind energy in achieving its maximum societal value. This value has energy, environmental and potentially wider social dimensions. Wind's energy value depends on its investment and operational costs compared against the benefits of its energy provision – a benefit that has significant temporal and locational variability and uncertainty that is largely determined by the characteristics and behaviour of power system demand and all other generation resources. The environmental values of wind can include greenhouse emission reductions that have little temporal and locational variation, but also regional air and water benefits as well as possible visual amenity costs. The social benefits of wind energy can include investment and job outcomes with industry development.

The policy and market design challenge is to maximize these very different values. Of particular interest here is maximizing the energy value of increasing wind penetrations given the impacts of this on other generation and associated network requirements. In restructured electricity industries, some mix of commercial (competitive) and regulated (monopoly) arrangements are used to establish such energy value over time and with respect to location and potential uncertainties

Key challenges for wind energy integration into such restructured electricity industries include:

• physical (technical) complexity in terms of the shared, non-storable, time-varying wind energy flux that is used by wind farms and the shared, non-storable, time-varying electrical energy flows that pass through the network according to the behaviour of all network elements, generators and loads. This has implications on connection requirements, network losses and constraints, protection arrangements, stability and hence potential security concerns with wind integration,

• commercial complexity that arises because the electricity industry is infused with short- to long-term risks that are difficult to commercialise (correctly allocate to industry participants). There are, for example, key questions for wind energy participating in market processes such as scheduling, and

• institutional complexity required because of all the shared issues in planning, grid connection, network operation and management of power system security. Wind energy adds to these challenges.

High wind energy penetrations will test the adequacy of electricity industry restructuring in all of these technical, commercial and regulatory aspects. The issues must be considered in a specific context, because the wind resource, power system characteristics and institutional arrangements differ between countries. This is certainly the case for Australia's National Electricity Market (NEM) which has a large geographical scope, rather different mix of generation from many other countries, and its own particular market arrangements.

Australia's National Electricity Market (NEM) and associated renewable energy policy support framework provides, in our view, an interesting example of wind energy integration challenges and options. In this paper we consider each of these technical, commercial and regulatory issues to draw some general conclusions on how well current and proposed future NEM arrangements might facilitate potentially high wind penetrations.

II. PHYSICAL AND TECHNICAL FRAMEWORK

The Australian NEM extends some 4000km from North to South and approximately half this distance East to West, and includes all States and Territories other than Western Australia and the Northern Territory. It has approximately 42GW of generation and a peak total demand to date of around 33GW.

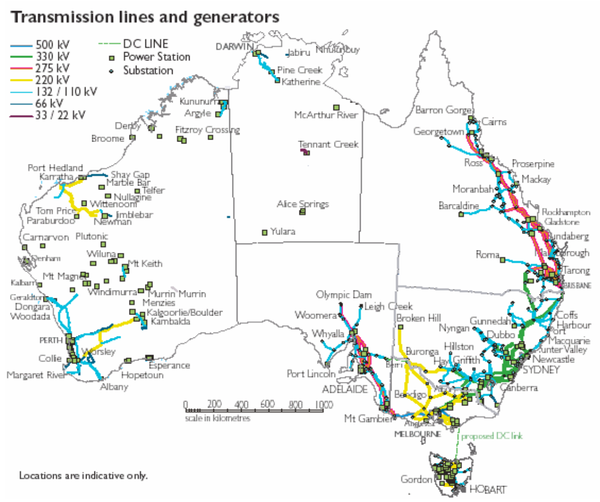

Fig. 1. Australian generating plant and Transmission network.

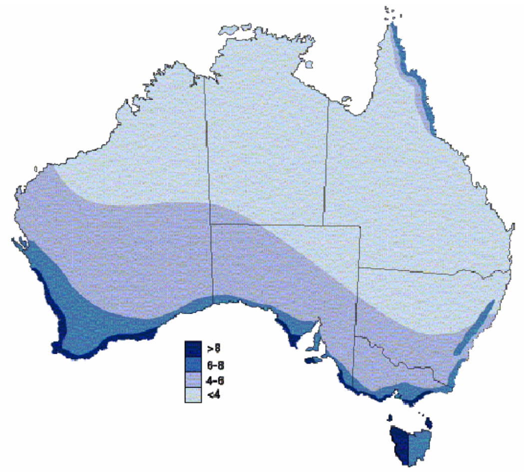

Fig. 2. Estimated Australian wind resource (average m/s) [2].

The generation mix is dominated by coal-fired plant (around 80% of electricity provision) with contributions from gas-fired generation and hydro power supplying the remainder [1].

Within the NEM, the match of wind resource and existing electricity demand, generation and network is reasonable in South Australia, Victoria and Tasmania. Around 1GW of wind generation is now operating or under construction within the NEM, with nearly all located in these states.

There are significant network constraints between these States, and between Victoria to NSW and hence Queensland – the two states with highest demand in the NEM. South Australia's wind penetration is already very significant by way of international comparisons given its interconnection constraints.

Technical connection requirements for wind generation within the NEM have been recently revised through a rule change on 'Technical standards for wind generation and other generator connections'. The general process is based around open access and 'shallow' connection cost obligations on those seeking connection. There are some outstanding issues on how 'deep' congestion issues are managed within the NEM rules, and these can have significant commercial implications for generators including wind farms. Some network connection agreements imposed by Network Service

Providers on wind farms have included the right to constrain wind farm output down under particular circumstances.

III. COMMERCIAL FRAMEWORK

A. The National Electricity Market

The centre-piece of the NEM is a set of regional gross-pool spot energy and ancillary services markets that solve a security-constrained dispatch every five minutes. There is a single spot market and system operator for the whole of this system, called the National Electricity Market Management Company (NEMMCO). Regions are currently located at all borders between States within the NEM. All generating plant of greater than 30MW capacity are required to participate as scheduled generators and submit offers to sell or bids to buy energy (and/or ancillary services) in the NEM dispatch process. The pre-dispatch processes forecasts up to 40 hours ahead of real time and provides public forecasts of energy and ancillary service prices and (privately to each dispatchable participant) dispatch levels based on participant bids and offers, the demand forecasts and the estimated effects of dispatch constraints.

There are eight Frequency Control Ancillary Services (FCAS) markets to provide load following (raise and lower) and three contingency responses of different speed (raise and lower) between the five minute energy dispatches Market dispatch co-optimizes energy and FCAS bids and offers to establish regional prices for both energy and FCAS for each five minute period. Commercial trading is based on these prices averaged over thirty minutes. Locational pricing within regions is achieved using averaged loss factors. Importantly all generators are permitted to change their offers (rebid) just prior to each five minute dispatch. The NEM is an energy-only market and participants are required to manage their own unit commitment and other inter-temporal scheduling challenges (within a range of technical dispatch constraints) [3]. They also participate in cost recovery for FCAS services as required.

At present, wind farms are classified as "intermittent" and have not been required to participate as scheduled generation. Within the dispatch process, such generators are effectively treated as negative load. They operate as price takers and dispatch all available wind power unless constrained down for security reasons. There are still significant market signals for wind farms in terms of the regional price (modified by intra-regional loss factors) they receive and the match between their output and general times of higher prices.

The last five years has seen a number of changes to NEM arrangements and rules to better facilitate higher wind penetrations including:

- Development of a centralized Australian Wind Energy Forecasting System to support security-driven and commercial decision making
- greater transparency through public reporting on historical generation output of large wind farms and other non-scheduled generation and
- a near-finalised proposal for wind generation to participate through a special semi-scheduled category of generator.

This latest development will require significant intermittent generators (such as wind farms) to participate in the central dispatch and PASA processes through submitting dispatch offers as for scheduled units, and limit their output at times when that output would otherwise violate secure network limits.

The intent is for NEMMCO to be able to efficiently manage network constraints when they arise by being able to constrain the maximum output of semi-scheduled generating units in the same way as scheduled generating units at those times.

Interestingly, intermittent generating units can choose to be classified as scheduled generating units and South Australia currently requires new wind farms in the state of significant size to register as scheduled generation in order to obtain a generation license [4].

In summary, the NEM would appear to have some advantageous arrangements with respect to wind integration, including:

- Temporal and locational price signals have significant implications for wind farm investment
- Supply/demand balance for regulation, contingencies and energy is managed through a gross pool rather than primarily bilaterally
- FCAS arrangements provide a highly transparent approach for pricing regulation and contingency ancillary services
- The freedom of a scheduled generator to rebid to the five-minute dispatch boundary allows scheduled wind farms to revise their offers to take account of improving forecasting information down to near real-time. It also provides other generators and loads with strong incentives to enhance their short-term operational flexibility [4].

B. The Mandatory Renewable Energy Target

The Australian MRET was the world's first renewable energy certificate trading scheme, commencing in 2001.

It requires all Australian electricity retailers and wholesale electricity customers to source an increasing amount of their electricity from new renewable generation sources. Eligible sources include hydro, biomass, wind, solar and co-firing of biomass in large coal fired power stations. Domestic solar hot water and small generators can also earn RECs through deeming provisions. The liable parties are electricity retailers in NEM states, large consumers who purchase directly from the NEM, and the notionally equivalent electricity industry participants in non-NEM states. The 'additional renewable electricity' liability that the liable parties are required to acquit was originally intended to be equivalent to 2% of their electricity purchases by 2010. This 2% target was translated into a fixed national target of 9500GWh of additional renewable generation in 2010. The annual target ramps up linearly to this 2010 target and was originally intended to remain at this level until

2020.

Investment for projects has been largely driven through Purchase Agreements between renewable project developers and liable parties, while there is also active broker and OTC spot and forward trading.

MRET has now been operating for some seven years. It has easily met its admittedly modest targets and driven considerable investment. The flexibility of this technology neutral approach has also proved valuable. Some early projections of which renewable technologies would contribute to the target suggested that biomass would make the greatest contribution. In practice, a number of proposed biomass projects have encountered difficulties. The market has therefore redirected its attention somewhat to other technologies, in particular wind projects.

There appears to be competition between project proposals that has project costs looking highly cost effective by international standards.

However, a number of factors have increased market uncertainty with regard to regulatory risk, and potentially impacted on new investment over the scheme's life. These factors include scheduled reviews, and also period calls from some policy stakeholders for its abolition [5].

Wind farm developers have typically received about half of their revenue from energy sales and half through the REC market. In this way, MRET supports renewable project development yet does not remove energy market signals in the way that feed-in tariffs may.

The new Federal Government has committed to an expansion of the scheme to achieve a 20% renewable contribution to electricity supply by 2020 and this seems certain to drive considerable investment and activity. Wind is expected by many to play a very significant role in achieving the target.

IV. Institutional Framework

The key bodies that constitute the governance and regulatory regime for the NEM are the Ministerial Council on Energy (MCE), the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER). These organizations have the following roles:

• The MCE coordinates Federal and State policy for the NEM

• The AEMC manages the National Electricity Rules and rule change process.

• The AER monitors compliance with the rule by participants, NEMMCO and NSPs as well as the overall effectiveness of the rules.

This regime has undertaken considerable work on wind energy over the past five years. Its highly formal processes have potentially significant time delays but do ensure high transparency and opportunities for stakeholder input.

The governance arrangements for MRET, on the other hand, have been far less formalized – particularly with respect to rule changes – and this has proven problematic.

V. Conclusions

Australia's National Electricity Market and renewable policy support arrangements both incorporate significant roles for commercial, competitively driven, decision making. The NEM provides what appear to be relatively efficient temporal and locational price signals for electricity generation. MRET seems to have created a relatively efficient market in renewable energy certificates. Wind project developers and financiers in Australia must make investment and operational decisions on the basis of possible future renewable energy market and energy market income streams arising from these competitive arrangements. Energy market income depends on the market region within which the wind farm is located and the match of its time varying output with the half hourly market price that exhibits daily, weekly and seasonal patterns and considerable uncertainty. There can be considerable variability in average incomes of differently located wind farms in these regards. The formal changes underway to better incorporate wind farms into the market's ongoing operational decision making through greater participation in its scheduling processes and centralized forecasting should both facilitate the integration of significantly greater wind generation under the expanded MRET target for 2020. As always, however, restructuring is an ongoing process and there are a range of potential challenges and opportunities likely to emerge over the coming decade. The introduction of a national emissions trading scheme in Australia in 2010 and growing attention on the need to enhance demand side participation will also both impact on this integration challenge – potentially in useful ways through greater use of flexible gas-fired generation and greater opportunities to manage supply demand balance through demand-side as well as supply side responses.

One key issue that will certainly need further work is that of transmission investment.

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VII. Biographies

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CEEM itself undertakes interdisciplinary research in the monitoring, analysis and design of energy and environmental markets and their associated policy frameworks. It brings together UNSW researchers from the Faculties of Engineering, Business, Science and Arts and Social Sciences. To learn more about CEEM and its work, visit the centre website – www.ceem.unsw.edu.au.

Hugh Outhred is a Professorial Visiting Fellow in the School of Electrical Engineering and Telecommunications at the University of New South Wales. He has over 30 years of research experience in electric power system engineering, electricity industry restructuring and renewable energy integration into competitive electricity industries. He has also held regulatory roles in the Australian electricity industry, as a member of the National Electricity Tribunal and of the NSW Licence Compliance Advisory Board.