

Wind Integration in Australia

F. K. Barker and H. R. Outhred
Centre for Energy and Environmental Markets
University of New South Wales
Sydney, NSW, 2052, Australia
flita@unsw.edu.au & h.outhred@unsw.edu.au

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1 Introduction

Australia has a large interconnected electricity network on the east coast, connecting the following states; New South Wales, Queensland, Victoria, Tasmania and South Australia. The system is long, near-radial and weakly interconnected. A fault in any area of the system has significant and far reaching consequences (much more than occurs in highly meshed systems). There are also smaller grids in Western Australia and the Northern Territory. At the end of 2005, there was 708MW of wind generation connected into the Australian electricity system, supplying 2,170GWh of electricity in 2005, which equates to 1% of the total electricity produced. There is a large amount of approved projects which will increase the amount of connected wind energy to 2,740MW, which equates to 3.7% of electricity produced. Though 3.7% is a small amount, the state of South Australia has 8.5% of their electricity coming from wind energy which is expected to increase to 20% [1],[2]. The eastern states are fully deregulated into generators, transmission, distribution and retail companies. These companies are public and private.

The interconnected network on the east coast is operated as the National Electricity Market (NEM). The NEM is operated by the National Electricity Market Management Company(NEMMCO). NEMMCO is owned by the five states which make up the market, and is paid for by the market participants. NEMMCO is also the system operator responsible for power system security and reliability. The NEM consists of 6 market regions; New South Wales, Queensland, Victoria, Tasmania, South Australia and the Snowy region. The NEM is a 'gross pool energy only' market, which sets dispatch targets and price every 5 minutes by constrained optimisation. The trading interval for the market is 30 minutes, the 6 five-minute prices are averaged to give the thirty-minute trading price in each region [3].

The National Electricity Laws (NEL) [4] describes the role, responsibilities, and authority of NEMMCO, the Australian Energy Regular (AER) and the Australian Energy Market Commission (AEMC). The National Electricity Rules (NER) [5] outlines the procedures and processes for market operations, power system security, network connection and access, and pricing for network services in the NEM. The AER is responsible for the enforcement of the NER. The AEMC is responsible for rule making and market development.

At the national level, NEMMCO released a report in 2003 looking at the issues related to intermittent generators in the NEM [6]. This report highlighted forecasting of wind energy output, Frequency Control Ancillary Services(FCAS) usage and cost, voltage control on distribution networks, network management, and system inertia as issues to be considered with increased intermittent generation. The Australian Greenhouse Office(AGO) commissioned a report[7] which assessed the level of penetration wind energy could make into the electricity networks of Australia without changes to the NER. The report recommended a level of 50% minimum load. In 2004, the Ministerial Council on Energy(MCE) set up the Wind Energy Policy Working Group(WEPWG). A subsection of this group the Wind Energy Technical Advisory Group(WETAG), released a document in 2005[8] outlining the issues arising from increased levels of wind energy, and possible solutions. NEMMCO commissioned a report in 2004 from the Commonwealth Science and Industrial Research Organisation(CSIRO) into possible ways of forecasting wind energy output[9]. This has led to an interim forecasting system, with a future system being developed with funds from the AGO due for release in 2008. NEMMCO also commissioned a report from DIgSILENT into the effects of wind energy on the stability of the electricity network in South Australia[10].

The South Australian(SA) region is weakly connected to Victoria(VIC) by 2 interconnectors,(1) a DC link, 220MW VIC to SA and 120MW SA to VIC, and (2) an AC link, 460MW VIC to SA and 300MW SA to VIC. South Australia has large wind resources and

currently has 8.5% of its electricity produced from wind energy and is expected to grow to 20%. In 2003, the South Australian government requested a study from the Electricity Supply Industry Planning Council(ESIPC) into the effects of the increased wind energy on the supply/demand balance, market signals, peak load, and energy contribution. ESIPC produced the South Australia Wind Study [11]. The AGO also commissioned a report in 2003[12], which highlighted uncertainty in power output forecasts, voltage and frequency disturbances, fault detection and clearing, and the management of voltage and frequency as issues to be considered before the extensive installation of wind farms. In late 2004 the Essential Services Commission of South Australia(ESCOSA), after receiving a large number of license applications, requested another report from ESIPC. The aim of the report was to provide advice on the impacts to the price, quality and reliability of electricity supplied the South Australian consumers with increased levels of wind energy. In March 2005, ESIPC released the Planning Council Wind Report to ESCOSA [13]. In response to the report and consultation with the industry, ESCOSA released licensing conditions for wind farms[14].

2 The life cycle of wind farm facilities

As a way of identifying the issues related to wind farm integration into the electricity system Table 1 was produced. The table displays the life cycle of a wind energy project. The life cycle is broken into the following stages

- Planning
- Construction
- Commissioning
- Operation
- End of life

Each of the stages is separated into **Technical**, **Contractual/legal** and **Financial** aspects. The technical classification is broken down further into *Wind farm* and *Power system* aspects. Each cell contains a brief description of the tasks involved.

The Planning stage is from when the developer wants to build a wind farm until an offer to [construct and] connect is made by the Network Service Provider (NSP) subject to approvals. In this stage the site assessments and initial security assessments are made. Business plans, development proposals and land holder agreements are also formulated.

The Construction stage begins when the connection agreement is signed by the developer and NSP. The developer is then able to build the wind farm and any network augmentations that are required in the connection agreement.

When the wind farm is constructed, the wind farm operator can then submit a registration application submission to the National Electricity Market Management Company(NEMMCO), and also if required, a licence application to relevant state bodies. The wind farm is then commissioned and tested for compliance with the connection agreement and any licence conditions. A security assessment is carried out of the power system with the wind farm and any network augmentations that were made. At the end of the commissioning, the registration application is approved and a licence issued if necessary.

Once registration with NEMMCO is complete the wind farm can generate electricity. All generators larger than 30MW are required to submit forecasts of energy outputs, these forecasts range from 5 minutes to 10 years. The type of registration effects the way the wind farm operates in the market. The wind farm receives income from the generation of electricity and any green certificates it qualifies for. If the wind farm is registered as a

scheduled generator it will be able to provide ancillary services which it can also receive income from.

When the wind farm reaches the end of its life it submits a notice of disconnection to the network service provider. Once this is submitted the wind farm can begin decommissioning the equipment and restoring the environment. The wind farm operator can submit a request to the NSP for the removal of equipment the wind farm had installed which assists in maintaining power system security. Once all of the decommissioning is completed the legal obligations will have terminated.

Table 1 has been categorised into three levels of understanding. These three levels are:

- Green: Understood and implemented
- Orange: Understood but implementation still in progress
- Red: Not fully understood

The following sections will explain the issues that are faced in each categories, the understanding of the issues and any solutions which have been implemented.

3 Red: Not fully understood

In Table 1 the following areas have issues which are not yet fully understood;

- Technical: Operation of the Wind Farm
 - Participation in the Electricity Market
 - Perform within connection agreement
 - Provide forecasts of outputs.
- Technical: Operation of the Power System
 - Maintaining of power system security and reliability
 - Aggregated effect of wind farms
- Contractual: Operation of the Wind Farm
 - Operate under the National Electricity Law [4] and Rules [5]
 - Compile with relevant commercial laws and license conditions

As highlighted in [7], once the installed capacity of wind reaches 50% of the minimum load changes need to be made for the operation of wind energy in the market. This gives a plausible installation of 500MW in South Australia, currently there is 388MW installed with another 973MW approved. As a result there will need to be research into the best ways to facilitate the necessary changes. In the WETAG[8] report of 2005 suggested a ‘semi-dispatch’ method which enables the curtailment of the output from wind farms when there is congestion on the network that services the wind farm. This option is currently being investigated by NEMMCO in conjunction with WEPWG. Current discussions have outlined that a semi-scheduled generator (i.e. wind farm) is required to put offers into the NEM and will be dispatched as part of the optimised dispatch process but won’t be penalised unless they are involved in a network constraint.

A rule change was made in December 2005 [15] for the provision of forecasts for energy output from all generators larger than 30MW. This has raised the need for reliable forecasts. In 2004, the CSIRO produced a report for NEMMCO highlighting possible ways for forecasting wind energy outputs over the timeframes needed for the electricity market,

using current meteorological timeframes and techniques [9]. In response to the report and rule change NEMMCO has commissioned an interim forecasting system [16]. The AGO has setup a project which will help develop a wind forecasting system for the NEM. This project is a collaboration between the AGO, CSIRO, Bureau of Meteorology(BOM) and Centre for Energy and Environmental Markets (CEEM) at the University of New South Wales(UNSW).

As discussed in [12], the locational diversity of wind farms is a large factor in the amount of wind energy the electricity system can take. The aggregation of wind farms is important to minimize the disturbance to the network from a change in the wind. Currently the electricity system views generators as single entities, the increase in wind farms will require research into an optimal way of aggregating wind farms when assessing system security and forecasting energy output. Aggregating wind farms will help reduce the cost and need for ancillary services.

4 Orange: Understood but implementation still in progress

The following areas have been identified in Table 1 as understood but the implementation is still in progress;

- Technical: Planning of the power system
 - Power system security assessment made by Network Service Provider(NSP) [17]
 - A due diligence report prepared by NEMMCO [18]
 - Any network augmentation is specified
- Contractual: Planning of the wind farm
 - Development approvals [19]
 - Initial negotiation with network service providers [17]
 - Agreement with land holders [20]
- Technical: Commissioning of the network augmentation
 - Testing to confirm compliance
 - Confirmation security assessment
- Contractual: Commissioning of the wind farm
 - Approval of registration application [5],[21]
 - Approval of generators license, if appropriate [14]
- Financial: Operation of wind farm
 - Income received from generation of electricity, renewable energy rebates and ancillary service provision
 - Expense of ancillary service use, participation fees, network services, operation and maintenance

The assessment of generator connections individually by NSPs when deciding on the necessary network augmentations has been raised as an issue in [8]. This issue not only applies to wind farms, but is made more visible by increased levels of wind energy penetration. A solution highlighted in [7] is “Integrated regional wind development strategies should be developed, which systematically take into account resource distribution, land use issues,

turbine technology and connection requirements, network voltage and flow constraints and other planning issues.” This would also help in the power system security assessments carried out by the NSPs, allowing them to look at the larger picture when considering new generator applications.

Wind farm owners are confronted with different regulations and planning processes for each state and council. This creates confusion in submitting applications, adds time to the planning approval process and may cause a lack of diversity in wind farm sites. The AGO has recognised this issue and recently released a discussion paper on a National Code for Wind farms[19]. The paper outlines the different planning and regulatory frameworks across the states, which emphasises the need for a national approach to wind farm approvals.

The registration of wind farms as unscheduled generators (as they are intermittent generators), is outlined in [5] and [21]. As unscheduled generators, wind farms are treated as negative demand and don’t participate in the optimised dispatch process of the NEM. This classification doesn’t require wind farms to participate in the supply or use of FCAS. As unscheduled generators they aren’t constrained if there is network congestion. The current technical standards in the NER [5] are designed for synchronous generators making it hard for wind farms to register as a scheduled generator. There has been a rule change proposal submitted by NEMMCO to AEMC [22] which proposes changes to the technical standards to address these issues. As highlighted in Section 3, the possibility of a semi-scheduled registration category is currently being discussed by NEMMCO with WEPWG.

Currently there are varying license requirements for different states. These vary from no license requirements (New South Wales) to specialised wind generator licenses (South Australia [14]). A uniform licensing policy for all states would create more stability for wind farm proposals.

As the Mandatory Renewable Energy Target(MRET) has been met. The decision of the Federal Government not to extend and expand the target or replace it with another program has lead to uncertainty in the financial viability of future wind farm developments. There has been state policies announced which range from a greenhouse gas trading scheme to state wind energy installation targets. To ensure further wind farm developments a national approach needs to be undertaken.

5 Green: Understood and implemented

In Table 1 the following areas were classified as understood and any required changed have been fully implemented;

- Technical: Planning of wind farm
 - Assessment of the viability of the site, design of the wind farm, construction considerations [20],[23],[19].
 - Technical specification provided to the network service provider, including models. [17].
- Financial: Planning of wind farm
 - Preparation of a business plan. Raising of capital to finance the project.
- Technical: Construction of wind farm
 - Build to specification as outlined in the connection agreement
- Technical: Construction of network augmentation
 - Build to specification as outlined in the connection agreement

- Contractual: Construction of wind farm
 - Construction according to specification
- Financial: Construction of wind farm
 - As per budget
- Technical: Commissioning of wind farm
 - Testing to confirm compliance to the standards set out in the connection agreement [17],[24],[25]
- Financial: Commissioning of wind farm
 - Registration [21] and licensing fees.
 - Commissioning costs.
- Technical: End of life for the wind farm
 - Disconnection and disposal of equipment.
 - Reinstatement of environment. [20]
- Technical: End of life for the wind farm in the power system
 - Disconnection of equipment from the grid, while maintaining power system security.
- Contractual: End of life for the wind farm
 - Decommissioning agreement between the network services provider and generator [5].
 - Planning requirements and obligations to the community at large.
- Financial: End of life for the wind farm
 - Decommissioning and environment restoration costs.

The technical planning of wind farms is covered in [20]. The assessment of the site viability and design of the wind farm are well understood. The technical specifications which are required to be submitted by the wind farm to the NSP are specified in [17], which is part of a series released by NEMMCO in 2006 to make the process of network connection for new generation easily understood.

The construction of the wind farm and necessary network augmentation is completed to the specifications outlined in the planning process, and doesn't raise any issues that need to be addressed with policy.

The commissioning process for wind farms is covered by [17],[24] and [25]. The end of life decommissioning process is specified in the connection agreement between the wind farm owner and NSP as required in the NER[5]. [20] also offers information on best practice for the decommissioning and restoration of the wind farm site.

6 Conclusions

This paper has explored the levels of understanding in each stage of the life cycle of wind farm facilities. The expansion of wind energy will require further research into the following key areas:

- Technical: Operation of Wind Farms
- Technical: Operation of the Power System
- Contractual: Operation of Wind Farms

These areas have raised issues that require a greater understanding into the optimal solution for wind energy's integration into electricity market and power system of Australia.

Changes are also required in regulations and policy for:

- Technical: Planning of the power system
- Contractual: Planning of the wind farm
- Technical: Commissioning of the network augmentation
- Contractual: Commissioning of the wind farm
- Financial: Operation of wind farm

These changes will allow wind farm projects to be built and integrated into the electricity system smoothly.

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Appendix A: Abbreviations

AEMC	Australia Energy Market Commission
AER	Australian Energy Regulator
AGO	Australian Greenhouse Office
AusWEA	Australia Wind Energy Association
BOM	Bureau of Meteorology
CEEM	Centre for Energy and Environmental Markets
CSIRO	Commonwealth Science and Industrial Research Organisation
ESCOSA	Essential Services Commission Of South Australia
ESIPC	Electricity Supply Industry Planning Council
FCAS	Frequency Control Ancillary Services
GWEC	Global Wind Energy Council
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
NER	National Electricity Rules
NSP	Network Service Provider
SEAV	Sustainable Energy Authority Victoria
UNSW	University of New South Wales
WEPWG	Wind Energy Policy Working Group
WETAG	Wind Energy Technical Advisory Group

		Planning	Construction	Commissioning	Operation	End of Life
Technical	<i>Wind Farm</i>	<ul style="list-style-type: none"> • Site assessment • Wind Farm design • Technical specifications 	<ul style="list-style-type: none"> • Build to specification 	<ul style="list-style-type: none"> • Testing of compliance 	<ul style="list-style-type: none"> • Operate to specification • Participation in market(if required) 	<ul style="list-style-type: none"> • Disconnection and disposal of equipment
	<i>Power System</i>	<ul style="list-style-type: none"> • Security assessment • Network augmentation 	<ul style="list-style-type: none"> • Build network augmentation to specification 	<ul style="list-style-type: none"> • Testing of network augmentation compliance • Confirmation security assessment 	<ul style="list-style-type: none"> • Maintain power system security 	<ul style="list-style-type: none"> • Disconnection and disposal of equipment
Contractual	<i>Wind Farm</i>	<ul style="list-style-type: none"> • Development approval • Land agreements • Connection negotiation 	<ul style="list-style-type: none"> • Build to specification 	<ul style="list-style-type: none"> • Registration • License(some states) 	<ul style="list-style-type: none"> • National Electricity Law and Rules • Commercial laws 	<ul style="list-style-type: none"> • Decommissioning agreement (NSP)
	<i>Wind Farm</i>	<ul style="list-style-type: none"> • Business Plan • Capital Raising 	<ul style="list-style-type: none"> • Wind farm • Network augmentation 	<ul style="list-style-type: none"> • Commissioning • Registration and licensing fees 	<ul style="list-style-type: none"> • Sale of • Electricity • Green Certificates 	<ul style="list-style-type: none"> • Decommissioning costs

Legend: *Understood and changes have been made (if required)* *Need additional changes but solvable* *Additional research required, current measures not complete*

Table 1: Life Cycle of Wind Farm Facilities