System Management

Effects of increased penetration of intermittent generation in the SWIS

January 2010

Executive Summary

With the probable introduction of emissions trading in conjunction with the Mandatory Renewable Energy Target (MRET), windfarm penetration in the SWIS is already committed to more than double in size by October 2010 from its current level of 190 MW, and may well increase further over the next few years. One reason for this is that the wind regime across the SWIS area is well suited to the installation of a number of large and small capacity windfarms. Also, while there are numerous alternative renewable technologies other than windfarms, at this stage none provide serious competition to windfarm developments, and therefore the MRET is expected to be largely met by windfarm development.

However, underlying factors in the SWIS have the potential to result in curtailment of windfarm generation. These include:

- increasing Load Following (frequency keeping) Ancillary Service requirements due to intermittent generation of windfarms;
- escalating operational difficulties overnight, due to increased amounts of base load plant, including coal fired thermal generators, cogenerators and windfarms; and
- increasing difficulties in scheduling of balancing energy due to intermittency effects over many time frames (however this may to some extent be mitigated by improved forecasting of windfarm output).

Many of the underlying factors relate to low overnight loads in the SWIS, which requires many generator units to reduce output and to decommit. As the ability to cycle[1] must-run[2] generation is limited, in order to maintain power system security by reducing generation as windfarm penetration increases, a trade-off is inevitable between the cycling of must-run generation and curtailment of windfarms. Thus, to ensure power system security and reliability, the lesser the amount of coal plant cycling, the greater the amount of intermittent generation that must be curtailed.

This report is to brief Participants on analyses completed by System Management and to endorse further work packages of the IMO's Renewable Energy Working Group to examine in more detail the impacts of higher penetrations of windfarms on the SWIS. The analyses performed for System Management do not take into account, amongst other factors, the new State Energy Initiative, a Carbon Pollution Reduction Scheme (CPRS), or security issues stemming from a reliance on gas.

System Management commissioned ROAM Consulting to quantify the extent of windfarm and other must-run generator curtailment in the foreseeable future (from 2009 to 2020). The main issues studied for System Management were the changing requirement for Load Following and degree of curtailment during low levels of demand expected from the increasing penetration of intermittent generation. This report includes two appendices

[1] Cycling refers to decommitment and subsequent commitment of a generator.

[2] A must-run generator cannot be decommitted for commercial or technical reasons.

which detail the assumptions and results of the curtailment analyses using a dispatch merit order (DMO) based on the Wholesale Electricity Market (WEM) Rules as well as a more cost-reflective DMO.

Two cases were defined: higher levels of wind penetration (1400 MW of wind in 2019) and lower levels of wind penetration (950 MW in 2019). Variations in the amount of must-run facilities were also considered, due to the expected changes to the WEM Rules and the consequences of cycling coal-fired plant. Thus the assumptions for 2019/20 for the four final scenarios[3] were[4]:

Scenario	Wind	Must-run plant	Wind in 2019	Coal in 2019	Cogen in 2019	Must-run plant in 2019	Load Following must-run plant in 2019
2	Higher	Lower	1392	2555	1271	876	814
4	Lower	Lower	952	1955	686	431	501
5	Lower	Higher	952	1955	686	1180	501
6	Higher	Higher	1392	2555	1271	1825	814

Must-run facilities were identified on basis of Power System Security. The difference in the level of must-run plant generally relates to the assumption in the higher must-run scenarios that up to 25% of coal-fired facilities are able to be cycled at any time so as to limit the risk to Power System Security and Reliability. This assumption represents a significant departure from the current operating regimes for coal-fired facilities, and puts the generating units into an operating regime not contemplated in their design. The changed operating regime also assumes that other plant, including wind, can be curtailed once the limit of cycling of coal fired facilities is reached. Commercial outcomes for the stations involved would also be changed by this level of cycling and curtailment.

In the lower must-run scenarios, all coal-fired facilities were assumed to be able to be cycled at any time. Co-generation and biomass facilities were also considered must-run plant.

Of importance, the modelling assumed that all plant will reduce outputs to minimum as required during intervals of low demand, particularly overnight. This is not the case under the current WEM Rules, where Verve Energy, as the balancing generator, must operate its portfolio to allow energy schedules[5] of other Participants to be implemented. Therefore,

[3] Following analysis, scenarios 1 and 3, which were similar to scenario 2, were excluded from results.

[4] Note a) figures are approximate, b) must-run plant capacity is based on minimum generation capacity, c) must-run plant capacity for facilities providing Load Following is based on the following calculation: [Minimum Generation Capacity + (Maximum Generation Capacity - Minimum Generation Capacity)/2]).

[5] Under the current WEM Rules, Verve Energy must provide balancing services ahead of any other Participant. Other Participants, known as Independent Power Producers (IPP's), are able to schedule their output as required through Resource Plans. The WEM Rules require that System Management operate Verve Energy facilities to allow the implementation of Resource Plan for other Participants.

current SWIS conditions require curtailment and some cycling of Verve Energy facilities, as facilities on Resource Plan do not reduce outputs to minimum during intervals of low demand. The outcomes from modelling performed do not reflect the full dispatch and decommitment disadvantage imposed on Verve by the current market rules and therefore do not indicate the worst case possible outcomes.

It is expected that changes to the balancing regime in the WEM Rules will introduce a more cost reflective dispatch and commitment regime. The cycling of base load plant would be spread between Verve and the IPPs.

From a System Management perspective the least problematic, and perhaps most probable scenario, is the lower wind higher must run case (scenario 5). Under this scenario the plant mixture features an increasing fleet of open cycle gas turbines (OCGT) in combination with modest growth in wind farms compared to the higher wind penetration scenarios. In this scenario, higher levels of must run plant (eg coal and cogeneration) are also assumed, in line with the assumed changes to the balancing regime previously highlighted. In this scenario, whilst the Mandatory Renewable Energy Target (MRET) is essentially met, there is a gradual reduction in utilisation of must run plant associated with cycling[6] and reserve shutdown[7] of some coal plant as well as minor curtailment of wind farms.

A more problematic scenario assumes higher levels of wind with higher levels of must run plant (scenario 6). In this scenario, a large increase in the fleet of coal and cogeneration plant is assumed, as well as a large growth in the windfarm penetration. In this scenario the increase in the total capacity of windfarms and must-run plant leads to an increase in risk to power system security and reliability. As a result System Management would be increasingly forced to curtail windfarms and to cycle coal-fired generators, or both. In this scenario, the MRET is not met, while wind farm and coal plant utilisation is significantly reduced.

The high wind penetration scenarios (2 and 6) resulted in significant (and untenable) cycling of coal facilities, and also significant curtailment of wind farms. In the higher wind and higher must-run scenario (scenario 6) the degree of wind farm curtailment reached 50% in 2019.

The analysis also showed that the Load Following requirement would increase to around 320 MW in 2019/20 for the higher wind penetration scenarios (2 and 6), and to around 220 MW in 2019/20 for the lower wind penetration scenarios (4 and 5). While scenarios 2, 4 and 5 essentially met the Renewable Energy Target, scenario 6 (higher wind higher must-run) did not.

The results indicated that changing the dispatch merit order (DMO) specified in the Wholesale Electricity Market Rules to a more cost-reflective basis has only marginal impact on the outcomes. The results also indicated that a future generation mix with a more significant proportion of open cycle gas turbines would lessen the amount of windfarm curtailment and cycling of must-run plant.

---

[6] Cycling involves the decommitment and subsequent commitment of a facility.

[7] Reserve Shutdown refers to the decommitment of must-run plant for an extended period due to low demand levels.

Whilst not considered in detail in the studies, it is apparent that energy storage and recovery technologies (e.g. pump storage hydro) have the potential to significantly reduce the impacts of windfarm intermittency and reduce the need for curtailment of windfarm output, as well as helping to mitigate concerns about power system security and reliability associated with high penetrations of windfarms.

Any future generation mix that results in curtailment of windfarms will have a wider impact on Market efficiency including:

- Loss of Renewable Energy Credits (RECS) for intermittent generators;
- Increased out of merit generation which will reduce overall efficiency;
- Increased usage of lower merit (i.e. higher cost) generation to maintain the increased Ancillary Service margins;
- Operation of generators at reduced efficiency due to displacement from intermittent generation.

Therefore, once the implications of curtailment of windfarm production are better understood, retailers may reconsider bilateral purchases of energy. This may reduce the commercial viability of windfarm projects.

While a more definite forecast of future development should be performed[8], the analysis clearly indicates that, without significant complementary resources, high levels of wind penetration in the SWIS will result in significant operational issues.

[8] The Renewable Energy Working Group's Work Package 1 will perform such a forecast.

Table of contents

1 Introduction

The Wholesale Electricity Market Rules impose an obligation upon System Management to ensure the security and reliability of the SWIS, and to dispatch registered generation according to prescribed measures. Currently, with only 190 MW of wind farm capacity, System Management has already been experiencing difficulty in a number of areas including:

- maintaining the system frequency due to large magnitude fluctuations in windfarm output
- meeting overnight low loads with significant must-run generation such as base load plant, cogenerators and windfarms
- ensuring there is sufficient quick start/ stop plant available to commit or de-commit to balance any unforeseen changes to total windfarm output

The capacity of wind on the SWIS is expected to more than double in October 2010, with the commissioning of the 200 MW Collgar Windfarm near Merriden. An expansion of 70 MW at Collgar is expected the following year.

At times the SWIS operating state is nearing the point where System Management must curtail windfarm outputs or face having to cycle baseload facilities. Cycling baseload facilities presents a danger that the facilities will not be available for re-commitment as required on the following day to meet the rapid load rate increase in the morning. This would subject base load plant to increased plant movements thus shortening the maintenance cycle times and reducing plant life.

Given government policy of mandatory renewable energy targets, the amount of windfarm proponents is increasing daily. Currently, a number of large windfarm projects are seeking immediate decisions from Western Power regarding access to the SWIS, and there is in the order of 3 GW of applications for windfarms in the SWIS. Of these, many are dependent on the construction of a 330 KV transmission line to Geraldton, which could provide a significant amount of capacity available to windfarm proponents.

In obtaining access to the SWIS it is important that Participants are made aware of the potential degree of regulatory curtailment which would be required to maintain power system security and reliability. The likelihood of consequential costs to the Market and Renewable Energy Credits (REC) which will be foregone also needs to be considered by windfarm proponents.

In an effort to define the operational outcomes, ROAM Consulting performed analysis for System Management focussing on SWIS operational issues including Load Following and curtailment from overnight operations and increasing penetration of windfarms. This report describes the analyses and summarises the results. The impact on Market outcomes (eg the cost of electricity) is not considered in this report.

While the above analysis is relevant to most other forms of intermittent generation, its focus is on wind powered generation, as wind powered generation is the most mature and dominant renewable technology at this stage, and has the largest number of proponents seeking access to the SWIS.

2 Background

2.1 Current wind farm situation

Currently the SWIS has 3 wind farms with a combined nameplate capacity of 190 MW. The capacity of wind on the SWIS will more than double in October 2010, with the commissioning of the 200 MW Collgar Windfarm near Merriden. An expansion of 70 MW at Collgar is expected the following year.

While the SWIS peak load is increasing at an average of around 4% per year, the system minimum load is growing more slowly at around 1.5% per year (or 50 MW per year). Thus in 5 years the system low load can be expected to increase from its current value of 1500 MW to 1650 MW[9]. However, recent trends indicate the growth in the system minimum low may be as low as 1% per year.

As the amount of generation for which curtailment is undesirable increases (eg. windfarms, base load plant and cogenerators), so too does the difficulty in managing the SWIS system minimum load. Currently, the amount of must-run generation[10] coupled with high penetrations of wind generation is such that at times Load Rejection[11] margin is insufficient at the load trough. This has at times led to the need to curtail windfarm generation. As windfarm capacity increases the need for curtailment can be expected to increase.

Further, since the start of the Market, System Management has been required to increase the quantity of Load Following[12] or frequency keeping from 30 MW to 60 MW, primarily due to the impact of wind generation on system frequency. As windfarms penetration increases, this requirement is expected to increase dramatically. In order to be capable of providing Load Following, a generator must be as flexible as an open cycle gas turbine (OCGT); thermal base-load plant is incapable of such flexibility.

Thus, even the small amount of wind generation capacity has had a significant impact on the operation of the SWIS. The current generation, and expected future installations, forms the basis of assumptions in the analysis.

2.2 Anticipated intermittent generation

Western Power Networks has indicated that approximately 3 GW of wind farm projects are currently requesting access to the SWIS. The actual amount of windfarm connections to the SWIS will be affected by both network capacity and the commercial viability of the projects based on the bilateral purchasing of energy.

---

[9] Note that this is system load as opposed to market load reported by the Independent Market Operator (IMO).

[10] A must-run generator cannot be decommitted for commercial or technical reasons.

[11] Load Rejection is the ability of generation to quickly reduce output following the sudden removal of demand from the SWIS. This Ancillary Service requirement is defined in the Market Rules.

[12] Load Following is an Ancillary Service defined in the Wholesale Electricity Market Rules as the service of frequently adjusting the output of one or more Scheduled Generators within a Trading Interval so as to match total system generation to total system load in real time in order to correct any SWIS frequency variations.

To be commercially viable, generation projects generally require a bilateral agreement with a retailer to purchase the energy produced. Due to the relatively high installation costs of windfarms, commercial viability may depend on the RECs produced. A potential loss of RECs resulting from windfarm curtailment could therefore lessen the viability of a proposed windfarm project.

It is anticipated that the proposed North Country Reinforcement (NCR) 330 kV connections would technically permit up to 400 MW of wind generation once completed. This could be enlarged to 1000 MW if the circuit is doubled. However, there still remains significant uncertainty as to the timing of these developments.

Further, the proposed 220 kV line to Southdown near Albany may permit up to 300 MW of further wind generation in a few years, and it may be assumed that a further 30 MW or more of distribution connected wind generation may be approved over the period 2009/10 to 2015/16 (around 20 sites at 1.6 MW each).

Thus, transmission capacity exists, or is proposed, that can accommodate a large increase in the amount of windfarm capacity on the SWIS.

2.3 Geographical Diversity

Anecdotal evidence and analysis at the 30 minute level indicates that the impact of current wind generation on the system is random, thus adding significantly to the requirement for Load Following. In the SWIS, System Management has been required to increase the load following requirement from 30 MW to 60 MW since the commissioning of Walkaway and Emu Downs windfarms. This is expected to double again once the Collgar windfarm is commissioned.

Analysis in other jurisdictions indicates that, without sufficient geographic dispersion, additional wind generation adds significantly to the requirement for Load Following. Therefore, significant geographical diversity of wind generation may help reduce the rate of increase of Load Following but further analysis is required to determine the effects on the SWIS with more confidence.

Diversity of the geographical locations of windfarms would help ensure that different weather patterns would cause output levels of windfarms to be independent of one another. On the other hand, concentration of windfarms in one geographical location could be expected to cause output levels to be more closely related.

Some initial correlation analysis has been performed on the three windfarms in operation in the SWIS at the 1 minute and 30 minute levels. The results indicate that there is almost no correlation between the Albany wind facility and the North Country facilities (Emu Downs and Walkaway). However, the Walkaway and Emu Downs wind facilities are somewhat geographically close (around 140 kilometres apart), and the outputs have a strong positive correlation (around 0.65). Thus, significant geographic dispersion is required to diminish the effects caused by wind generation in the SWIS.

Wind generation in areas other than the North Country may mitigate or exacerbate the effect of wind generation on Load Following and balancing.

2.4 Renewable generation required for energy targets

The national Renewable Energy Target (RET) for 2020 is 45,000 GWh.[13]. Based on the IMO's 2008 Statement of Opportunities[14], the predicted SWIS energy for 2020 is around 24,840 GWh, while an estimate of the national demand in 2020 is around 292,000 GWh. Given the recent announcement by the Minister that Verve Energy and Synergy will obtain their Renewable Energy Credits (RECs) from WA, then the RET quota will be based on WA's proportion of national demand.

The WA RET requirement will therefore be in the order of 3830 GWh[15], or 15.4% of WA electricity demand in 2020. Note that the requirement is not 20% of energy in 2020. However, as the RET involves banking of RECs, the actual requirement in 2020 may be somewhat less than 3830 GWh.

The requirement can be met by any renewable energy generator, such as wind, biomass, landfill gas, solar or other forms. However, it is anticipated that the requirement will be met mainly by windfarms, due to the lack of maturity of other forms of renewable energy. The installation of future windfarm capacity to meet the RET requirement is one of the primary assumptions used in the analysis.

3 System consequences from increased wind generation

Windfarms, being intermittent generation, can cause, or exacerbate, Power System Security issues that other non-intermittent generation does not. While the analysis examines the degree of windfarm curtailment required from frequency of balancing issues, there are other issues that may result in windfarm curtailment. These technical issues are not modelled in the analysis, but should, at least, be noted. Both system level and locational issues will be discussed.

3.1 System security issues

3.1.1 Frequency issues

Load Following is an Ancillary Service defined in the Wholesale Electricity Market Rules as the service of frequently adjusting the output of one or more Scheduled Generators within a Trading Interval so as to match total system generation to total system load in real time in order to correct any SWIS frequency variations.

The standard for Load Following is the capacity sufficient to cover 99.9% of the short term fluctuations in load and output of Non-Scheduled Generators and uninstructed output fluctuations from Scheduled Generators, measured as the variance of 1 minute average readings around a thirty minute rolling average. At present, all Load Following is provided by Verve Energy.

Effectively, sufficient Load Following provides the ability for the system to absorb changes in system load. As discussed, as the variation in windfarm output increases, so too does

---

[13] http://www.climatechange.gov.au/renewabletarget/index.html

[14] The 2008 Statement of Opportunities, prepared by the IMO, is available from www.imowa.com.au.

[15] This result determined by the WA proportion of national demand multiplied by 45000.

the demand on load following. Also, increased variation in windfarm output is likely to lead to larger swings in system frequency, particularly in periods of rapid system load variation such as the morning rise to the system peak[16].

As the Wholesale Electricity Market design does not take limited system ramping capacity into account[17], therefore generators of Independent Power Producers (IPP)[18] can ramp up or down exceedingly quickly to meet Resource Plans without regard to system security and reliability. The consequence of large variations in scheduled generator and windfarm output may result in frequency excursions outside the operating limits defined in the Technical Rules.

If the imbalance in load and generation is in the other direction[19] there is the possibility of SWIS frequency being driven to critically high values with the consequential tripping of windfarm and other generators on over-frequency[20]. This has a further consequence that the system frequency could then drop to critically low levels as the windfarm contribution to system total generation is suddenly decreased.

3.1.2 Balancing energy requirements (in various time frames)

Verve Energy's balancing generators are committed and dispatched in various time-frames to ensure that there is sufficient generation to meet demand, but also to vary in accordance with other system requirements such as movements of IPP facilities and Ancillary Services. The variation of wind generation coupled with the longer lead times for decommitment and recommitment decisions for thermal based generators adds to this complexity. The current Market Rules require that Verve Energy be displaced prior to moving IPPs off resource plan to provide increased margins to balance the intermittent generation outputs.

As the SWIS is isolated and not interconnected with significant external systems, as is the case for many other systems, flexible generation is required to match the variability of wind generation over several time frames. Thus, as the penetration of windfarms increase, there will be a requirement for increased flexibility in the capacity available which may have a consequential effect on market efficiency and potentially market design.

To assist it in making commitment and dispatch planning decisions System Management is seeking approval in its Allowable Revenue submission to complete investigation and implementation of an industry standard windfarm output forecasting system.

3.1.3 Security issues from low overnight minimum loads

As discussed, maintaining Power System Security during low load overnight periods with high output of wind and significant amounts of must-run generation is increasingly an issue

---

[16] SWIS demand increases at up to 10 MW/minute in the morning rise to the daily peak.

[17] System Management is considering changes to the WEM Rules in this area.

[18] IPP refers to any non-Verve Energy generator.

[19] In this situation load is decreasing and generation is increasing.

[20] It may be possible to ameliorate this effect by imposing a requirement for windfarms to reduce output as the frequency increases. This requirement is being considered by System Management, but would require changes to the Technical Rules.

for System Management. While the peak load is increasing at an average of around 4 percent per year (or an increase of 150 MW), the system low load is growing more slowly at around 1.5 percent per year (or an increase of 50 MW per year). This would result in the system low load increasing from its current value of 1,500 MW to 1,650 MW over 5 years[21].

During this period, total generation capacity is expected to increase substantially due to system peak load growth, and new generation may well be must-run plant. Currently, the amount of "industrial process-based" generation coupled with high penetrations of wind generation, which can comprise up to 10 percent of total generation, is such that at times, there has been a need to curtail wind farm generation in order to maintain Power System Security. As intermittent generation capacity, such as wind farms, or must-run generation increases the need for curtailment can be also expected to increase.

System Management also experiences some difficulty in ensuring security over a 24 hour time frame as the Market Rules require Verve Energy to balance the SWIS. With the current levels of "industrial process-based" generation, System Management must de-commit Verve Energy before curtailing other Participants. As much of Verve Energy's plant is coal or gas fired thermal generation it is not well suited to daily cycling. Therefore, there is a risk that the facilities may not be available for the morning peak, creating a security concern. This risk escalates with an increase in must-run plant.

As the Market does not discriminate between generation types the quantity of "industrial process based" generation on the SWIS may increase, leading almost inevitably to cycling of Verve Energy thermal facilities coupled with curtailment of wind generation. Neither of these measures is likely to be introduced without difficulty.

3.1.4 Impacts on scheduled generators and the SWIS

The above discussion has indicated several consequences for scheduled generators on the SWIS. The quantity of "industrial process-based" and wind generation on the SWIS has been increasing each year, and current market conditions are resulting in Verve Energy base load generation being cycled at night. As coal and gas fired thermal generators are not suited to cycling, due to their design as base load plant, there are several short- and long-term effects.

In the long-term, thermal cycling may well result in increased wear and tear, increasing generator maintenance which may reduce the reliability of the facilities.

In the short-term, cycling may prevent the thermal generators from being available as required the next day, which will result in increased consumption of gas and potentially liquid fuels. This may also, at times, reduce system security and reliability through reduced generation available to meet the system peak, as well as reduced amount of liquid or gas fuel needed to meet the daily requirements.

Essentially, due to the Market Rules requirement that all Resource Plans and intermittent generation must be accommodated, Verve Energy facilities must be curtailed and decommitted as much as possible. The issue is most manifest between 3 am and 4 am, during the system load minimum. Thus, whereas the SWIS is secure at other times, it is during those hours that there may be generation in excess of demand.

---

[21] Recent trends indicate the growth of the system low load to be as low as 1% per year. Note that this is system load, as opposed to market load reported by the Independent Market Operator (IMO).

At these times, Verve Energy generators are operating at their minimum levels, and the next step, required by the Market Rules, is to decommit Verve Energy generators (such as Muja generators or Collie Power Station) before generators of other Participants, including most windfarms, are curtailed. However, decommitment and recommitment of coal facilities is a process that takes many hours. Also, due to limitations on gas availability, virtually all Verve Energy coal facilities are required to be in operation in order to meet the system peak. Further, coal facilities such as Muja and Collie Power Station are not designed to be cycled[22] on a daily basis, and therefore the reliability of such cycled generators being available to meet the system peak reduces. This may result in involuntary load shedding.

Therefore, in order to maintain system security while complying with the Market Rules, System Management must consider the risk to power system security and reliability at the system peak, by cycling Verve Energy coal facilities.

Thus, along with increased windfarm capacity, the quantity of must-run generation on the SWIS may increase, leading almost inevitably to cycling of Verve Energy thermal facilities coupled with curtailment of wind generation. Neither of these measures is likely to be without difficulty.

3.2 Locational issues

Aside from system wide issues, additional wind generation may impose significant regional transmission issues where the load centre is not closely coupled to the main network.

Due to the wind resource, most proposed windfarm localities are at the boundaries of the SWIS network where transmission capacity is limited or fully utilised. For example, the capacity of the North Country 132kV network is fully utilised by existing generation. To overcome transmission capacity limitations to allow significant windfarm capacity to connect to SWIS, network reinforcement is often required.

3.2.1 Island operation

The physical location of wind generation on the SWIS can impose significant requirements. For example, while the Alinta and Emu Downs wind generation facilities are 140 kilometres apart, they are located in the same region of the North Country. Thus, when the North Country is islanded the combined output of these facilities may need to be curtailed to ensure that frequency in that region can be controlled.

3.2.2 Regional connection constraints

Many Participants, not just wind facilities, are often unwilling to bear the expense of additional transmission capacity to mitigate the risk of transmission constraints. As a consequence, participants will often accept run-back schemes as a condition of access to the SWIS. These schemes ensure the output of the facility is curtailed to ensure that the transmission constraint is not exceeded. Note that these constraints are not related to Market outcomes and occur under the Technical Rules, not the Market Rules.

These locational measures are impacted by both the amount and type of generation in the general region. Thus, for example, further wind generation in the North Country may impact the run-back schemes of existing facilities.

---

[22] Cycling refers to the decommitment and re-commitment over a generator, usually within a 24 hour period.

It should be noted that both the Walkaway and Emu Downs facilities have run-back schemes as a condition of access to the SWIS. The Collgar facility is also expected to have several run-back schemes applicable.

3.2.2.1 Thermal Constraints

Relatively weak interconnection between the main grid and a regional load area with local generation exposes the local generation to the possibility of runback if the interconnection is not rated to support the load flow for the first contingency. First contingencies in this case may include loss of local generation, major loss of local load (eg load rejection) or tripping of one of the interconnection circuit elements.

3.2.2.2 Reactive power and voltage security

Where real power transfer increases the demand for reactive power to cover losses increases. Additional reactive support equipment is often required at remote locations from the source of the increased demand for reactive power. This equipment often needs to be dynamic.

Therefore, windfarms located at remote areas, may increase the requirement for dynamic local reactive power support.

3.2.2.3 Potential for synchronous stability issues

Where the regional interconnection to the main grid is weak there is increased potential for synchronous instability problems to occur with existing synchronous generators as more intermittent generation is added. Fault clearance timing is critical to the prevention of synchronous instability during fault conditions. It may be necessary for additional measures such as dynamic VAR compensation devices to be installed where windfarms worsen the synchronous stability situation.

4 Consequences of curtailment

As discussed, there are many issues related to intermittent generation that may affect Power System Security. To maintain security and balance system load the Market Rules dispatch merit order requires System Management to adjust the load of all Verve Energy plant before the outputs of Independent Power Producers[23] (IPPs) can be varied.

Therefore, this may require taking plant off line overnight which may render it unavailable the following morning. In some cases this may directly cause a risk to system security because of inadequate supplies of alternative fuels (gas and or liquid). This may also cause a risk to system security in the longer term.

Reducing the number of fast moving and flexible generation on line may also cause further risks to system security and reliability. Once overnight decommitment decisions are made, if unforeseen increases in wind generation result in Load Following (frequency keeping) issues, the only option available to System Management to preserve power system security may be to curtail to wind generation.

For the windfarms, and the market, the following would result:

[23] An IPP refers to any non-Verve Energy facility.

- lost energy- the wind generator would be prevented from generating above a set level, which may be zero. This may also affect the level of Capacity Credits in future years;
- RECS would be forgone;
- Dispatch Instructions – in order to curtail generation, System Management would issue a Dispatch Instruction (DI) in accordance with the Dispatch Merit Order (DMO). However, in the cases of a security or reliability issue, System Management may be forced to deviate from the DMO if required for system security or reliability reasons;
- commitment of other plant – to replace the capacity and energy of curtailed windfarms, other plant may need to be dispatched or committed to meet the load demand; and
- increased demand for ancillary services.

Therefore, as the ability to cycle must-run generation is limited, in order to maintain power system security by reducing generation, a trade-off will occur between the cycling of must-run generation and curtailment of windfarms. Thus, to ensure power system security and reliability, the lesser the amount of coal plant cycling, the greater the amount of intermittent generation that must be curtailed.

In order to determine the amount of curtailment that may be required, System Management commissioned analysis which will now be discussed.

5 Analysis undertaken

5.1 Analysis required

Analysis was undertaken by System Management to quantify the extent of windfarm and other must run generator curtailment in the foreseeable future. The main issues regarded the changing requirement for Load Following and degree of curtailment during low levels of demand expected from the increasing penetration of intermittent generator. The period of the study was 2009 until 2020.

5.2 Scenarios

Initially, one wind installation scenario was used, with several timing variations of the commissioning of scheduled generation (scenarios 1, 2 and 3). Following the initial results, it was determined that a more wide-ranging base of installation assumptions was required.

Two final cases were defined: higher levels of wind penetration (1400 MW of wind in 2019) and lower levels of wind penetration (950 MW in 2019). Variations in the amount of must-run facilities (ie generation, which for technical or commercial reasons cannot be decommitted) were also considered, due to the expected changes to the WEM Rules and the consequences of cycling coal-fired plant.

Thus the assumptions for 2019/20 for the four final scenarios[25] were[26]:

Scenario	Wind	Must-run plant	Wind in 2019	Coal in 2019	Cogen in 2019	Must-run plant in 2019	Load Following must-run plant in 2019
2	Higher	Lower	1392	2555	1271	876	814
4	Lower	Lower	952	1955	686	431	501
5	Lower	Higher	952	1955	686	1180	501
6	Higher	Higher	1392	2555	1271	1825	814

Must-run facilities were identified on basis of Power System Security. The difference in the level of must-run plant generally relates to the assumption in the higher must-run scenarios that only 25% of coal-fired facilities are able to be cycled at any time so as to limit the risk to Power System Security and Reliability This assumption represents a significant departure from the current operating regimes for coal-fired facilities, and puts the generating units into

[25] Following analysis, scenarios 1 and 3, which were similar to scenario 2, were excluded from results.

[26] Note a) figures are approximate, b) must-run plant capacity is based on minimum generation capacity, c) must-run plant capacity for facilities providing Load Following is based on the following calculation: [Minimum Generation Capacity + (Maximum Generation Capacity - Minimum Generation Capacity)/2]).

an operating regime not contemplated in their design. This operating regime also assumes that other plant, including wind, can be curtailed once the limit of cycling of coal fired facilities is reached. Commercial outcomes for the stations involved would also be changed by this level of cycling and curtailment.

In the lower must-run scenarios, all coal-fired facilities were assumed to be able to be cycled at any time. Biomass plant and "industrial process-based"[27] generation (known as cogenerators) was also considered must-run.

Of importance, the modelling assumed that all plant will reduce outputs to minimum as required during intervals of low demand, particularly overnight. This is not the case under the current WEM Rules, where Verve Energy, as the balancing generator, must operate its portfolio to allow energy schedules[28] of other Participants to be implemented. Therefore, current SWIS conditions require curtailment of intermittent generation and some cycling of Verve Energy facilities, as facilities on Resource Plan do not reduce outputs to minimum during intervals of low demand. It is expected that changes to the balancing regime in the WEM Rules will remove this discrepancy, and the modelling included this assumption. In a more cost reflective balancing regime some cycling of base load IPP plant would also be likely.

It should be noted that the lower wind scenario meets the SWIS peak demand requirements through higher penetration of open cycle gas turbines (OCGT).

The analyses were then conducted using a dispatch merit order based on the existing Market Rules. Essentially, the current Market Rules require all Verve Energy plant to be curtailed and decommitted before the plant of other Participants is curtailed. As the majority of wind farms are operated by Participants other than Verve Energy, the Market Rules require that, should demand be insufficient, Verve Energy coal facilities, such as Collie Power Station, should be curtailed and decommitted prior to wind farms being curtailed.

Following the production of these results, and given current political considerations, it was then determined that the analysis should be performed using a more cost-reflective based

---

[27] For example, cogenerators exist to provide steam which is used in a commercial process. The electricity is basically a by-product, but to produce the steam, the electricity must be produced. If the steam is not produced the plant which relies on it (often an extremely expensive refinery process), must shutdown. In addition to commercial reasons, this may also affect safety. Consequentially, the generator producing the steam may not be able to respond to an instruction to turn off, and may not respond to an instruction to be curtailed past a certain point, which may, in turn, affect system security.

[28] Under the current WEM Rules, Verve Energy must provide balancing services ahead of any other Participant. Other Participants, known as Independent Power Producers (IPP's), are able to schedule their output as required through Resource Plans. The WEM Rules require that System Management operate Verve Energy facilities to allow the implementation of Resource Plan for other Participants.

[30] Note a) figures are approximate, b) must-run plant capacity is based on minimum generation capacity, c) must-run plant capacity for facilities providing Load Following is based on the following calculation: [Minimum Generation Capacity + (Maximum Generation Capacity - Minimum Generation Capacity)/2]).

dispatch merit order. That is, both Verve Energy and other Participant's plants would be curtailed and decommitted based on an estimate of the short-run marginal cost of the facility. This merit order required that intermittent generation only be curtailed if the alternative was to decommit must-run facilities. Therefore, Verve Energy coal facilities that were not deemed must-run would still be decommitted prior to wind farms being curtailed.

In order to simplify the analyses, the wind installation was deemed to occur in one of four locations (adjacent to existing wind generation sites): Merriden, Albany, Emu Downs and Walkaway. Because of this assumption it was possible to utilise existing generation data for the 2007-08 year as a basis for the study. In effect, the wind profile for 2007-08 was identical for each year of the study and varied only according to the installation schedule.

The installation assumptions were not based on economic modelling, and the analyses did not consider network constraints, the new State Energy Initiative, security issues stemming from a reliance on gas, or a Carbon Pollution Reduction Scheme (CPRS).

The installation schedules and results are provided in two reports attached, detailing the analysis of future curtailment of wind generation.

5.3 Load Following

5.3.1 Background

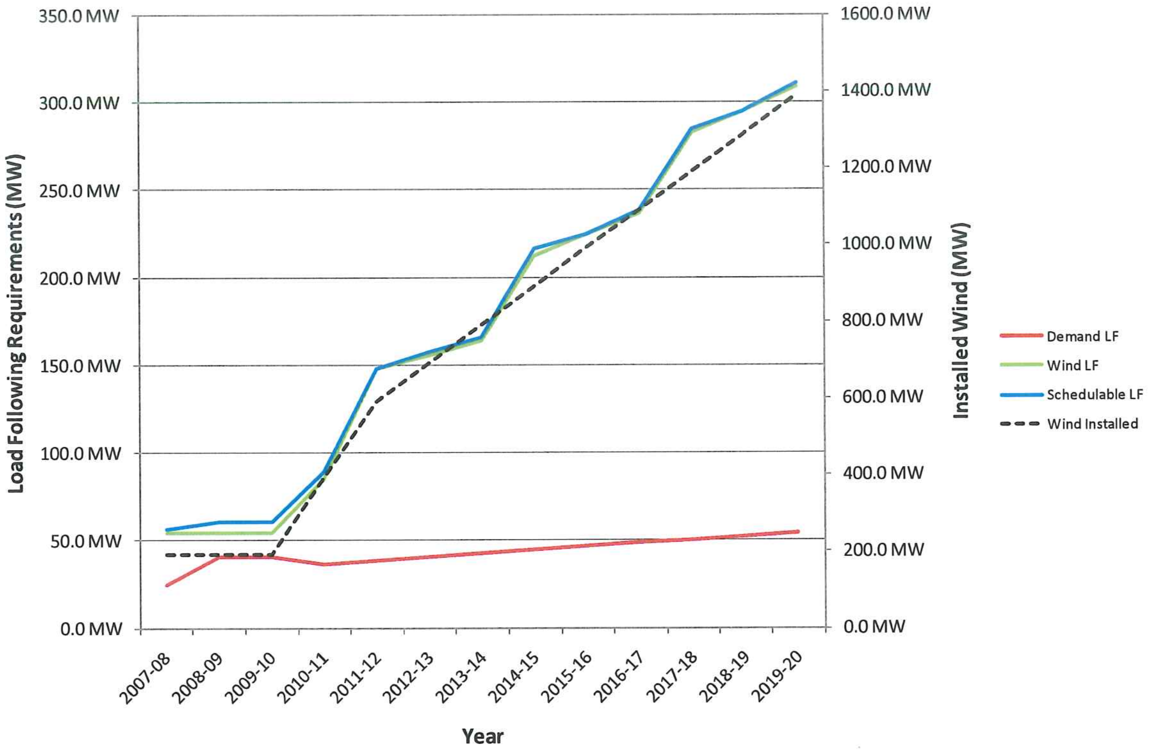
Load Following is an Ancillary Service defined in the Wholesale Electricity Market Rules as the service of frequently adjusting the output of one or more Scheduled Generators within a Trading Interval so as to match total system generation to total system load in real time in order to correct any SWIS frequency variations.

The standard for Load Following is the capacity sufficient to cover 99.9% of the short term fluctuations in load and output of Non-Scheduled Generators and uninstructed output fluctuations from Scheduled Generators, measured as the variance of 1 minute average readings around a thirty minute rolling average. At present, all Load Following is provided by Verve Energy.

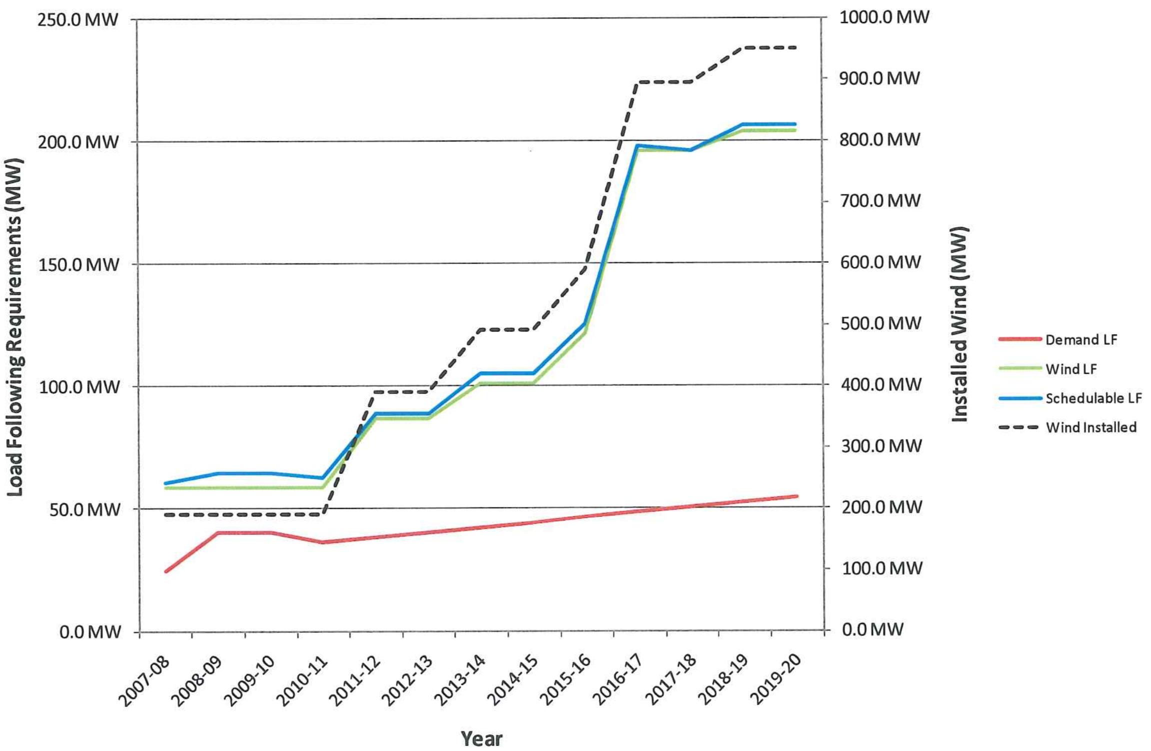
ROAM Consulting (ROAM) undertook analysis to determine the impact of future wind farms on Load Following. Based upon historical data provided by System Management, ROAM determined the expected output of existing and proposed wind generators at various times of day and during various parts of the year. From this, ROAM determined the expected size and requirement (ie ramp rates) on Load Following of the total proposed installed capacity of wind farms for the installation schedule.

Based on the installation schedule defined in the attached reports the conclusions are detailed in the following graphs, and indicate a significant increase in the requirement for Load Following as indicated in the following graphs.

5.3.2 High wind scenario- Load Following requirement



5.3.3 Low wind scenario- Load Following requirement



5.4 Curtailment

System Management also engaged ROAM to determine the expected operation of facilities based on the future scenarios. This provided indications of the degree of cycling of coal generation and curtailment of wind generation that would be required to maintain Power System Security as an outcome of the type, quantity and operation of generation in the SWIS. The analysis did not consider technical issues such as curtailment from run-back schemes.

As discussed, an increase in the number of windfarms and must-run plant will lead to a gradual increase in risk for power system security and reliability, and as a result System Management will be increasingly forced to curtail windfarms or cycle coal-fired generators. To ensure Power System security, the cycling of coal-fired generators may need to be limited, and therefore, depending on the extent of windfarm penetration and must-run plant, curtailment of intermittent generation will be required.

The analysis does not consider other mechanisms to reduce minimum generation capacities of scheduled generation below levels indicated in Standing Data.

5.4.1 General conclusions

In brief the conclusions from the attached reports are:

- Results are largely identical using a Market based or cost-reflective dispatch merit order. Due to this, further discussion will only consider the Market based dispatch merit order.
- As must-run plant increases, wind-curtailment or cycling of coal plant, or a combination of both, increases due to low overnight loads. Therefore, in either the higher wind or the lower wind scenario, the impacts are exacerbated by the presence of increased levels of must-run plant. However, to ensure Power System Security and Reliability, the cycling of coal-fired plant must be limited, therefore further discussion will only consider higher levels of must-run plant.
- The higher wind scenarios result in significantly lower emissions, while the lower wind scenarios do not increase emissions.
- In each scenario, as wind penetration increases the Load Following requirement increases, adding a significant must-run burden.
- Higher amounts of wind penetration with moderate/higher amounts of must-run plant result in significant wind-curtailment and significant (probably untenable) cycling of coal plant.
- With higher amounts of wind penetration and moderate/high amounts of must-run plant capacity factors of coal plants decrease from 70% to 30%, and cycling of Verve/IPP coal plants rise to once a day (which is not feasible for Power System Security).

5.4.2 Wind curtailment results

In order to discuss wind curtailment results, the core assumptions should be reiterated. As discussed, the final assumptions for 2019/20 were[30]:

Scenario	Wind	Must-run plant	Wind in 2019	Coal in 2019	Cogen in 2019	Must-run plant in 2019	Load Following must-run plant in 2019
2	Higher	Lower	1392	2555	1271	876	814
4	Lower	Lower	952	1955	686	431	501
5	Lower	Higher	952	1955	686	1180	501
6	Higher	Higher	1392	2555	1271	1825	814

The analyses assumed that all facilities reduce output to minimum technical operation limits during intervals of low demand, particularly overnight. As discussed, the current WEM Rules are at variance with this assumption, and wind farms are currently being curtailed (though this is expected to be remedied). Therefore the outcomes may be optimistic.

The Table below shows the amount of wind curtailment occurring in the study by year for each case. In all scenarios except scenario 6, it is not necessary to curtail wind for reasons related to ancillary services until 2015-16. However, in the high wind scenarios, by 2019-20 a large proportion of the total wind energy is not able to be dispatched due to the large quantity of plant that must be kept online to provide the Load Following service.

Scenario		4	5	**Scenario**	2	6
Wind		Low	Low	**Wind**	High	High
Must-run		Low	High	**Must-run**	Low	High
Year	**Total Installed Wind (MW)**	**% of Annual wind energy curtailed**		**Total Installed Wind (MW)**	**% of Annual wind energy curtailed**	
2010-11	190.7	0.00%	0.00%	391	0.00%	0.00%
2011-12	390.7	0.00%	0.00%	591	0.00%	0.70%
2012-13	390.7	0.00%	0.00%	691	0.00%	1.10%
2013-14	490.7	0.00%	0.00%	791	0.00%	11.20%
2014-15	490.7	0.00%	0.00%	891	0.10%	18.00%
2015-16	590.7	0.00%	0.20%	991	1.00%	28.80%
2016-17	895.7	0.00%	5.00%	1091	2.90%	42.60%
2017-18	895.7	0.00%	4.50%	1191	3.90%	48.80%
2018-19	950.7	0.00%	5.40%	1291	9.30%	56.40%
2019-20	950.7	0.00%	4.60%	1391	14.90%	61.50%

It should be noted that the MRET requirement is satisfied by all of the above scenarios with the exception of scenario 6.

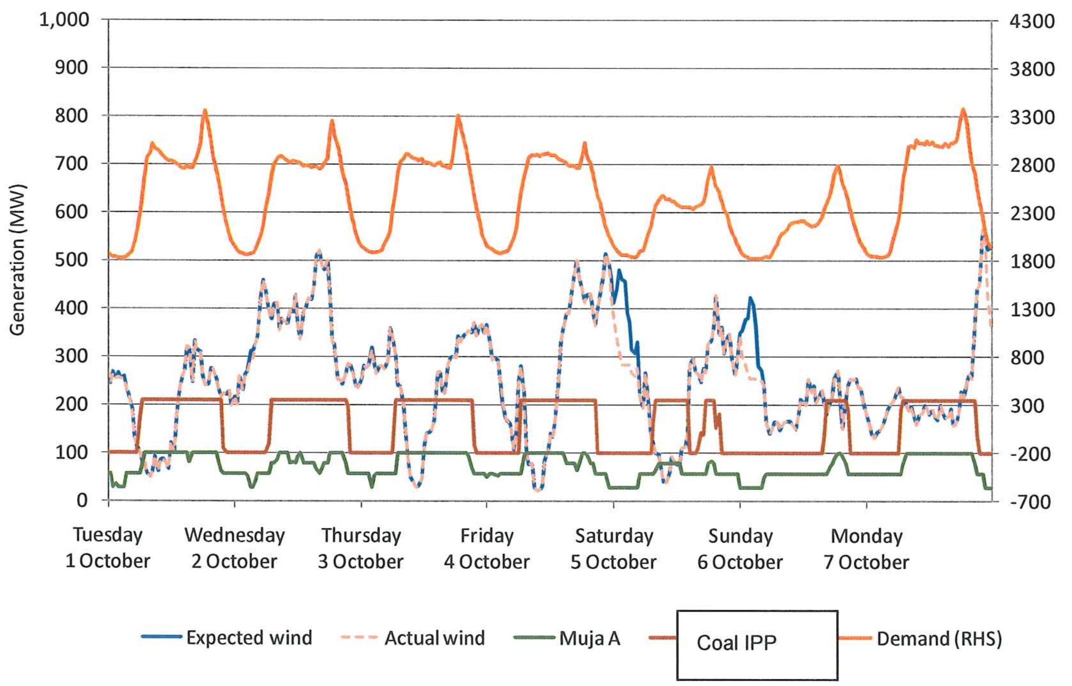
5.4.3 Low Wind Outcomes

5.4.3.1 Scenario 4 and 5 results

The following discussion relates to scenario 5 (lower wind, higher must-run scenario) using a Market DMO, but applies to the results of all lower wind scenarios.

Wind farms, on occasion, are required to be constrained under this installation schedule, as shown in the following graph. The blue line indicates the amount of wind generation that was technically available, and the red (lower) line shows how much of that wind generation could actually be dispatched.

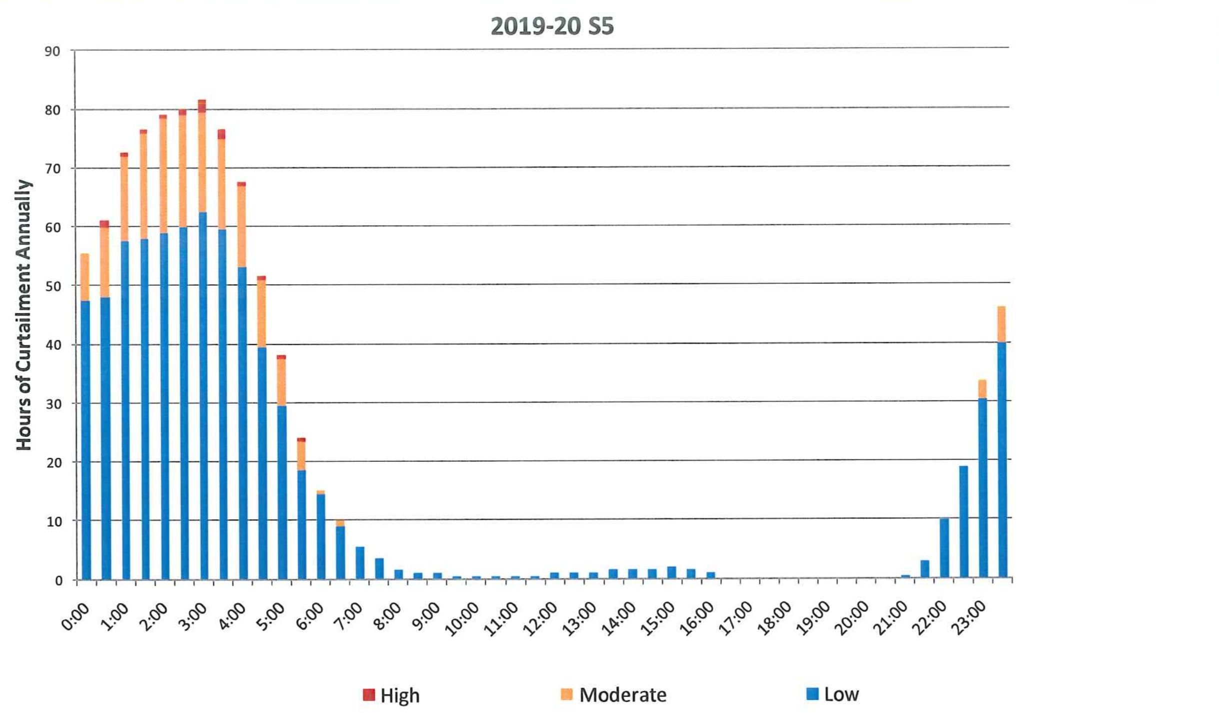
Wind curtailment in 2019-20 (Scenario 5)



In this scenario, wind is constrained first in every period and therefore lower levels of cycling occur. In scenario 4 (lower wind, lower must-run), by comparison, due to the mix of machines in service, cycling occurs as required and therefore wind output is not curtailed.

The following graph indicates the timing of curtailment. *High* curtailment (shown in red) is defined as curtailment of more than 50% of the total installed wind farm capacity in that year. This level of curtailment occurs occasionally during overnight periods, accompanied by moderate levels of curtailment.

Hours of curtailment by time of day in 2019/20 (Scenario 5)



High – More than 50% of the wind capacity was curtailed
Moderate – Between 25% and 50% of the wind capacity was curtailed
Low – Between 0% and 25% of the wind capacity was curtailed

In the lower wind scenarios, gas generation increases in response to the entry of new gas plant. Combined cycle gas turbine (CCGT) generators maintain capacity factors throughout the study. OCGT generation shows relatively significant increases in capacity factor, due to the rapidly increasing amount of plant required to operate constantly for load following purposes (OCGT units being the primary providers of load following). As soon as a plant is required for load following, it operates consistently at a high capacity factor. With a large quantity of OCGT plant required to be online to offer load following in future years, the cost impact may be significant.

The greenhouse emissions from the SWIS change over time as the generation mix changes. Emissions from coal generation decrease due to displacement by wind and gas in the later years of the study. Emissions from gas generation increase over the study, due to the entry of new gas plant. Cogeneration[31] and wind generation maintain capacity factors throughout the study.

5.4.3.2 Conclusions and recommendations for the lower-wind scenarios

With around 950 MW of wind generation installed in the SWIS in 2020, the operation of the SWIS will need to vary from the present method. Currently, 60 MW of load following is required to manage the variability in the demand and installed wind. With the introduction of the amount of wind generation included in this study, the load following requirement is forecast to increase to 220 MW by 2019-20. This will necessitate the constant operation of

[31] As discussed, cogenerators are must-run plant.

a significant quantity of plant capable of providing load following and balancing energy (typically OCGT plant). This mode of operation, while not resulting in wind curtailment or technically infeasible levels of cycling of coal plant, is likely to be significantly less efficient and more expensive than current operations. Nevetheless there is a significant departure from the current operating regimes for coal-fired facilities into a regime not contemplated in the plant design.

5.4.4 High Wind Outcomes

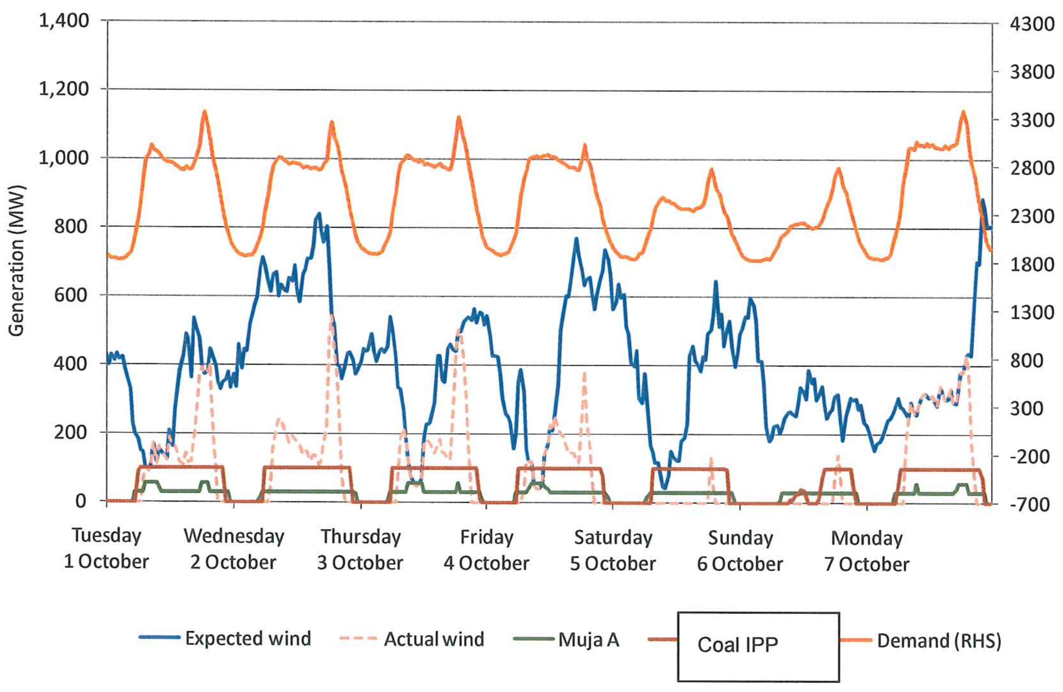
5.4.4.1 Scenario 2 and 6 results

The following discussion relates to scenario 6 (higher wind, higher must-run scenario) using a Market DMO, but applies to the results of all higher wind scenarios.

In this scenario wind farms in overnight periods are completely constrained off, due to demand being met by load following gas plant and must run coal plant. However, even some of the "must run" coal plant is forced to cycle during overnight periods due to the large quantity of load following gas plant online (demonstrated below for Coal IPP and Muja A). By comparison, in scenario 2 (higher wind, lower must-run), curtailment of wind is forecast to typically occur during overnight periods, when the demand is low.

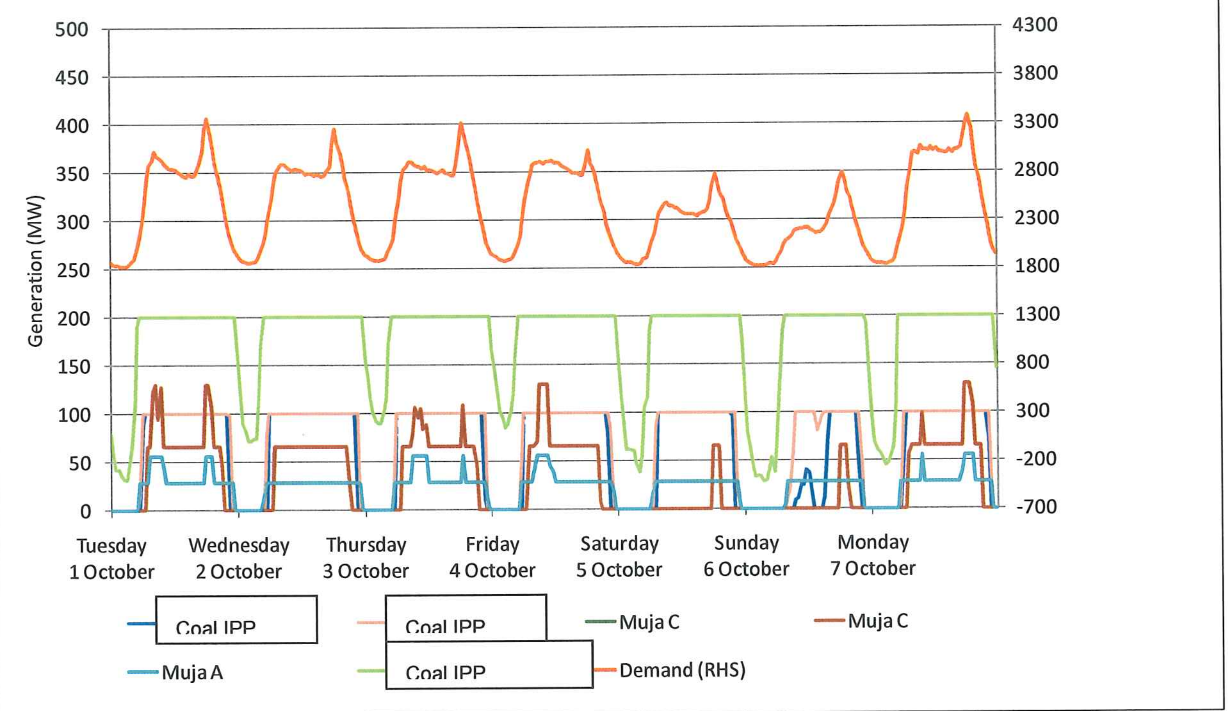
The figure below shows a sample week where high levels of wind curtailment occurred, due to high output from the wind generation. The wind generation had to be significantly curtailed to allow the required Load Following plant and other must-run plant to remain online. The blue line indicates the amount of wind generation that was technically available, and the red (lower) line shows how much of that wind generation could actually be dispatched.

Wind curtailment in 2019-20 (Scenario 6) – high levels of curtailment



In this scenario, several coal power stations are still required to cycle, despite their must-run status, during periods of high wind/low demand as shown in the following graph. The large amount of wind combined with the correspondingly large amount of load following gas plant exceeds demand on a regular basis. It should be noted that this degree of cycling, once every day, is infeasible from a Power System Security perspective.

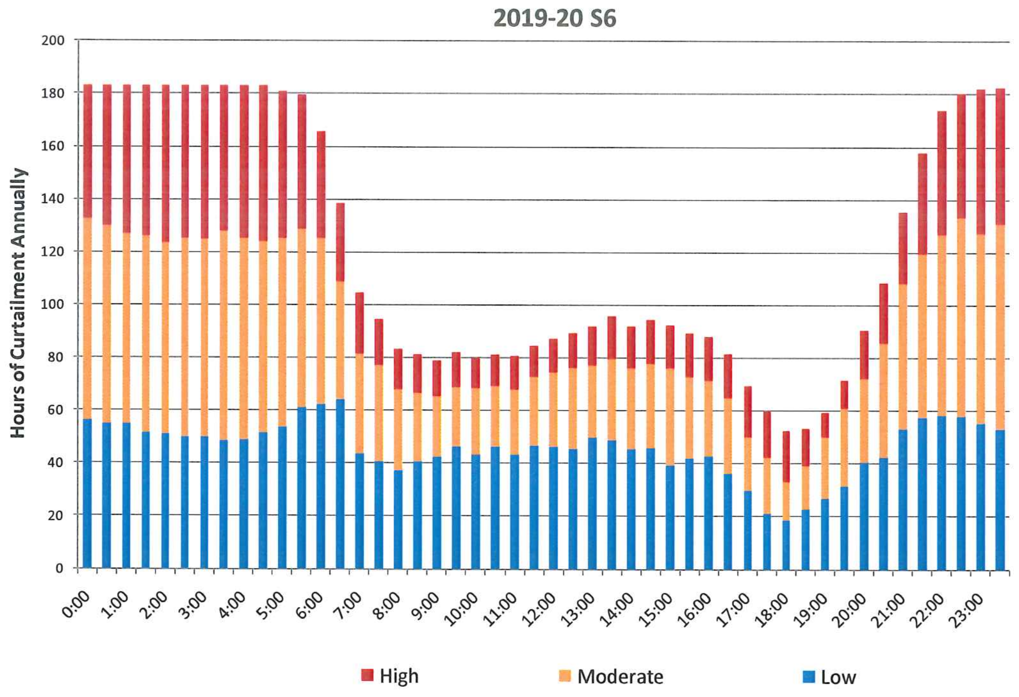
Time-sequential generation of coal-fired plant in 2019-20 (Scenario 6)



The Figure below shows the number of hours in each period of the day where wind curtailment occurred in the final year of the study (2019-20). *High* curtailment (shown in red) is defined as curtailment of more than 50% of the total installed wind farm capacity in that year. This level of curtailment occurs throughout each day. Thus, during day-time periods curtailment is observed for approximately 10 hours in each half-hourly period during the middle of the day (ie in the order of 11 hours of *high* curtailment were observed between 10.30 am and 11 am during the year, 12 hours between 11 am and 11.30 am, and so on), while up to 50 hours of high curtailment are observed during each half-hourly period overnight.

Moderate levels of curtailment (25-50% of wind farm capacity) were also observed in all periods, but similarly occurred more often during overnight periods. Commercial outcomes for the windfarms involved would be significantly altered by this level of curtailment.

Hours of curtailment by time of day (Scenario 6, 2019-20)



High – ***More than 50% of the wind capacity was curtailed***

Moderate – ***Between 25% and 50% of the wind capacity was curtailed***

Low – ***Between 0% and 25% of the wind capacity was curtailed***

In the high wind scenarios, coal generation reduces significantly in response to the entry of large quantities of wind generation (in excess of the load growth). Coal generator capacity factors reduce significantly to between 25% and 40% by 2019-20 (averaged across all coal generators). Commercial outcomes for the stations involved would be significantly altered by this level of cycling.

Gas generation increases in response to the entry of new gas plant. Combined cycle gas turbine (CCGT) generators maintain capacity factors throughout the study. OCGT generation shows significant increases in capacity factor, due to the rapidly increasing amount of plant required to operate constantly for load following purposes (OCGT units being the primary providers of load following). As soon as a plant is required for load following, it operates consistently at a high capacity factor. With a large quantity of OCGT plant required to be online to offer load following in future years, the cost impact may be significant.

The greenhouse emissions from the SWIS change over time as the generation mix changes. Emissions from coal generation decrease dramatically since most coal plant has significantly reduced generation volumes in the later years of the study. Emissions from gas generation increase over the study, due to the entry of new gas plant. Cogeneration and wind generation maintain capacity factors throughout the study except for a small drop in wind generation capacity factor in the final year, due to curtailment in overnight periods.

Due to the increasingly large quantity of OCGT plant that must be kept online to provide load following as windfarm penetrations increase, coal plant is operated on a cycling basis, turning off completely overnight. This is likely to be expensive and may be technically difficult or infeasible. The extent to which these generators can be operated in this fashion will need to be investigated and if necessary operation routines varied.

5.4.4.2 Conclusions and recommendations for the higher-wind scenarios

With such a large quantity of wind generation installed in the SWIS (almost 1400 MW by 2020) and a significant amount of must-run plant, the system will need to be operated in a significantly different fashion. With the introduction of the amount of wind generation included in this study, the load following requirement is forecast to increase to 321 MW by 2019-20. Similarly, the ramp rate requirement is forecast to increase from the current requirement of -6.6/8.5 MW/min to -23.1/23.4 MW/min. This will necessitate the constant operation of a large quantity of plant capable of providing load following and balancing energy (typically OCGT plant). This mode of operation is likely to be significantly less efficient and more expensive. It is recommended that the cost of this approach be determined, and alternative methods for providing reliable system operation investigated.

During overnight periods, the quantity of load following plant required to be operating will necessitate regular daily cycling of all coal-fired power stations in the SWIS (by 2019-20). This is likely to be very expensive and possibly technically infeasible. From a Power System Security perspective this is considered infeasible, and it is recommended that the feasibility of daily cycling of coal-fired generators in the SWIS be investigated in detail. Commercial outcomes for the stations involved would also be significantly altered.

By 2019-20, with the modelled quantity of wind generation installed, it will be necessary to regularly curtail wind generation during overnight periods. With the low levels of overnight demand and the very high quantity of load following plant required, wind curtailment reaches 60% of the total annual wind energy available. Despite the very high capacity factors available to wind farms in the SWIS (due to the excellent underlying wind resource) this level of curtailment is likely to be prohibitively high, preventing cost effective operation of these wind farms.

The SWIS faces significant challenges in integrating the large quantities of wind generation required to meet the MRET into the system. However, there are likely to be a variety of opportunities for more sophisticated management of the system that would allow significant quantities of wind to enter the market, whilst maintaining system reliability at a reasonable cost. Varying load following requirements by time of day or season, efficient plant dedicated to load following, or reasonable limitations placed on wind farm operation are amongst the realm of possible strategies for managing such a system.

6 Future options

System Management is examining several options to mitigate the effects described above.

Smart grid may provide future assistance to stable power system operations in the form of load management schemes. Load management may take the form of shifting suitable types of loads from times of low windfarm output to times when windfarm outputs are high.

Locating windfarms in more diverse geographic regions (eg. in association with distribution connection) may also lessen the high correlation of output levels within the windfarm portfolio and lessen the burden on load following and energy balancing.

Other options that will be described in more detail are energy storage, other renewable options and wind generation forecasting.

6.1 Energy Storage

A special mention should be made of energy storage because of its potential to offer a robust technical solution to the intermittency problem associated with windfarms. Energy storage, for example pump storage or battery storage, would overcome a number of problems over different timeframes. The storage mechanism could be directly powered by wind generation, or could be used in conjunction with wind generation.

In the former option the wind generation would be connected to the storage facility, and this in turn would be connected to the SWIS. In this case the output of the facility would in actuality be that of a scheduled generator. This would effectively mitigate the increased load following or balancing demand associated with high levels of wind generation. Unfortunately, locations suitable to wind generation are not necessarily those suitable to pump storage. Other storage technologies are not sufficiently advanced to be commercially viable at this stage.

In the latter option the wind generation would be connected to the SWIS which could be used to power the storage facility, which would also be connected to the SWIS. In this case the two facilities would not need to be co-located and, depending on sufficient network capacity, could well be located at the most suitable sites for each. Here, the output of the storage facility could be used to 'balance' the output of the wind generation during peak hours, effectively minimising the impacts of wind generation on load following. During off-peak hours, the storage facility would increase system load and be powered by the wind generation. The increase in off-peak load would allow further generation to be operated to maintain system frequency.

For storage to be a viable part of a generation portfolio, legislation may be necessary to mandate or encourage wind generation projects to be accompanied by a storage mechanism to mitigate the effects on frequency keeping and balancing. The two facilities could be treated as one for the purposes of the Market and operational dispatch. However, no mechanism currently exists in the Network Access Code to allow such an arrangement, and, the Market Rules currently prevent the aggregation of facilities that are not co-located.

6.2 Other Renewable Technologies

Other renewable energy technologies are in various stages of development such as biomass, solar or wave.

These technologies may become an important part of future generator portfolios. Some may offer significant advantages over wind generation, such as better correlation with load, higher capacity factor and availability, ability to be dispatched, lower levels of intermittency, some energy storage capability. The potential resource diversity may even help overcome a number of the issues described in this paper which high penetrations of windfarms on SWIS would impose.

A number of projects using technologies other than wind are proposed or in some stage of development but these technologies are largely not commercially proven and doubts remain about commercial viability in many cases.

6.3 Windfarm Forecasting

An accurate forecast of the output of windfarms in various timeframes would help in scheduling commitment and dispatch of balancing plant so as to conform with generator ramp rates, as well as shutdown and restart times. Unfortunately, on the world stage accurate windfarm forecasting has yet to be achieved. However, any improvement which reduces forecast error, even to a small degree, would be beneficial to operators, generation plant and fuel schedulers.

Windfarm forecasts would assist System Management in managing the system moment to moment, up to an hour ahead as well as for scheduling plant over short term (3 hours to 24 hours) and medium term (1 day to 1 week).

System Management is currently working to secure and assess a systematic forecast of windfarm output for the 3 major windfarms on the SWIS at the moment based on an existing wind speed and direction forecast provided by the Bureau of Meteorology. If successful this pilot will be followed up by a more comprehensive approach along the lines of the AWEFS used in the National Electricity Market.

To achieve this goal System Management will require access to real time feeds of actual wind and load data from existing and proposed windfarms with historical data. While there is some resistance by windfarm proponents to provide historical and real time wind speed and direction data, System Management is negotiating with proponents to address their concerns about data confidentiality and to highlight the benefits of windfarm forecasts to the proponent and the market in general.

7 Conclusions

System Management welcomes renewable energy on the SWIS. However, wind farms, the major type of renewable energy expected, pose issues to Power System Security and Reliability due to the intermittency of output.. Intermittent generation also adds to difficulties with excessive generation during periods of low system load[32]. As the SWIS is currently experiencing these issues with only 190 MW of intermittent generation, and in 2010 the capacity of windfarms on the SWIS will double with the introduction of the Collgar Wind Farm, these issues can only be exacerbated in the future.

The number of wind generation facilities and the total nameplate capacity of wind generation are likely to increase dramatically in next few years. If these increases occur without mechanisms to balance changes in the output of those facilities, power system security and reliability will be threatened.

Cycling of coal-fired generation facilities to make room for windfarm output overnight is inevitable. Cycling has already commenced and will increase as more windfarms are connected onto SWIS. This represents a significant departure from the current operating regimes for coal-fired facilities, and puts the generating units into an operating regime not contemplated in their design.

Under the current Market Rules, System Management will be increasingly forced to curtail the output of windfarm facilities where power system security and reliability is at risk. Once the full implications on wind generation output are understood it may be that retailers will be

[32] Note that balancing issues during low system loads may be militated to a degree through changes to balancing dispatch in the Market Rules.

less inclined to sign bilateral contracts with wind generation facilities wanting to operate in the SWIS.

While a more definite forecast of future development should be performed[33], the analysis performed clearly indicates that, without significant complementary resources, high levels of wind penetration in the SWIS result in significant operational issues. The results also indicated that changing the dispatch merit order (DMO) specified in the Wholesale Electricity Market Rules to a more cost-reflective basis has only marginal impact on the outcomes. The results also indicated that a future generation mix with a more significant proportion of open cycle gas turbines would lessen the amount of windfarm curtailment and cycling of must-run plant.

Due to these issues, it is apparent that increased amounts of complementary technologies, such as storage solutions, or OCGT balancing generators, will be needed as windfarm penetration increases. However, these options require further investigation and to become viable will probably require substantial changes to existing legislation. For example, balancing or storage measures, which may reduce the effects of the security issues, are not strongly incentivised under the Market Rules.

Smart grid technology may also provide future assistance to stable power system operations in the form of load management schemes to shift demand to suit the availability of renewable generation sources.

Finally, it should be noted that the inclusion of other forms of more predictable renewable energy (such as biomass, wave, or solar) would offer greater diversity to the SWIS and may help militate the system stability problems associated with intermittency.

[33] The Renewable Energy Working Group's Work Package 1 will perform such a forecast.