Tactical Wind Generation Project

Rationale for proposed rule changes to accommodate the connection of further wind generation until the Wind Generation Investigation Project is complete.

Version	
Final	
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Nomenclature

AOPO	Asset Owner Performance Obligation – a performance obligation specified in section III of Part C of the rules with which asset owners must comply.
AGC	Automatic Generation Control.
Dispensation	An exclusion from compliance with an AOPO or Technical Code granted by the System Operator in accordance with Part C of the rules.
EGRs	The Electricity Governance Rules.
Frequency keeping	An ancillary service that maintains the system frequency within the normal band.
IR	Instantaneous Reserves. An ancillary service comprising one or more of the following interruptible load, partly loaded spinning reserves, tail water depressed reserves.
Must Run Dispatch Auction	A process by which generators participate in an auction to determine whether they are authorised to offer electricity at zero price. The process is set out in section IV of Part G of the rules.
Part C	The part of the rules which concerns maintenance of system quality.
Part G	The part of the rules which concerns trading of wholesale electricity.
PPOs	Principal Performance Obligations. The obligations of the System Operator set out in rule 2 of section II of Part C of the rules.
Technical Code	Technical Codes contained in Schedule C3 of Part C of the rules.
The rules	The Electricity Governance Rules.
WGIP	Win Generation Investigation Project.
Wind Generation Investigation Project	A project initiated by the Electricity Commission to identify the necessary changes to the rule and industry arrangements to accommodate the connection of further wind generation to the New Zealand power system.

1. Executive Summary

The System Operator has been engaged by the Electricity Commission to identify and propose any rule changes needed to accommodate the connection of further wind generation to the power system during the period from now until the long term solutions identified by the Wind Generation Investigation Project are implemented.

The purpose of this paper is to set out the process and rationale by which the System Operator has identified immediate rule changes it believes are necessary to accommodate wind generation planned to be commissioned over the next few years.

A number of areas that need to be addressed have been identified, largely from the Manawatu wind report[1]. These issues fall into the following categories:

- Impacts arising from large sudden changes in wind generation output.
- Impacts arising from the variability and unpredictability of wind generation output.
- Asset capability of wind generation turbines and related equipment.
- Rule drafting – issues needing specific consideration and integration of intermittent generation in rule drafting.

In setting out the proposed interim changes, the System Operator has drawn on the analysis of the Manawatu wind generation report. A copy of the executive summary of the report is attached as Appendix A.

The System Operator has considered whether the areas that need to be addressed are best managed through:

- Existing controls and measures (e.g. the procurement of increased amounts of frequency keeping ancillary service as provided for under the rules).
- The dispensation process for wind generation assets which are non-compliant with the Asset Owner Performance Obligations and Technical Codes.
- Immediate rule changes.
- Referring the issue to the appropriate forum (e.g. Wind Generation Investigation Project or the relevant advisory group) for determination of a long term optimum solution.

A summary of the issues and the means by which the System Operator proposes to manage those issues in the interim period before long term rule changes are considered by the WGIP and other forums is shown in Table 1.

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[1] "Manawatu wind generation, observed impacts on the scheduling and dispatch processes, Second revision", November 2005. Available at http://www.electricitycommission.govt.nz/pdfs/opdev/comqual/windgen/Man-wind-gen-impact-rpt.pdf.

Issue	Results in	Most effectively managed in the short term by	Should be managed in the long term by
Large sudden change in wind generation output	Increased demand on frequency keeping stations (and potentially increased costs)	Increasing the amount (and costs) of frequency keeping procured Dispensations only granted if applicant has demonstrated the use of technology consistent with best international practice	Move to optimum frequency management[2] Consider use of hydro balancing or integrated storage
	Power swings overloading transmission circuits	Dispensations only granted if applicant has demonstrated the use of technology consistent with best international practice Appropriate use of transmission constraints to manage equipment loading.	Move to optimum frequency management[2] Appropriate use of transmission constraints to manage equipment loading.
Variability and unpredictability of wind generation output – limited accuracy of wind generation forecasts	Increased difficulty in assessing power system security	Rule change to require wind generators to provide most accurate forecasts possible	Consider other options (e.g. Centralised wind forecasting)
Asset capability of wind generating turbines - rules do not reflect capability of wind generation technology	Non-compliance with rules	Use dispensations to deal with non-compliances Rule changes for wind generation indications and measurements.	Appropriate AOPOs and Technical Codes for wind generation implemented by WGIP
Asset capability of wind generating turbines – limited frequency support	Reduced ability to meet PPOs	Dispensations only granted if applicant has demonstrated the use of technology consistent with best international practice Procure additional frequency keeping and instantaneous reserves	Appropriate AOPOs and Technical Codes for wind generation implemented by WGIP Move to optimum frequency management[2]
Asset capability of wind generating turbines – no required fault ride through capability for wind generation	Cascade failure	No dispensations will be granted. Manage requirements for fault ride through via existing protection AOPOs and Technical Codes.	Appropriate AOPOs and Technical Codes for wind generation implemented by WGIP

Table 1 – Summary of issues and preferred methods of management

[2] For example, the introduction of AGC.

Issue	Results in	Most effectively managed in the short term by	Should be managed in the long term by
Rule drafting – definition of "synchronised"	Literal interpretation implies that wind generation does not have to provide voltage and frequency support	Rule change to definition of "synchronised" to include wind generating units connected to the power system.	
Rule drafting – wind generation does not participate in must run dispatch auction	Total must run generation scheduled is in excess of system load is scheduled	Rule change to require wind generation to participate in must run dispatch auction, if wind generation wishes to offer at zero price	Changes to must run dispatch auction process
Rule drafting – the loss of a wind farm is not considered a contingent event	Risk to PPOs	Rule change to define the loss of a wind farm as a contingent event	

Table 1 – Summary of issues and preferred methods of management

The System Operator has identified the following general issues:

- that the amount of wind generation installed or ordered in the next two years will affect the System Operator's ability to meet the PPOs and that the System Operator has determined preferred methods for managing these issues over the interim period until long term solutions are determined and implemented;
- that it will not be prudent to continue to grant dispensations from the frequency AOPOs unless the applicant has demonstrated that they have installed plant that has the capability to meet best international practice in terms of frequency support;
- that there is a potential need to procure additional voltage support, frequency keeping and instantaneous reserves to continue to meet the PPOs with the connection of further wind generation ahead of the implementation of the WGIP outcomes;
- that additional transmission constraints will be required to manage equipment loading in the absence of asset owners adopting other controls to manage asset loading risk due to wind variability;
- that there is a need to review the issues relating to the current level of frequency keeping procurements and this matter should be referred to the Commission to progress;

The System Operator has identified a number of proposed rule changes and recommends that the Commission progresses the implementation of these rule changes in the short term:

- to include the loss of an intermittent generating station in the definition of contingent events for which the System Operator provides reserve;
- to require intermittent generators to offer at $0.01/MWh (thereby requiring the intermittent generator to participate in the must run auction if the wind generator wishes to bid at zero price;
- to set performance requirements on wind generation for forecast accuracy, require more frequent offers from intermittent generators and require publication of offer accuracy by the System Operator;
- to require wind generation to provide certain indications and measurements;
- to change the definition of "synchronised" to include wind generating units connected to the power system.

The System Operator recommends that the Commission notes that there is a degree of urgency in determining and implementing the optimum long term solutions (e.g. possible introduction of AGC, centralised wind forecasting and redesign of the must-run dispatch auction process) given the likely additional wind generation that will be commissioned or ordered in the next 2-3 years.

The Electricity Commission and Transpower recommend that parties considering potential wind generation investment in New Zealand (whether grid connected or not) should contact Transpower as soon as possible to discuss connection and/or asset owner obligations. The nature of the New Zealand power system (small and islanded) means there are some technical requirements for wind generation that can be more onerous than those found in larger interconnected grids of other countries. In addition, the electricity governance rules and industry arrangements are being reviewed in respect of wind generation. Changes to performance requirements for wind generating plant and market arrangements may affect the economics of wind generation projects. Transpower is keen to assist parties by providing as much information as possible on these issues so that they do not become a difficulty for an investor. Transpower will treat all inquiries and discussions over future connection confidentially.

Your initial contact to commence discussions with Transpower is:

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2. Introduction

2.1 Purpose of paper

The purpose of this paper is to define the process and rationale by which the System Operator has identified immediate rule changes it believes are necessary to accommodate wind generation planned to be commissioned over the next few years.

2.2 Wind Generation Investigation Project (WGIP)

The Electricity Commission initiated the Wind Generation Investigation Project (WGIP) with the following objectives:

- to identify and quantify the technical and market impacts of increased wind generation on the New Zealand power system over the next ten years;
- to recommend any amendments to the Electricity Governance Rules (EGRs) and other relevant processes required, to ensure future power system security and market outcomes are consistent with the Government Policy Statement on Electricity Governance (GPS) and the Electricity Commission's Principal Objectives and Outcomes;
- to recommend an implementation plan for proposed changes (to the extent that this is required).

The WGIP is a long term project to consider the impact of wind generation capacity that will be installed over the next 10 years. It is likely the WGIP and any subsequent rule change recommendations will take two years to implement.

2.3 Tactical Wind Project

To manage any short term issues, the Electricity Commission has engaged Transpower, as System Operator, to undertake a tactical study to:

- assess the impact of Manawatu wind generation on scheduling and dispatch processes;
- identify and propose any rule changes required to accommodate increased wind generation over the next two years.

A report on the impacts of the Manawatu wind generation ("Manawatu wind generation, observed impacts on the scheduling and dispatch processes, Second revision") was published in November 2005. The executive summary of this report is included in Appendix A.

In June 2005 the Electricity Commission issued a Request for Information (RFI) to request participants' views on the likely development of wind generation in New Zealand and any pressing issues arising as a result. Sixteen submissions were received to the Electricity Commission’s RFI.

The System Operator has used the issues identified in the Manawatu report and the submissions to the RFI to identify and propose necessary interim rule changes for wind generation.

This paper sets out the process and rationale by which the System Operator has identified immediate rule changes it believes are necessary, to accommodate wind generation planned to be commissioned over the next few years. The System Operator will provide the associated specific rule change proposals to the Electricity Commission separate to this paper.

2.4 Proposed Rule Changes

Any interim rule changes proposed by the System Operator will go through the Electricity Commission rule change process and may be modified in the process.

The proposed rule changes will provide a signal to participants of the important issues for Part C and Part G in the rules, in relation to accommodating further wind generation. This will enable investors to identify possible future rule changes and requirements upon wind generation.

The System Operator has also identified other issues that are not addressed in the interim rule changes:

- Some of these issues will be recommended to be considered in the Wind Generation Investigation Project.
- Other issues (such as in the Must Run Dispatch Auction process) should be addressed independently of the WGIP.

3. The impact of wind generation

3.1 Short term forecast

The System Operator expects that a considerable amount of wind generation may be commissioned or committed within the next two years and that the effect of this wind generation will affect the System Operator's ability to meet the PPOs. This paper does not predict the amount of wind generation connected to the New Zealand power system in the long term as this will be done within the Wind Generation Investigation Project.

There is approximately 170 MW of installed wind generation capacity in the North Island. Resource consents for another 220 MW of wind generation in the North Island have been granted. Applications for an additional 560 MW of wind generation are going through the consent process.

While some of the wind generation projects may not be commissioned or ordered in the next 2 to 3 years, it is quite likely that there will be over 800 MW of wind generation capacity installed or in the process of construction in the North Island in two to three years time. This estimate is based on the sites that currently exist, are consented, or are going through the consent process (see Table 3.1.a).

Status	Name	Installed capacity (MW)	Total MW (rounded)
Existing	Brooklyn	0.225	
Existing	Gebbies Pass	0.5	
Existing	Hau Nui 1	3.9	
Existing	Hau Nui 2	4.8	
Existing	Tararua 1	31.7	
Existing	Tararua 2	36.3	
Existing	Te Apiti	90.8	
Existing Total			***170***
Consented	Awhitu	20	
Consented	Tararua III	93	
Consented	Te Rere Hau	48.5	
Consented	Whitehill	58	
Consented Total			***220***
Consented & appealed	Hawkes Bay	270	
	Titiokura	48	
Consented & appealed Total			***320***
In process of gaining consent	Awakino	41	
	Taumatatotara	38	
	West Wind	210	
In process of gaining consent Total			***290***

Table 3.1.a – Existing and consented wind generation

There is likely to be around 290 MW of installed wind generation capacity in the Manawatu region.

Based on observations in the Manawatu region[3], an installed capacity of 800 MW of wind generation (with 290 MW in the Manawatu region) is likely to produce the following effects:

- Around 12 events per year of 200 MW sudden change in Manawatu wind generation output over five minutes;
- Around 12 events per year of 230 MW sudden change in the combined wind generation out over five minutes;
- Errors in wind generation forecasts of 230 MW for more than 10% of the time.

The sudden rapid changes will require management through increased frequency keeping or rules changes.

3.2 Issues

A number of Issues for the integration of wind generation have been identified. The issues broadly fit into the following categories:

- Impacts arising from large sudden changes in wind generation output;
- Impacts arising from the variability and unpredictability of wind generation output;
- Asset capability of wind generation turbines and related equipment;
- Rule drafting – issues needing specific consideration and integration of intermittent generation in rule drafting.

These issues are discussed in greater detail in Section 4.

3.3 Controls and Measures

There are a number of ways of controlling and mitigating the issues. These are:

- Manage the impact of the issues through existing controls and measures provided for in the rules. This may lead to increased costs to participants (e.g. increases in the amount of frequency keeping procured);
- Manage through dispensations granted under the rules. Part C of the rules provides for the System Operator to grant dispensations from Asset Owner Performance Obligations and Technical Codes. The use of dispensations, with appropriate conditions, can mitigate the effect of non-compliant wind generation assets;
- Propose interim rule changes. These are necessary changes that can be immediately put in place;

[3] See the Manawatu Wind Generation Impact Report (Appendix A).

- Seek optimum long term solutions through WGIP and other forums. The impact of the variability of wind generation output can be mitigated with changes to the way in which frequency is managed in the New Zealand power system (e.g. through the introduction of automatic generation control (AGC));
- A combination of the above measures listed above.

3.4 Assessing Controls and Measures

The potential controls and measures for each issue were assessed according to the following criteria.

Control and Measure	**Criteria**
Existing controls and measures within the rules	Net Impact on Market Outcomes. Who pays any increased costs.
Dispensations	Net impact on the System Operator's ability to meet the PPOs. Implementation cost. Ability to implement the solution within six months.
Interim Rule Changes	Net impact on market outcomes. Net impact on the System Operator's ability to meet the PPOs. Implementation cost. Ability to implement the solution within six months.

The System Operator has identified the preferred management method for each issue taking into account the above criteria.

Potential long term solutions are identified for some issues. These solutions will require significant analysis before an optimum solution can be determined.

3.5 Cost Benefits

Estimates of costs and benefits for the issues have been made where possible. Extensive analysis has not been carried out in determining these estimates for the following reasons:

- These rule changes are interim in nature and are intended to work over a period of two years before the WGIP identifies and implements the appropriate long term solutions.
- Some generators may have already made their investment decisions in respect of wind generation that will be installed over the next two years. Further detailed cost-benefit analysis will not provide benefits in respect of this committed investment.
- Where more detailed analysis is needed, it is more appropriately carried out in the WGIP.

4. The Issues

4.1 Large sudden changes in output – effect on frequency keeping

Based on observations in the Manawatu region[4], an installed capacity of 800 MW of wind generation across New Zealand and 290 MW in the Manawatu region is likely to produce the following effects:

- Around 12 events per year of 200 MW sudden change in Manawatu wind generation output over five minutes;
- Around 12 events per year of 230 MW sudden change in the combined wind generation out over five minutes.

Sudden large changes in wind generation output such as the above will impact on operation of the power system and the electricity market. Managing these large changes in output in real time will present operational difficulties, especially for frequency keepers that just meet the current minimum ramp rate requirement for frequency keeping (e.g. large thermal generation units).

4.1.1 Impact

The rate of increase or decrease in wind generation output can exceed a frequency keeper's ability to maintain island frequency within the normal frequency limits. For example, the thermal generation units used for frequency keeping in the North Island do not respond as quickly as hydro plant nor do they have adequate capability to cover such a rapid change in generation output.

The current requirement for frequency keeping stations is that they can change output by a minimum rate of 10 MW per minute. The Manawatu wind generation output has been observed to change output by 20 MW per minute. With 800 MW of installed wind generation capacity across New Zealand and 290 MW closely located in the Manawatu region, it is expected that total wind generation output will change by more than 40 MW per minute around 24 times per year.

A large increase or decrease in wind generation output can be greater than the dispatched frequency keeping band (currently up to +/-50MW) and may cause the frequency keeper to exceed its dispatched quantities.

4.1.2 Options

Existing Controls and measures

The System Operator can dispatch a wider frequency keeping band. This is a measure that can be applied when required under the ancillary services procurement plan. This will help the frequency keeper avoid going outside its

[4] See the Manawatu Wind Generation Impact Report.

dispatched frequency keeping band. An increase in dispatched frequency keeping band is likely to increase frequency keeping costs.

Increased performance specifications for frequency keeping stations (e.g. minimum rate of change of output) can be required through the procurement plan. The procurement plan is reviewed annually and making changes of this nature are relatively straight forward. The consequence of making this change is a reduction in frequency keeping service providers as some plant (especially thermal) is not capable of changing output at a rate much faster than the current minimum rate of 10 MW per minute. A reduction in service providers is likely to result in increased frequency keeping costs.

Under the rules, frequency keeping costs are allocated to retailers. It is likely that some of the increased costs will be passed to wind generators as far as they have a retail base, however it is likely that a significant portion of the increased costs will be borne by other parties.

An accurate estimate of the costs of dispatching a wider frequency keeping band is not possible. One factor with any change in market based procurement is that participants' response to the change can include changes in behaviour given the impact on their commercial position. As a guide, the additional costs of dispatching a 75 MW frequency keeping band (compared to the present 50 MW) is estimated to be around $2M per month.

This estimate is based on the current frequency keeping offers by service providers, market prices and participant behaviour in September 2005. There are two components to frequency keeping costs: dispatch costs and constrained on/off costs. The increase in dispatch costs has been estimated by taking the current service providers' offers and extrapolating those to a 75 MW band. The increase in constrained on/off costs has been estimated by calculating these costs assuming a 75 MW frequency keeping band was in effect.

Dispensations

Rule 5.1.2 of Technical Code A of Schedule C3 of Part C of the rules requires generators to ensure that each of their generating units has a rate of change of output that does not adversely affect the system operator's ability to plan to comply with the principal performance obligations. The rate of change must be adjustable to allow for changes in grid conditions.

It is expected that total rates of change in wind generation output will exceed 40 MW per minute regularly if no ramp rate limiting controls are in effect on wind generation. Such controls, if applied to each wind turbine, will reduce the overall rate of change and thus reduce the amount of other measures required to be put in place to manage rates of change (e.g. increased frequency keeping).

Wind generation has limited ability to control its output as the output is largely dependent on the amount of wind blowing. Modern wind generation turbines have control systems that are capable of ramp rate limitation and operating in ways that can support the system operator's ability to comply with the principal performance obligations. The cost of installing or retrofitting this control capability is believed to be quite low in terms of the capital costs of the wind generating turbine.

At present, frequency keeping stations are required to be capable of changing output at a minimum rate of 10 MW per minute. Some of the stations currently providing frequency keeping are not capable of a rate of change much greater than this. The currently observed rates of change of the Manawatu wind generation exceed the capability of the least capable existing frequency keeping service providers.

The System Operator understands that ramp rate limitation capability and control systems are now a standard feature of modern wind turbine technology and can be specified or retrofitted at moderate cost (one estimate is around $50,000 for a 100 MW wind farm). There may be higher costs for retrofitting such capability to wind farms having older types of generator control technology.

The rules currently require all generating units to have a rate of change of output that does not adversely affect the system operator's ability to plan to comply and comply with the principal performance obligations. The System Operator has identified that it will not be prudent to continue to grant further dispensations in respect of rule 5.1.2 unless the applicant has demonstrated that they have installed ramp rate limitation capability and control systems on their wind generation turbines that meet international best practice.

Interim rule changes

Rule changes in respect of frequency keeping will affect both Part C and Part G of the rules and will have impacts on participants industry wide. Such rule changes are beyond the scope of the Tactical Wind Project and need to be managed via the appropriate forums.

It is noted that the Electricity Commission and its advisory groups (particularly the Common Quality Advisory Group) are already considering the future of frequency management on the New Zealand power system.

The System Operator has not identified any other interim rule changes in respect of this issue that could be implemented in the short term and recommends reliance on the combination of the use of a wider frequency keeping band when required and dispensations required in the installation of ramp rate control capability .

4.1.3 Preferred Management Method

The System Operator believes that that the effect of large sudden changes in wind generation output on frequency keeping can be managed in the interim by a combination of procuring increased frequency keeping when required and specifying ramp rate limits for individual wind farms when required.

This assumes that the recommendations of this report are implemented and that the amount of installed wind generation capacity in the interim period does not exceed 800 MW of dispersed wind generation and 290 MW in the Manawatu region.

4.1.4 Long term options

Some potential long term solutions to manage large sudden changes in wind generation output have been identified:

- The introduction of automatic generation dispatch is one measure that will mitigate the effects of sudden large changes in wind generation output;
- Changes to the principal performance obligations to allow greater frequency excursions;
- The introduction of Asset Owner Performance Obligations and Technical Codes specific to wind generation including requirements for ramp rate limitations and control systems;

It is recommended that the WGIP investigates these potential solutions.

4.2 Large sudden changes in output – effect on transmission circuit loading

Changes in power flow across the grid following sudden changes in wind generation output may cause transmission circuits to exceed their limits until re-dispatch of generation occurs.

4.2.1 Impact

The need to accommodate sudden changes in wind generation output may reduce the amount of power that can be safely transferred between different parts of the power system (i.e. affect power system capability limits).

The rate of change and total change of wind generation output is not predictable prior to the event, and the rate of change can also vary during the event. Manual or automatic re-dispatch of generation during an event will therefore need to be done in such a way to minimise the risk from wind variability.

The System Operator will need to operate the power system with sufficient allowance for swings in power flows, following large sudden changes in wind generation output, to ensure that assets do not exceed their capability. Alternatively, asset owners may choose to reduce the advised capability of their assets to avoid potential damage or danger from sudden changes in power flow. A reduction in advised asset capability may result increased constraints on the power system and increased pre-event load shedding to keep assets within their advised capability. A further option is for asset owners and wind generators to install special protection schemes.

4.2.2 Options

Existing controls and measures

Large changes in wind generation output may result in power system capability limits being exceeded. An existing measure available under the current rules is the application of constraints on the power system to:

- dispatch generation so the circuits in question will not exceed stated capability for a sudden change in wind generation output;
- constrain off wind generation during times when there is a risk of these circuits exceeding stated capability.

Therefore, constraints can be applied during scheduling and dispatch using the existing process. There will be times when wind and other generation will be required to reduce output and “spill” wind. The application of constraints will increase the electricity prices and therefore, will have an impact on participants. The severity and impact of the constraints will depend greatly on a wind generator’s ability to control its output (Rule 5.1.2 of Technical Code A).

Other options to reduce or avoid the need for constraints include special protection schemes (such as inter-trips and run-backs) and installing technology with the ability to reduce output to relieve the constraint. Special protection schemes and constraint application can be accommodated within the existing rules.

Whilst the application of such constraints will impact on generation dispatch, overloading transmission equipment will damage equipment and may result in cascade failure. The System Operator’s over-riding obligation is to meet its PPOs. A critical part of this requirement is to maintain equipment within stated capability. In the absence of any alternatives (as outlined above), the application of constraints is the only viable way the System Operator can maintain a secure power system.

Dispensations

Rule 5.1.2 of Technical Code A of Schedule C3 of Part C of the rules requires generators to ensure that each of their generating units has a rate of change of output that does not adversely affect the system operator’s ability to plan to comply with the principal performance obligations. The rate of change must be adjustable to allow for changes in grid conditions.

As discussed previously in regard to the effect of large sudden changes of wind generation output on frequency keeping, the System Operator has identified that it is not prudent to grant further dispensations in respect of rule

5.1.2 unless the applicant has demonstrated that they have installed ramp rate limitation capability and controls systems on their wind generation turbines that meet international best practice.

Interim rule changes

As discussed previously, rule changes in respect of frequency keeping will affect both Part C and Part G of the rules and will have impacts on participants industry wide. Such rule changes are beyond the scope of the Tactical Wind Project and need to be managed via the appropriate forums.

The System Operator has not identified any other interim rule changes in respect of this issue that could be implemented in the short term. The System Operator recommends reliance on the application of additional constraints or other alternatives (such as installation of special protection schemes) when required until such time as the outcomes of the WGIP are implemented.

4.2.3 Preferred Management Method

The System Operator believes that the effect of large sudden changes in wind generation output on circuit loading can be managed over the next two years (when the appropriate long term solutions should have been implemented) by the application of constraints and the use of dispensations until the WGIP investigates and implements further rule changes. It also notes that other options such as generation runback schemes are available to participants to mitigate the impact on constraint management.

4.2.4 Long term options

The same long term options as set out in section 4.1.2 apply.

The balancing of hydro generation output against wind generation output with the aim of maintaining a constant combined total output will help reduce the effects of the variability of wind generation output. This would reduce pressure on frequency keeping stations and reduce changes in power flows across the system. However, hydro balancing may create local asset loading issues (e.g. loading issues on the transmission circuits between the wind generation and the balancing hydro generation). In these cases, the solutions to system-wide problems may create regional issues.

4.3 Variability and unpredictability in wind generation output

Wind generation output has the potential to vary considerably within a trading period. Accurate forecasting of wind generation output is difficult.

Generators (other than intermittent generators) offer into the electricity market and will be dispatched (if cleared) in accordance with their offer. Generators are required to produce the dispatched amount of energy unless genuine reasons exist for not doing so.

Wind and other forms of intermittent generation have limited ability to offer their output to the electricity market in this manner as they can not forecast their future output with any accuracy nor easily control their amount of output to meet dispatch instructions.

The rules that came into effect on 1 March 2004 did not consider wind or other forms of intermittent generation either in terms of trading arrangements or common quality. Changes to Part G of the rules were required to allow Te Apiti wind farm to participate in the electricity market. No changes to Part C of the rules have been made in respect of intermittent generation.

4.3.1 Impact

Wind farm generation offers (used for the scheduling process) are a forecast of the average amount of wind generation expected in future trading periods. Actual dispatch is based on current output and is essentially unrelated to the offer.

Nevertheless, the wind farm offer accuracy is important. The wind farm offers are incorporated into the generation schedules for publication to participants in advance of each relevant trading period. Each generation schedule provides information for a number of trading periods in the future and enables participants to manage resources, and adjust generation offers and demand bids in response to forecast schedule prices.

Such information enables participants (and the System Operator) to identify any system constraints in advance, and allows generators to optimise the efficiency of their generating units and to plan starting and stopping of their plant.

Price forecasts are used by purchasers to adjust their demand (for example, planning to reduce consumption in future trading periods where the price is high). The accuracy of schedules will be even more important for this purpose if “demand side participation” changes are progressed.

The System Operator uses the generation schedules for system security analysis, including assessment of reserve requirements, to plan to avoid, to the extent practicable, security problems in real time. The System Operator considers that wind generation forecasts need to be as accurate as practically possible to minimise the uncertainty around wind generation output when power system security is assessed.

4.3.2 Options

Existing controls and measures

There are no requirements for forecast accuracy within the rules. There are no means within the rules by which accurate forecasts of wind generation output can be required of wind generators.

Dispensations

Dispensations can be granted in respect of Asset Owner Performance Obligations and Technical Codes in Part C only. However, dispensations are not relevant here as scheduling and dispatch of wind generation are Part G matters.

Interim rule change

Forecast accuracy is a function of a generator's investment in processes and technology to forecast output from wind generation. The rules should in the short term require wind generators to have processes and technology consistent with "good industry practice" in formulating and making offers and to use reasonable endeavours to continue to reduce the difference between offers and actual generation.

It is not possible at this stage to specify a percentage accuracy standard for a wind generator's offer. Such a standard will require further research and debate. The WGIP should perform this investigation.

It is proposed to require the following offers and revisions from intermittent generators:

- An initial offer by 13:00 of each day for the following day (unchanged from current requirements)
- An updated offer every two hours for the schedule period
- A revised offer within two hours immediately prior to the trading period (unchanged from current requirements)

It is believed that the additional cost to generators of requiring an updated offer every two hours for the schedule period will be very low.

It is understood that most wind generators base their current forecasts of output on data provided under contract from a metrological forecasting service. It is believed that this information is currently updated every six hours. To deliver valid two hour forecasts of output, generators will need to arrange for a two hour update of any third party data used in the forecast.

The cost of installing appropriate equipment to facilitate accurate wind forecasting when a wind farm is built is believed to be moderate ($50-100k per wind farm). The cost of retrofitting such equipment may be slightly higher but still moderate.

The proposed rule changes are to require wind generators

- to have processes and technology consistent with good industry practice in formulating and making offers
- to provide an updated offer every two hours for the schedule period.

4.3.3 Preferred Management Method

There are significant impacts if the effects of variability and unpredictability in wind generation output are not mitigated. The impacts include risks to power system security, loss of accuracy in pre dispatch price and generation quantity, along with costs associated with additional constrained on/off payments to generators and increased operating fuel costs from inefficient plant operation. The benefits of reducing these effects have not been quantified but are likely to be significant. The costs of requiring wind generators to have processes and technology consistent with “good industry practice” are low. By investing in appropriate processes and technology at construction, new wind farms can avoid the need of more costly retrofitting at a later stage.

The System Operator believes that any measures beyond the proposed interim rule changes for two hour updates in forecasts to mitigate the effect of variability and unpredictability in wind generation output scheduling need to be evaluated under the WGIP. The System Operator notes that this issue should be considered a high priority as the overall impacts could be significant even with 800 MW of installed wind generation capacity within two years.

4.3.4 Long term options

The optimum method for forecasting wind generation output should be investigated as part of the WGIP. A centralised approach to wind generation output forecasting, as implemented in other countries is a possible consideration.

4.4 Asset capability of wind generation turbines and related equipment - general

In determining necessary rule and process changes, an important test is whether the System Operator will still be able to plan to comply with its PPOs using the policies and means set out in its Policy Statement in Schedule C4 of Part C of the EGRs. The Asset Owner Performance Obligations (AOPOs) and Technical Codes set out technical standards for assets connected to the power system. These technical standards support the System Operator’s ability to meet the PPOs.

Properly designed wind farms do meet many of the existing AOPOs and Technical Codes:

- Voltage Support (with the inclusion of switched static and dynamic reactive plant);
- Voltage Range;
- Communication facilities;
- Grid Interface;
- Protection (including fault ride-through);
- Synchronising facilities.

Older wind turbines can not meet all aspects of the frequency and voltage response and control requirements. This can be mitigated in the case of voltage by the addition of reactive plant at the wind farm.

As noted previously, the rules that came into effect on 1 March 2004 were not written to incorporate the particular requirements and capabilities of intermittent generation, including wind generation. While subsequent rules changes to Part G were made to allow the Te Apiti wind farm to participate in the market, no changes to Part C were made at the time.

4.4.1 Impact

Existing wind generation has different performance characteristics to other forms of generation. The current AOPOs and Technical Codes do not necessarily reflect these differences. As a result, existing wind generators have to date applied for, and been granted dispensations by the System Operator from a number of the requirements of the AOPOs and Technical Codes.

However, from the analysis in the updated Manawatu wind report it appears the System Operator may not be able to continue to meet its PPOs with the proposed increase in wind generation without significantly more support for the frequency PPOs than it currently receives from wind generator asset owners. The System Operator has identified that with the amount of wind generation capacity likely to be installed in the next two years, and even with the implementation of the proposed interim rule changes, it is not prudent to continue to grant dispensations from a number of the AOPOs and technical codes for which dispensations have previously been granted to wind generators.

The System Operator has identified two types of AOPO that it is not prudent to continue to grant dispensations for, without limitation,

Frequency Performance:

- *Generating Units and associated control systems* (C3 Tech A 5.1.1) Each generator must ensure it will support the System Operator to comply with its PPOs and is able to synchronise as set out in their asset capability statement;
- *Rate of change of output*. (C3 Tech A 5.1.2) Large sudden changes in wind generating unit output have been observed in the Manawatu. There is a requirement on generators for the rate of change in their output to be adjustable and not to adversely affect the System Operator's ability to meet the PPOs;

- *Speed governor*. (C3 Tech A 5.1.3 and 5.1.4) Unlike hydro or thermal generating units, wind generating turbines do not have speed governors. However, modern wind generation technology has limited ability (through control of the pitch angle of the blades or via the use of power electronics) to regulate output in response to changes in frequency.

Protection:

- *Protection of assets and the grid*. The Technical Codes for protection systems require that the operation of protection systems will support the System Operator's ability to meet the PPOs. Generating units require the ability to ride through faults on the power system, i.e. remain connected during the fault and following removal of the faulted assets. If generating units do not have this ability, then faults on the power system are likely to lead to widespread disconnection of generating units and cascade failure. The requirement for the protection systems for wind farms to be selective in operation and to preserve system stability (specified in rule 4.4 of Technical Code A) requires a fault ride through capability for wind generators. This capability is available from modern wind generation technology.

The management of the frequency support and protections AOPOs is discussed in sections 4.5 and 4.6. The remainder of this section sets out how the System Operator intends to manage the rest of the AOPO and Technical Code issues. These issues are:

- Voltage support and voltage control;
- Indications and measurements.

4.4.2 Options

Existing controls and measures

AOPOs for voltage support and voltage control are provided for in the rules. The rules requirements exceed the typical capability of existing individual wind turbines and additional reactive plant and control systems are usually required.

The rules require generators to provide certain indications and measurements to the System Operator. These indications and measurements are designed for hydro and thermal power stations and are neither practicable nor meaningful for large wind farm installations. It is noted that the Electricity Commission will soon be consulting on indications and measurements and it is proposed that some changes relevant to wind generation are made at that time.

Dispensations

Existing wind generation turbines do not provide the required amounts of reactive power import and export as set in rule 3.2 of section II of Part C, nor necessarily have voltage control systems that meet the requirements of rule 5.2 of Technical Code A of Schedule C3 of Part C. Wind generation owners have either provided additional reactive plant at the wind farm in order to become compliant or have sought dispensations from the above requirements.

The System Operator will grant dispensations for voltage support or voltage control systems where it believes it can still continue to meet the PPOs (for example through the procurement of additional voltage support where available). Asset owners who are granted dispensations for voltage support are allocated the costs required to procure the additional voltage support.

The System Operator will grant dispensations from the required indications and measurements provided that the wind generator provides the necessary indications and measurements, to enable the System Operator to meet the PPOs.

Interim rule change

The rules require generating units with a point of connection to the grid to have certain voltage support capability. While wind turbines can not easily meet these standards, any voltage support short fall can be dealt with through the dispensation process and no interim rule change is proposed. The drafting of appropriate AOPOs and Technical Codes for voltage support and voltage control for wind generators will require considerable investigation and cost-benefit analysis. Such investigation and analysis can not be completed quickly. It is recommended that the drafting be completed with the WGIP.

The System Operator believes there are two areas in indications and measurements for wind generation that need to be addressed:

- Knowledge of the number of wind turbines connected to the power system is important for ensuring that appropriate models of the wind farm are incorporated in dispatch and market system tools. It is therefore recommended that the rules require an intermittent generator to provide the number of wind turbines connected to the power system at each GIP.

- The existing rules do not provide for the frequency of updates for those indications from asset owners. Intermittent generators are dispatched entirely using SCADA output information, provided under Technical Code C of the rules. Given the large and sudden changes in wind generation output that can occur, the rules should require current indications and measurements at no greater than four second intervals.

The Electricity Commission is currently consulting on the required Indications and Measurements in Part C. Rule changes for indications and measurements for wind generation should first be pursued via this consultation. If the necessary rule changes are not achieved through the current consultation process then the above proposed rule changes should be progressed as part of the interim rule changes.

4.4.3 Preferred Management Method

The System Operator believes that

- voltage support performance of wind turbines can be dealt with through the dispensation process until such time that the appropriate voltage support AOPOs and Technical Codes for wind generation can be implemented.
- indications and measurements required of wind generation turbines and related equipment can be dealt with through existing controls and measures (e.g. through dispensations) until such time that the appropriate indications and measurements are set out in the rules. The proposed rule changes for indications and measurements should first be progressed through the current consultation process or if this fails as part of the interim rule changes for wind generation recommended in this paper.

4.4.4 Long term option

The requirements for rule changes related to voltage support provided by wind generators will require extensive analysis and investigation which is best carried out in the WGIP.

4.5 Asset capability of wind generation turbines and related equipment – Frequency Support

Existing wind generation does not provide frequency support during excursions outside the normal frequency band or frequency support within the normal band. Currently available best practice wind turbine generators and generator control system technology can provide significantly more frequency support than some existing, older installed wind turbine control systems[5]. Therefore, in the interim, the rules and the application of the rules should require wind generators to take practicable steps to purchase up to date control technology capability, so that wind generating units can support the ability of the System Operator to achieve it's PPOs to the full ability of current technology.

4.5.1 Impact

If the rules do not provide incentives for wind generators to acquire and install capability consistent with the requirements of the AOPOs and technical codes for other generators, additional costs will be imposed on the industry which will be borne by all participants, regardless of whether their own generation plant is compliant with the rules.

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[5] O. Anaya Lara; M. Black; M.Hughes; M.Jenkins; G. Strbac. *Integration of wind energy into large multi-machine power systems*. School of Electrical and Electronic Engineering. University of Manchester.

The System Operator can not continue to comply with the PPOs for the proposed increase in wind generation in two years if the new wind generation technology does not support the System Operator's ability to meet the PPOs. The System Operator has identified that it will not be prudent to continue to grant dispensations to some AOPOs and Technical Codes as the System Operator has been able to in the past. The System Operator will require wind generators demonstrate they have taken all practicable steps to incorporate technology to meet the existing rule requirements through the installation of best practice generator control technology.

However, in the interim period until the WGIP recommendations are implemented, compliance with rules as far as practicable using the new technology will be necessary to balance the additional costs to the industry from procuring additional ancillary services (frequency keeping and instantaneous reserves) to compensate for the lack of frequency support provided by wind generating units.

4.5.2 Options

Existing Controls and Measures

The rules require generating units to meet the following requirements:

- *Generating Units and associated control systems* (C3 Tech A 5.1.1) Each generator must ensure its generating units and associated control systems will support the System Operator to comply with its PPOs and is able to synchronise as set out in their asset capability statement;
- *Rate of change of output*. (C3 Tech A 5.1.2) There is a requirement on generators for the rate of change in their output to be adjustable and not to adversely affect the System Operator's ability to meet the PPOs;
- *Speed governor*. (C3 Tech A 5.1.3 and 5.1.4) Generating units are required to have speed governors.

These requirements relate to generating plant's ability to regulate its output. The output of wind generation is largely dependent on the wind blowing at the time and the ability of wind generation to regulate its output is more limited than hydro or thermal generation. Modern control systems for wind generating units do provide some capability for supporting the System Operator to meet the PPOs and to control the rate of change of output (i.e. ramp rate limiters). Unlike hydro or thermal generating units, wind generating turbines do not have speed governors. However, modern wind generation technology has limited ability (through control of the pitch angle of the blades or via the use of power electronics) to regulate output in response to changes in frequency.

Under the rules, the System Operator has the following measures available should wind generators' non-compliance with the above AOPOs and Technical Code threatens the System Operator's ability to meet the PPOs:

- Procure additional frequency keeping and dispatch additional instantaneous reserves to maintain frequency in the normal band and to avert frequency collapse following the loss of generation or transmission can be procured. In cases where insufficient frequency support is provided by generators, the System Operator can procure additional frequency keeping and instantaneous reserves (at increased cost to non-compliant participants).
- Ultimately, the System Operator, acting reasonably and prudently, has the discretion under rule 5.2 of Section III of Part C to not dispatch assets if it is satisfied that the assets do not meet the AOPOs and Technical Codes. The System Operator may therefore apply constraints on the dispatch of wind generation.

Dispensations

The necessary functionality (support frequency, limit rate of change of output and regulate output in response to changes in frequency) is available and is becoming standard in modern control systems for wind generating units. The cost of requiring wind generators to provide the best possible technology to support frequency is low.

Given the amount of wind generation capacity that is likely to be installed over the next two years, the System Operator has identified that it is not prudent to continue to grant dispensations in respect of frequency support if asset owners have provided evidence that they have installed the best possible technology to support frequency (e.g. the applicant has demonstrated that they have installed ramp rate limitation capability and control systems on their wind generation turbines that meet international best practice).

The conditions of the dispensation will allocate any increased costs on other parties resulting from the dispensation to the holders of the dispensation (as required by the rules).

Where the granting of a dispensation requires the procurement of additional ancillary services then the additional costs will be allocated to the holder of dispensation as provided for under the rules.

Interim rule changes

No interim rule changes have been identified for frequency support capability of wind generation.

4.5.3 Preferred Management Method

The System Operator believes that the effect of frequency support capability of wind generation turbines can be managed through existing controls and measures and dispensations until the WGIP investigates and implements further rule changes.

4.5.4 Long term options

Some potential long term options relevant to the frequency support capability of wind generation are

- The introduction of automatic generation control;
- The introduction of Asset Owner Performance Obligations and Technical Codes specific to wind generation including requirements for ramp rate limitations and control systems;

4.6 Asset capability of wind generation turbines and related equipment – fault ride through

There is no specific fault ride through capability requirement for generating units within the rules. The System Operator manages fault ride through indirectly via the Technical Code requirements for protection systems. The Technical Codes for protection systems require that the operation of protection systems will support the System Operator's ability to meet the PPOs.

4.6.1 Impact

Generating units need the ability to ride through faults on the power system (i.e. remain connected during the fault and following removal of the faulted assets). If generating units do not have this ability, then faults on the power system are likely to lead to widespread disconnection of generating units and cascade failure. The requirement for the protection systems for wind farms to be selective in operation and to preserve system stability (specified in rule 4.4 of Technical Code A) implies a fault ride through capability for wind generators. This capability is available from modern wind generation technology.

4.6.2 Options

Existing Controls and measures

The rules require protection systems on assets (e.g. wind turbines) to be selective with grid protection, so that wind generation units will remain connected during and following nearby faults on the grid.

Dispensations

No dispensations will be granted in respect of protection systems for large wind farms.

Interim Rule Changes

Determining appropriate requirements for fault ride through capability (e.g. a standard fault voltage profile that the wind turbine will be expected to remain connected through) will require considerable analysis and investigation which is best carried out in the WGIP.

4.6.3 Preferred Management Method

The System Operator believes that requirements for fault ride through capability for wind generating turbines can be managed through existing controls and measures and dispensations, until the WGIP investigates and implements further rule changes.

4.6.4 Long term option

One long term option is to codify the requirements for fault ride through in the rules.

4.7 Rule drafting – definition of "synchronised"

The rules that came into effect on 1 March 2004 were not drafted to reflect the capability of wind generation technology. Changes to the rules were required to allow Te Apiti to participate in the electricity market. The System Operator has identified a number of places in the rules where further change is required.

A number of the voltage support AOPOs and some of the frequency AOPOs require generators to meet the standards when "synchronised". It can be argued that these AOPOs do not apply to wind generation, because the generators do not meet the strict definition of "synchronised" in Part A.

4.7.1 Impact

The System Operator's ability to meet the PPOs will be reduced if wind farms do not provide voltage and frequency support. The System Operator may need to procure additional voltage support (both static and dynamic), frequency keeping and instantaneous reserves to meet the PPOs which will result in additional costs to other participants.

This is an oversight that requires resolution. The rules have not deliberately excluded wind generation from these requirements and to do so will directly affect either the System Operator's PPOs and/or impose additional costs on participants in areas where additional voltage support is required. The additional costs of voltage support will significantly exceed the cost of a rule change.

Resolving the issue via a rule change will be lower cost than resolving disputes via the rule breach process (which may lead to a rule change in any case as part of a settlement).

4.7.2 Options

A simple change to the definition of "synchronised" is proposed to clarify that intermittent generation, like other generation, is required to provide its contribution to voltage and frequency.

4.7.3 Preferred Management Method

The System Operator believes this issue is best managed through a rule change to the definition of synchronised.

4.8 Rule drafting – Must Run Dispatch Auction

Under the current rules, wind generators can offer their output at zero price ($0.00/MWh). Grid-connected generators that are not intermittent generators and wish to offer in at $0.00 / MWh must successfully compete in the daily must run auction run by the Clearing Manager. Wind generators are not treated on the same basis as other generators in terms of their ability to offer at zero price.

The must run dispatch auction will allow up to 80% of the lowest daily load to be offered into the Electricity Market as zero priced generation. The must run auction process does not account for the amount of wind generation that will be offered at zero price.

4.8.1 Impact

At times of light load, the combination of generation that is successful in the must run dispatch auction, embedded generation and the wind generation offering at $0.00 / MWh may exceed the minimum system load. The additional wind generation that is proposed to be commissioned within the next two years will exacerbate the existing situation. This situation occurs with the following effects:

i. Some generation that has secured the right to offer at $0.00 / MWh will not be dispatched. This will occur at times of light system load. Some of the displaced generation may be slow ramping plant that is unable to come back up to full load when it is required for the morning peak. This can cause security of supply issues during peak times, which may not be able to be alleviated without demand shedding.

ii. There is an acknowledgement by some wind generators that it would be better to "spill wind" at times of minimum system load rather than constrain other generation down or to have to disconnect from the power system with the associated security of supply risk noted above.

When prices are already clearing close to $0.00/MWh, there is very little cost suffered by participants in being constrained down or off.

iii. An intermittent generator has less incentives to accurately forecast output when it is automatically able to offer at a zero price. As stated in section 4.3, better accuracy in forecasting is considered to be an important issue to resolve in the short term.

4.8.2 Options

Existing controls and measures

There are no existing controls and measures available to the System Operator to mitigate this issue.

Dispensations

Dispensations do not apply as must run dispatch is a Part G issue, not an AOPO or Technical Code, for which dispensations can be granted by the System Operator.

Interim rule change

The issue can be addressed by taking either of the following actions:

- Require wind generation to participate in the must run auction process if they wish to offer in at $0.00 / MWh. This rule change will require the system operator to schedule wind generation at its offer price at $0.01 / MWh. This is a simple change which will place wind generation on the same basis as other generation wishing to offer at zero price.

- Revise the must run auction process to incorporate the forecast wind generation output. This is possible, but will not address issues ii and iii above.

The most appropriate option is to require wind to participate in the auction process if it wishes to run. This will go some way to addressing all issues raised with the zero priced generation. If this option can not be implemented in the short term, then immediate changes to the must run dispatch auction process are recommended to exclude wind generation from the overall total.

The costs of issues i (security) and ii (spill) above are likely to be considerably greater than the cost arising from a of a rule change to tidy up MRDA requirements.

4.8.3 Preferred management method

The System Operator believes that the must run dispatch process issue is best managed through a rule change to require wind generation to offer at $0.01 / MWh unless it has secured rights under the must run dispatch auction.

4.8.4 Long term option

The must run auction process is a measure needed by current market design and software to deal with generation which would otherwise wish to offer at zero or negative price. One possible solution is to change market design and software to facilitate negative prices. A more short term solution is to redesign the must run auction process.

4.9 Rule drafting – Contingent Event

The System Operator operates the power system to be secure following the occurrence of a defined set of contingent events. The current definition of contingent events includes the loss of a single generating unit.

4.9.1 Impact

Wind farms pose a similar risk in that some or all of their generation output can be lost by the operation of a single component (the grid interface circuit breaker). The amount of wind generation output that can be lost will be dependent on the configuration of assets that connect the wind farm to the grid. The loss of some or all wind farm output is not treated as a contingent event.

4.9.2 Options

Existing controls and measures

There are no existing controls and measures available to the System Operator to mitigate this issue.

Dispensations

Dispensations can be granted in respect of non-compliance with an AOPO or Technical Code. The definition of contingent events does not fall in this category for which dispensations can be granted by the System Operator.

Interim rule change

The following rule change is proposed:

- The definition in Clause 12.4 of the Policy Statement in Schedule C4 of contingent events is revised to include the loss of an intermittent generation station.

4.9.3 Preferred Management Method

The System Operator believes that this issue is best managed through rule changes to the definition of contingent events.

4.9.4 Long term options

It is possible that future wind farms may set the risk for the procurement of instantaneous reserves. Under the current rules, wind farms are not allocated a share of the instantaneous reserves availability costs as they do not meet the requirements for allocation.

Generators who own generating units with capacity greater than 60MW are allocated a portion of the instantaneous reserves (IR) availability costs under rule 11 5.1 of section IV of Part C. Wind farms comprise many small generating units (each typically less then 3 MW of installed capacity). As such, wind generators do not have to pay any portion of the availability cost event, even though the wind farm capacity can be far greater than 60MW.

It is recommended that the Commission consider (either through the WGIP or other processes) the allocation of instantaneous reserves availability costs to wind farms.

5. Optimum Long Term Solutions

The implementation of some of the optimum long term solutions may potentially take considerable time. This time will include:

- The time required to determine the optimum solution (e.g. through the WGIP).
- The time required to make the necessary changes to the rules and industry arrangements.
- The time required to design and build the necessary infrastructure to support the solution.

It is likely that the implementation of the optimum long term solution in certain areas (e.g. frequency management, improvements in wind generation forecast accuracy, improved must run dispatch auction process and dispatch at times of light system load) could take five years or longer if the development is not given priority.

This paper assumed that there would be over 800 MW of wind generation commissioned or ordered over the next two years. Based on proposed wind generation known to the System Operator, the amount of wind generation that may wish to be connected over the next years could be in excess of 1500 MW. In the absence of appropriate long term solutions being implemented in a timely manner, the System Operator may be forced to apply constraints on the dispatch of wind generation beyond this outlined in this report to continue to meet the PPOs.

It is recommended that implementing long term solutions should be given high priority either through the WGIP or other forums as appropriate.

6. Recommendations

The System Operator has identified the following general issues:

- that the amount of wind generation installed or ordered in the next two years will affect the System Operator's ability to meet the PPOs and that the System Operator has determined preferred methods for managing these issues over the interim period until long term solutions are determined and implemented;
- that it will not be prudent to continue to grant dispensations from the frequency AOPOs unless the applicant has demonstrated that they have installed plant that has the capability to meet best international practice in terms of frequency support;
- that there is a potential need to procure additional voltage support, frequency keeping and instantaneous reserves to continue to meet the PPOs with the connection of further wind generation ahead of the implementation of the WGIP outcomes;
- that additional transmission constraints will be required to manage equipment loading in the absence of asset owners adopting other controls to manage asset loading risk due to wind variability;
- that there is a need to review the issues relating to the current level of frequency keeping procurements and this matter should be referred to the Commission to progress;

The System Operator has identified a number of proposed rule changes and recommends that the Commission progresses the implementation of these rule changes in the short term:

- to include the loss of an intermittent generating station in the definition of contingent events for which the System Operator provides reserve;
- to require intermittent generators to offer at $0.01/MWh (thereby requiring the intermittent generator to participate in the must run auction if the wind generator wishes to bid at zero price;
- to set performance requirements on wind generation for forecast accuracy, require more frequent offers from intermittent generators and require publication of offer accuracy by the System Operator;
- to require wind generation to provide certain indications and measurements;
- to change the definition of "synchronised" to include wind generating units connected to the power system.

The System Operator recommends that the Commission notes that there is a degree of urgency in determining and implementing the optimum long term solutions (e.g. possible introduction of AGC, centralised wind forecasting and redesign of the must-run dispatch auction process) given the likely additional wind generation that will be commissioned or ordered in the next 2-3 years.

Appendix A - Executive Summary of the Manawatu Wind Generation Impact report

Manawatu wind generation
Observed impacts on the scheduling and dispatch processes

Second revision
September 2005

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Executive Summary

1.1 Background

The integration of large scale wind generation into power systems is a challenge facing regulators, system operators and grid owners worldwide. Wind and other forms of intermittent generation have quite different characteristics to the forms of generation around which power system operation and electricity markets have been designed. In addition, the challenge of integrating large scale wind generation into New Zealand power system is compounded by three factors:

- The New Zealand power system has no interconnections to other power systems and can not draw upon other power systems' resources.
- The long and stringy nature of the New Zealand power system (generation and load are connected by long transmission lines).
- The nature of the wind resource in New Zealand (gusty and concentrated in certain areas rather than even flows and diversely spread across the country).

The Electricity Commission has instigated two initiatives to meet the challenge of integrating large scale wind generation. These are:

1. *The Wind Generation Investigation Project (WGIP).*
   The objective of the WGIP is to
   - identify and quantify the technical and electricity market impacts of wind generation upon the New Zealand power system over the next ten years;
   - Recommend (if and as required) amendments to the Electricity Governance Rules and other relevant arrangements / processes to ensure power system security and market outcomes are achieved that are consistent with the Government Policy Statement on Electricity Governance (GPS) and Commission's Principal Objectives and Outcomes; and
   - Recommend an implementation plan for proposed changes, to the extent that this is required.

   This is a long term project and as a result the rule changes identified by the WGIP are expected to take two years to implement.
2. *The Tactical Project*.
   The Tactical Project has two objectives. The first objective is an assessment of the impact of the Manawatu wind generation on scheduling and dispatch. The second objective is to identify and recommend any necessary rule changes required to accommodate the integration of wind generation into the New Zealand power system for the interim period before the WGIP is completed.

The process for the first part of the Tactical Project (for which this report is the culmination) has been to:

- assess the impact of Manawatu Wind Generation on scheduling and dispatch for November and December 2004 and publish a report. This report was published in March 2005,
- continue the analysis for the period January to April 2005,
- consult informally with Meridian Energy Limited and Trustpower on the outcome of analysis,
- publish a revised report in September 2005. (This report).

The process for the second part (to identify any necessary rule changes for the interim period) is to:

- request information (via the Electricity Commission consultation framework) to identify possible rule changes. This consultation was carried out in July-August 2005,
- identify the necessary rule changes and propose recommendations to the Electricity Commission. This is expected to be completed in October 2005.

1.2 The integration of large scale wind generation into power systems

Wind and other forms of intermittent generation are quite different to the forms of generation around which power systems have evolved. Conventional hydro and thermal generation plant has the ability to control its output by adjusting its fuel input. Such generating units can maintain a set level of power output by adjusting the fuel input. The power output of conventional hydro and thermal generation is largely predictable and constant.

Wind generation can not control its power output in such a way – it is dependent on the wind that is blowing at the time. This has some implications for power system and electricity market operation which has been designed around predictable and constant generation.

When the level of wind generation penetration is small, the effects of its unpredictability and variability make little impact on the power system. However, with increasing amounts of wind generation connected to the power system, there comes a point where the impacts of unpredictability and variability of wind generation become significant for the operation of the power system.

This report analyses the impact that the unpredictability and variability of the Manawatu wind generation output has had upon the operation of the New Zealand power system and upon scheduling and dispatch during the period between November 2004 and April 2005.

1.3 Scope of this report

The analysis of the impact of the Manawatu Wind Generation on scheduling and dispatch has been limited to the areas of:

- quantifying the physical impact upon the operation of the frequency keeping ancillary service
- quantifying the impact on the accuracy of wind generation and load forecasts
- quantifying the impacts of changes in power flows across the grid following a change in wind generation output, and
- a discussion of possible mitigating measures.

The assessment of market costs relating to Manawatu wind generation variability and the effect of the wind generation on electricity prices and participant behaviour are not in the scope of this report.

The report only considers impacts on the power system that have been observed to date. There are other power system issues (which have been observed elsewhere) that will need to be further investigated. These issues include:

- the effect of wind farms on the dynamic behaviour of the power system (e.g. possible impacts arising from the reduction in system inertia and the extent to which the impact of wind farms on the dynamic performance of the power system can be modelled);
- the effect on voltage control of the grid when large scale wind farms substitute for conventional generation; and
- possible impacts arising from reduction in fault levels, particularly on the operation of the HVDC link.

1.4 Manawatu Wind Generation

There are two existing wind farm sites in the Manawatu region – Tararua wind farm owned by Trustpower Limited and Te Äpiti wind farm owned by Meridian Energy Limited. Figure E.1 shows the lower North Island and the Manawatu region. The Tararua wind farm is embedded behind the Linton and Bunnythorpe grid exit points and has been in operation since 1999. The Te Äpiti wind farm is connected to the grid near Woodville and was fully commissioned in late 2004. The combined installed capacity of the two wind farms is over 150 MW (around 90% of the total installed wind generation capacity in New Zealand).

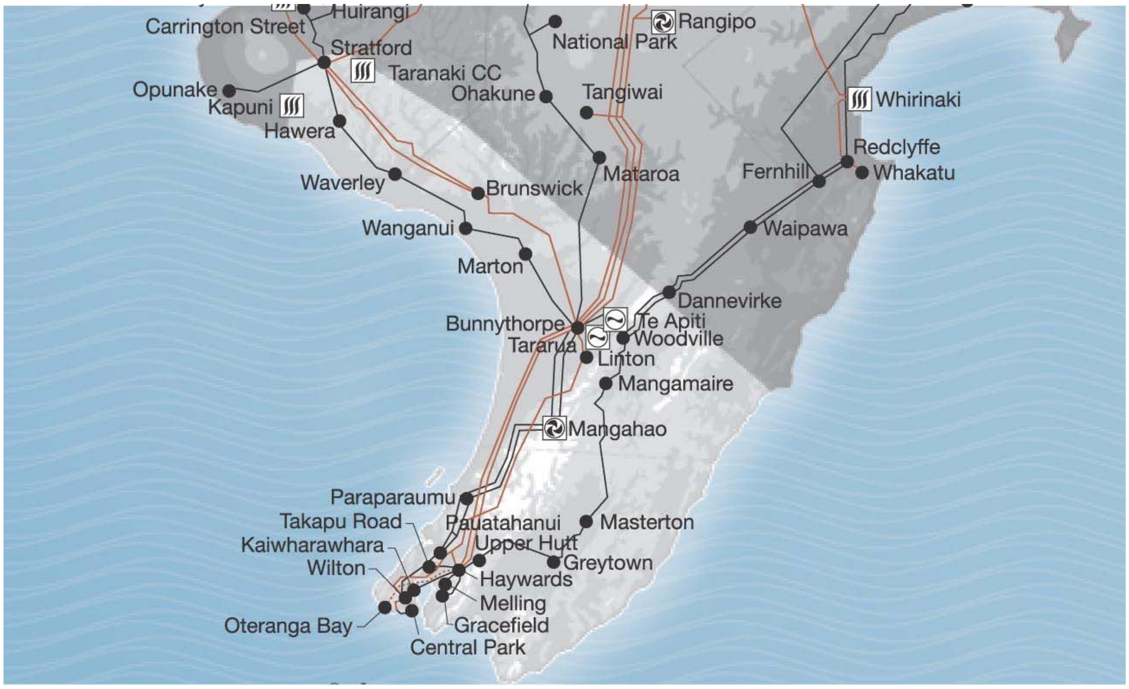

Figure E.1 – Lower North Island

This report focuses on the impact of the combined Manawatu wind generation for the period between November 2004 and April 2005.

1.5 Manawatu Wind Generation Output variability

The amount of generation output from the two wind farms in the Manawatu region has been observed to vary significantly over a day. This variability makes the forecasting of future amounts of wind generation difficult. There have also been a number of large generation changes within short time periods. Managing these large changes in output in real time can pose operational difficulties.

Figure E.2 shows the number of observed changes in combined Manawatu wind generation output of above 25 MW over five minutes for the period December 2004 to March 2005, plus events greater than 50 MW over five minutes for November 2004. It should be noted that six months is not long enough to observe all events that might occur. Further observation is required to confirm the probability of the occurrence of sudden large events in Manawatu wind generation output.

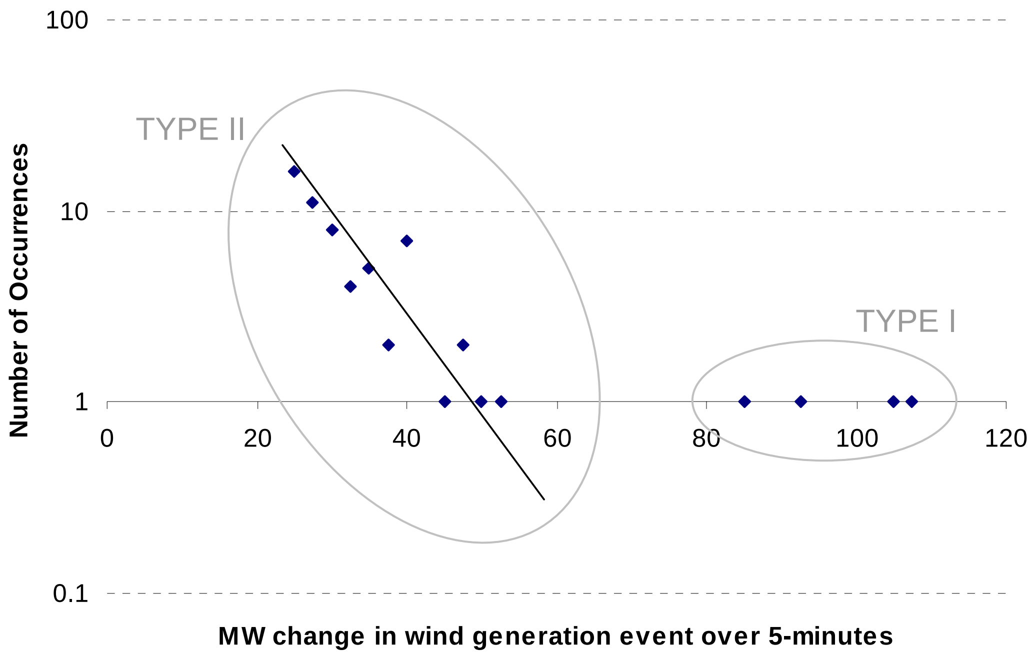

Figure E.2 – Number of observed changes in Manawatu wind generation output as a function of size (MW)

Figure E.2 suggests that there are two apparent types of sudden change in the amount of generation output. The first type of sudden change (Type I) seems to occur during certain specific weather conditions, which are discussed in detail in Section 3.1.2 in the main body of the report. The average size of these events is around 100 MW which is roughly equivalent to 66% of the currently installed wind generation capacity in the Manawatu region. Based on observations to date, it is expected that around 10 events of this type will occur each year. It is possible that this type of change is a result of weather conditions unique to the location of wind farms in the Manawatu region.

The second type of sudden change (Type II) is smaller in size and seems to show a correlation between the number of occurrences of an event and size of the sudden change in generation. It is possible that these events may reflect the natural variability of wind speeds (and hence wind generation output) in the region. Based on observations to date, it is expected that around 12 events of a change of 50 MW (33% of currently installed wind capacity) in five minutes will occur each year.

The analysis in this report indicates that the Manawatu wind generation does impact on the operation of the power system and electricity market. Of course, the behaviour of other generation and load also impacts upon the operation of the power system and electricity market. This behaviour is generally understood and accounted for in the operation of the power system and electricity market. The impact of the variability of the existing amount wind generation farms is significant and as yet not well understood. The impact of the variability of the amount of future wind generation proposed to be connected to the power system will require changes to power system operation and the electricity market.

The impacts of 150 MW of installed wind generation capacity in the Manawatu region are being already observed. There are currently 670 MW of wind generation projects in the North Island which have already gained consents or for which consents are currently being sought. The amount of wind generation capacity installed in the North Island in three to five years time could potentially be in the range of 850 MW to 1300 MW (see Section 1.10.2 later in the report).

1.6 Large changes in Manawatu wind generation output

A number of sudden large changes in the combined Manawatu wind generation output were observed during the period from November 2004 to April 2005. Analysis of the impact upon power system operation of some of these events (i.e. those where an increase or decrease of greater than 50 MW in a five minute period occurred) has been carried out.

There are two reasons why this size of event has been examined:

- A 50 MW change in five minutes equates to the minimum required frequency keeper[6] response rate of 10 MW per minute, and
- ±50 MW is the size of the dispatched frequency keeping band.

Six such events (a change of greater than 50 MW over five minutes) have been identified. These are listed in Table E.1.

Event Number	**Date and Time**	**Approximate output change and interval**
1	15 Nov 2004, 01:00 to 02:00	140MW in 13 minutes increase (105MW in 5 minutes)
2	23 Nov 2004, 23:50 to 24:00	110MW in11 minutes increase (85MW in 5 minutes)
3	30 Dec 2004, 16.45 to 17.00	130MW in 12 minutes increase (93MW in 5 minutes)
4	14 Feb 2005, 11:30 to 12:00	70MW in 12 minutes increase (53MW in 5 minutes)
5	14 Feb 2005, 14:30 to 14:45	120MW in 10 minutes increase (109MW in 5 minutes
6	25 Mar 2005, 10:50 to 11:05	70MW in 8 minutes increase (50MW in 5 minutes)

Table E.1 - List of events during November 2004 to April 2005 where there was a change of greater than 50 MW over five minutes.

[6] See Section 1.7.1.

1.7 Impacts on power system operation

1.7.1 Frequency Keeping

The System Operator manages power system frequency (nominally 50 Hz) by procuring the frequency keeping ancillary service. This ancillary service is provided by a generating station which is contracted and dispatched for that purpose. The frequency keeping station (the “frequency keeper”) in each island changes output to match changes in other generation and load in order to maintain power system frequency between 49.8 Hz and 50.2 Hz (the normal band). There is usually one frequency keeper in each island. Sudden changes in the level of Manawatu wind generation output are largely compensated by the frequency keeper until re dispatch of other generation occurs.

During each of the six events in Table E.1, the impact of the sudden change in wind generation output on the frequency keeper was analysed. It is evident that the frequency keeper compensates for this rapid change in wind generation output in each of these events.

Figure E.3 shows the effect of a sudden large event occurring on 15 November 2004 starting at around 01.00 hours on the North Island frequency keeper and on North Island frequency. The dispatched frequency keeping (band) limits are shown to illustrate when the frequency keeper has had to go outside the dispatched band (±50 MW) in an effort to maintain the island frequency.

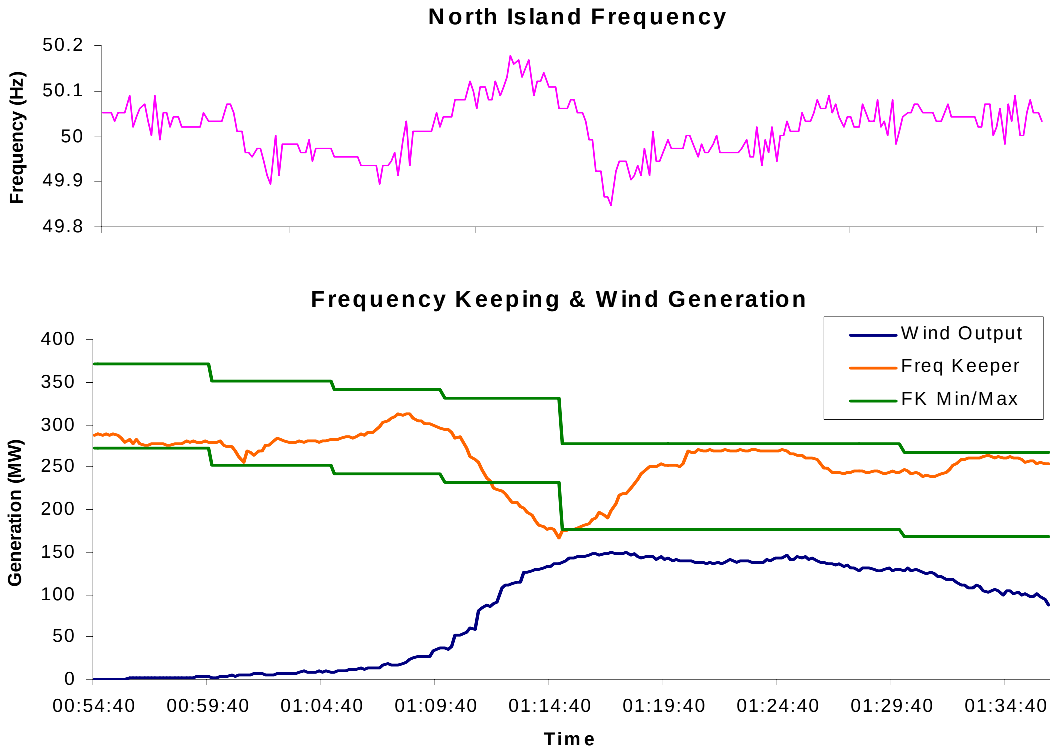

Figure E.3 -North Island frequency, frequency keeping generation (and frequency bands) in response to the event on 15 November 2004

Figure E.3 shows a rapid increase in Manawatu wind generation output from around 01:00. During this event the total wind generation output increased by 105 MW over 5 minutes and 150 MW in 20 minutes. From Figure E.3, it is evident that in the initial period nearly all of this increase in generation is offset by the frequency keeper which reduced output in response to the increase in the North Island frequency. During this time the frequency keeper moves below the dispatched frequency band and the North Island frequency moves 0.3 Hz to a peak near 50.2 Hz, the upper limit for normal frequency band.

For two of the six events (15 November 2004 and 25 March 2005) the sudden change in wind generation output resulted in the frequency keeper going outside their dispatched MW frequency keeping band. These events have an impact on North Island frequency, and on one occasion (23 November 2004) the North Island frequency moved outside the normal frequency band. Two of the events (15 November 2004 and 14 February 2005) had rates of change of output that were twice the contracted frequency keeper response rate (of 10 MW per minute), and were twice the size of the dispatched frequency keeping response band (±50 MW) at the time.

It should be noted that during five of these events frequency keeping was being provided by a hydro generation station. This type of generation plant has a high response rate in terms of frequency keeping. The high response rate of the frequency keeper combined with the response of other generating plant connected at the time meant that the impact of wind generation output increase was able to be managed with minimal impact on the power system. Thermal generation units used for frequency keeping in the North Island do not respond as quickly as hydro plant nor (normally) have adequate capacity to cover such a rapid change in generation.

More frequent re-dispatch of generation will help mitigate the impact of sudden large changes in wind generation output. In the short term, automation of the issuing of dispatch instructions (currently a manual process) can be investigated as an interim measure until a permanent solution is implemented. The need for a permanent solution is urgent given the considerable amount of wind generation that is proposed to be connected to the power system within the next three years. A high priority needs to be placed on putting in place the framework whereby a permanent solution (e.g. some form of AGC solution) can be agreed and implemented.

1.7.2 Transmission constraints

The sudden increase in wind generation output in the Manawatu region combined with a corresponding reduction in generation output by the frequency keeper causes a change in power flow within the circuits that make up the transmission grid. This change in power flow has the potential to cause some transmission circuits to exceed their stated rating until the System Operator is able to dispatch other generators to compensate for the change. Reduced power system capability limits may need to be put in place to avoid assets exceeding stated capability during a sudden change in wind generation output.

Two scenarios have been identified where the change in power flow, following a change in Manawatu wind generation output, has an effect on power system capability limits:

- High North transfer through the North Island.
  A sudden increase in Manawatu wind generation output can cause power system capability limits to be exceeded during high power transfer to the north of Bunnythorpe. The limitation is on the Tokaanu - Whakamaru circuits.
- HVDC South transfer.
  Power system capability limits can be exceeded during high power transfer to the south of Bunnythorpe during a sudden decrease in Manawatu wind generation output. The limitation is on the Brunswick - Stratford circuits and applies while summer ratings are in effect.

Further information on the effect of Manawatu wind generation on power system capability limits has been included in the July 2005 Amendment to the System Security Forecast (http://www.transpower.co.nz/?id=4464). The deployment of automatic systems to limit or reduce win generation output when assets are at risk (i.e. runbacks or inter-trip schemes) by wind generators and the grid owner could negate the need to reduce power system limits

1.8 Impacts on the electricity market

1.8.1 Forecast accuracy

Wind generation (and other forms of intermittent generation) is not offered[7] into the electricity market in the same manner as other types of generation are offered. As part of the wind generation offer, a forecast of the amount of wind generation in a trading period is provided to the System Operator. The accuracy of the provided forecast is dependent on the wind generator's ability to predict the amount of wind generation in advance.

As part of the scheduling process, the System Operator schedules offered generation to meet forecast load. The forecasts provided by wind generators are used in the scheduling process. Inaccuracy in wind generation forecasts means that generation that is actually dispatched in a trading period can be quite different to the generation that was scheduled earlier. This has two impacts.

Impact on power system security

The System Operator uses the scheduling process to identify possible power system security issues (e.g. not enough generation offered in a particular trading period). Inaccurate wind generation forecasts can mean that generation dispatched in a trading period is quite different to the generation that was scheduled and for which power system security analysis was carried out. This increases the risk that power system security issues emerge during dispatch. This affects the System Operator's ability to manage the power system securely.

The current level of wind generation forecast accuracy is manageable within the current scheduling and dispatch processes (although the effects of forecast inaccuracy are being observed). As increasing amounts of wind generation capacity is installed, there will come a point where the inaccuracy in the wind generation (or other intermittent generation) is so large that power system security can not be safely managed using the current processes and software tools.

[7] It should be noted that the output of Te Apiti is the only wind generation currently offered into the electricity market. The output of Tararua North and South wind generation will be offered in the near future.

One option to improve the accuracy of wind generation forecasts is to consider the use of a common centralised wind generation forecast in the scheduling and dispatch process as has been implemented in other countries.

Impact on market outcomes

Pre-dispatch Generation schedules produced in the scheduling process provide information to market participants who can then adjust their offers of generation and bids of load in response to the forecast prices in the schedules. This allows generators to optimise the efficiency of their generating units and to plan starting and stopping of their plant. Price forecasts are used by purchasers to adjust their bids, for example, reducing the amount of electricity they intend to consume during future trading periods where the price is high.

Inaccuracy in wind generation forecasts affects the accuracy of the generation schedules. Generators and purchasers who use the information in the pre-dispatch schedules to plan their offers and bids will find that the actual dispatch in some trading periods is quite different to the schedule around which they based their offers and bids. This difference will result in increased plant operating costs and opportunity costs (e.g. where generators did not offer their plant based on low forecast prices but where the final prices were high).

1.8.2 Te Äpiti Forecast Accuracy

Figure E.4 shows the cumulative distribution of the two hour Te Äpiti forecast generation error for the period November 2004 to April 2005. The two hour forecast is significant in the scheduling and dispatch process as generators are not permitted to change their offers in the two hours before dispatch except for certain defined circumstances.

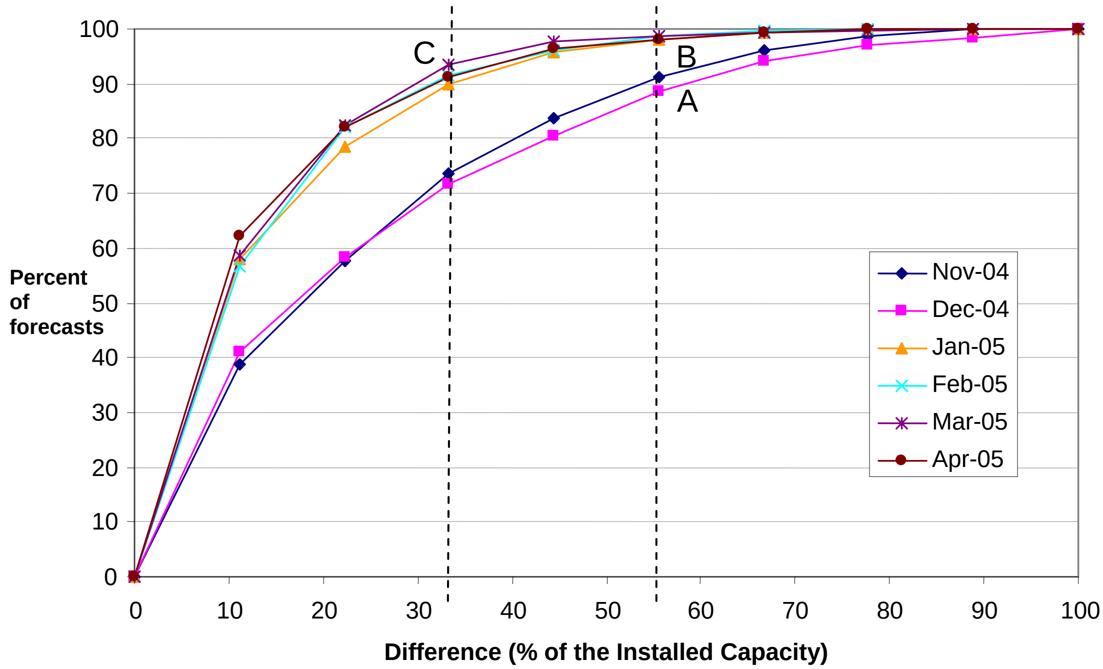

Figure E.4 - Cumulative distribution of the Te Äpiti two hour forecast generation error (for months November 2004 to April 2005).

The accuracy of Te Äpiti's two hour forecasts has improved markedly since the start of 2005. In November and December 2004, 90% of forecasts had an error of less than 55% of the installed capacity of Te Äpiti wind farm (point A on the graph). From January 2005 this has improved to 98% of forecasts (point B). However, 10% of the improved forecasts still have an error greater than 33% of the installed capacity (point C).

The pre-dispatch schedules provide important information for market participants and are used by the System Operator to assess power system security. Security assessments are carried out four times a day. Participants are notified of identified security issues enabling them to respond to such warnings and revise their bids or offers. The longer range forecasts (such as twelve hours out) are important for standby generation availability given it can take thermal units over eight hours to commit. The shorter range forecasts (such as six hours out) are important as participants will revise their offers and bids to in response to notified security issues.

While the two hour forecasts of Te Äpiti wind generation output have improved, the six and twelve hour forecast errors for Te Äpiti wind generation have not improved since the analysis carried out in November and December 2004.

1.8.3 Must Run Generation

The output of some generating units is offered into the electricity market at zero prices. The reason for doing this can be because the fuel source for the generation can not be stored (e.g. run of the river hydro generation) and the fuel must be used at the time it is available. Alternatively, the generator may prefer that the generating unit stays connected throughout the day as costs of starting and stopping the generating unit are high.

Under the current dispatch rules in the EGRs, generators wishing to offer zero priced generation into the market must first bid into a must-run dispatch auction held daily by the Clearing Manager. Where a generator's bid is successful, the generator is authorised to offer a quantity of electricity at zero price for the relevant trading period. Any generation not cleared in the must-run dispatch auction must offer its output at $0.01/MWh. Generation successfully bid into the must-run dispatch auction will be dispatched (at zero price) ahead of the unsuccessful generation which will be dispatched at a price of $0.01/MWh.

Wind generation is a form of "must run" generation in that generation only occurs when the wind is blowing. Wind generation is treated as a zero priced generator in the dispatch process and is effectively a must run generator even though it is not bid into the must-run dispatch auction. This arrangement was a temporary measure implemented to allow Te Äpiti to be incorporated into the dispatch process until more permanent rules could be developed.

At certain times (e.g. low load conditions) the amount of zero priced generation offered in one island can exceed the island demand. The excess generation is not dispatched. The result is that potential electricity generation is lost (e.g. water is spilled) or thermal plant is dispatched off with high costs. Wind generation has two effects on the amount of zero priced generation.

First, wind generation is effectively treated as being must-run generation but is not bid into the must-run dispatch auction. This increases the likelihood of too much zero priced generation being offered as the current design of the must-run auction process takes no account of the zero priced wind generation.

Second, increasing amounts of wind generation connected to the power system increases the pool of generation that is offered or that generators may wish to offer at zero price. An excess of zero priced generation at certain times (e.g. low system loading) requires that some of this generation is not dispatched.

The overall effect of wind generation on must run generation is that the likelihood of some other forms of must run generation not being dispatched is increased (with the result that water is spilled by must run hydro or high starting and stopping costs are incurred by thermal plant). One option for mitigating these effects is to change the process by which must run generation is dispatched. The efficient and equitable inclusion of wind generation in the 'must run' generation dispatch process will help ensure that:

- any necessary “spilling” of fuel resource at times when must run generation is in excess of total system demand is done in a manner that best meets the government policy objectives for the Electricity sector,
- other types of must run generation from renewable sources are treated on the same basis as wind generation.

1.9 Options for mitigating the impacts

The observed impacts to the power system of the combined Manawatu wind generation are manageable under the current Electricity Governance Rules (EGRs). The connection of further wind generation (either in the Manawatu region or elsewhere) will increase variability in the power system. This may require changes to the way in which the operation of the power system and electricity market is managed. The effects of variability in the output of wind generation could be mitigated by a number of means.

1.9.1 Ramp rate controls

Ramp rate controls on wind turbines have been suggested as a means to reduce the impact of sudden changes in wind generation output and avoid the need for wider frequency keeping bands and increased frequency keeping costs. The ramp rate restriction has been analysed to determine the amount of time per event that generation would need to be restricted, and the total energy lost due to the restriction. The EGRs currently place no specific obligations for intermittent generation to have ramp rate control.

1.9.2 Improvements in Forecasting Accuracy

Inaccurate forecasts affect participants in the electricity market and the ability of the System Operator to meet the Principal Performance Obligations set out in Part C of the EGRs. Inaccuracy in forecasting affects participants by increasing uncertainty in trading outcomes. The security impact of greater inaccuracy in the schedule is the increased risk of transmission-constrained dispatch ‘surprises’ in real time. It is understood that the MetService, in conjunction with wind farm owners, is developing methods to improve the wind farm forecasts.

The centralised forecasting of wind generation output may be more accurate than forecasts provided by individual wind generators. This is an area that will be investigated in the Electricity Commission’s Wind Generation Investigation Project or that could be implemented by wind generators collectively as an initiative prior to the completion of the Wind Generation Investigation Project.

1.9.3 More frequent re-dispatch of generation

More frequent re-dispatch of generation will help mitigate the impact of sudden large changes in wind generation output. In the short term, automation of the dispatch process to produce dispatch instructions every five minutes and at any time when the wind generation output has changed materially away from the dispatched amount can be investigated. Such automation can help mitigate the effect of sudden large changes in wind generation output and also has benefits for the frequency keeper and for other generating plant as generation is re-dispatched more quickly to meet the changed power system conditions relieving the need for the frequency keeper and other generating plant to compensate for the sudden change in wind generation output.

The more frequent dispatch of generation using current processes is but an interim solution. A permanent solution may be required within a relatively short time frame. A high priority needs to be placed on investigating and implementing a permanent solution (such as Automatic Generation Control) as soon as possible. A high priority needs to be placed on putting in place the framework whereby a permanent solution (e.g. some form of AGC solution) can be agreed and implemented.

1.9.4 Changes to Frequency Keeping Management

The highest rates of change observed in the output of Manawatu wind generation are greater than the current minimum requirements for frequency keeping stations (i.e. 10 MW per minute). While some frequency keepers can provide a more rapid rate of change, frequency keepers are contracted to provide only the minimum rate of change. In addition, the magnitude of some changes (around 100 MW) exceeds the contracted and dispatched MW frequency keeping band (50 MW).

Options immediately available to the System Operator include increasing the minimum requirements for frequency keeping service providers and increasing the amount of frequency keeping procured. This is likely to increase the costs of the frequency keeping service. Another option is a requirement for ramp rate controls on wind turbines (which has been discussed previously). The implementation of Automatic Generation Control is another option.

1.9.5 Revision of transmission constraints

Changes in power flows across the grid following sudden large changes in Manawatu wind generation output may require revision of power system capability limits. It may also be necessary to revise operational policies to ensure that transmission circuits do not exceed stated capability if Manawatu wind generation output was to rapidly increase during a contingent event.

A variety of measures can be used to manage the risk of exceeding power system capability limits when there are changes in wind generation. This includes operators of wind generation arranging with Transpower for automatic schemes to monitor transmission capacity and wind generation output and modify the output of their wind generation. In the absence of any other controls applied collectively by asset owners, constraints to ensure that assets within the power system are kept within their stated capability will need to be applied in power system operation. Constraints can be used to:

- Dispatch generation so that the circuits in question will not exceed stated capability for a sudden increase in Manawatu wind generation output or constrain off Manawatu wind generation at the times when there is a risk of these circuits exceeding stated capability.
- Restrict the rate at which wind generating units change output.

1.9.6 Changes to dispatch of must run generation

Wind generation is effectively treated as zero priced generation in the scheduling and dispatch process. Wind generation is currently not bid into nor accounted for in the current must-run dispatch process. This increases the likelihood that some must-run generation is not dispatched with consequent spilling of water or the incurring of high starting and stopping costs). Interim rule changes to either the must run auction process or the way in which wind generation is treated by SPD will be considered. This is an area that will also be investigated in the Electricity Commission's Wind Generation Investigation Project. See also earlier comments in section 1.8.3 on this matter.

1.10 Increased installed wind generation capacity in the Manawatu region and the North Island

1.10.1 Manawatu Region

The first part of the analysis in this report illustrates the current effect of wind generation in the Manawatu region on the power supply of New Zealand. Consents for further wind generation in the Manawatu region have been sought and some have been gained. It is likely, that the new wind generation in the Manawatu region may show a similar correlation to the strong correlation observed between the Tararua and Te Äpiti wind farms.

There is currently over 150 MW of installed wind generation capacity in the Manawatu region (Te Äpiti and the Tararua North and South wind farms). Resource consents have been gained for the Tararua III wind farm (93 MW) and the Te Rere Hau wind farm (48.5 MW). As a result, it is likely that there will be an additional 140 MW of installed wind generation capacity in the Manawatu region in the future. There is likely to be 300 MW of installed wind generation capacity in close proximity to the Manawatu gorge.

If this is the case, the size (MW change in five minutes) of the Type I events will be expected to increase proportionally as more wind generation capacity is added. Hence events that are 66% of the current capacity of the wind farms will increase from 100MW to 200MW if the output of the wind farms were to increase from 150MW to 300MW. The analysis has shown that this type of event would be expected to occur around 10 times each year.

The size of the Type II events would also be expected to increase with the addition of further wind generation capacity in the Manawatu region. If the new wind generation was strongly correlated with the existing wind generation then this type of variability would be expected to increase proportionally. Hence the 12 forecast Type II events each year of a change of around 33% of installed wind capacity in five minutes can be expected to increase from 50 MW in size to 100 MW if the output of wind generation in this area were to double. If the new wind generation is not strongly correlated then an increase in this type of variability would still be expected, but to a lesser degree.

1.10.2 North Island

There is currently just less than 170 MW of installed wind generation capacity in the entire North Island. Resource consents for another 210 MW of wind generation in the North Island have been granted. Resource consents for an additional 560 MW of wind generation have been applied for. Responses from the Request For Information on wind generation (put out in July 2005) indicate that a further 370 MW of wind generation beyond that already consented or in the consent process is being considered.

It is likely that the amount of installed wind generation in the North Island will at least double within the next two years as the consented wind generation is commissioned. The amount of wind generation capacity installed in the North Island in three to five years time could potentially be in the range of 850 MW to 1300 MW.

The correlation between changes in wind generation output in different regions has not yet been determined. However, it seems likely for installed North Island wind generation capacity in the range 850 MW to 1300 MW that:

- Sudden large changes in North Island wind generation output of between 200 MW to 400 MW over five minutes might be expected to occur on a monthly basis. This is based on characteristics of the Type II (non weather condition related) events observed at Te Äpiti and is consistent with information provided by a wind generator for wind speeds at sites in a number of regions across New Zealand. Changes of this size will have significant implications for the management of frequency and transmission circuit loadings and potentially voltage management and other power quality issues.

- The inaccuracy in the total of the forecasts for wind generation output in the North Island could be greater than 250 MW for 10% of the time. This assumes that 10% of forecasts will have an error of greater than 33% of installed capacity (similar to Te Äpiti forecast accuracy) but that some of the errors will cancel out.

In formulating interim rule changes, the Tactical Project will consider what rule changes will be required to manage the effects of the committed and existing wind generation along with that likely to be committed and operating within two years. The scope of the WGIP is to consider power system operation and market changes required to manage wind generation capacity that will be installed over the next 10 years.

1.11 Conclusions

Analysis of the variability of Manawatu wind generation indicates:

- Sudden large changes in wind generation output (of 50 MW or greater in five minutes) are likely to occur around 20 times[8] per year for the current amount of installed wind generation capacity in the Manawatu region.
- Large changes in wind generation output over a short period may cause power system frequency excursions.
- The observed rates of change in Manawatu wind generation are at times greater than the minimum ramp rates requirements for frequency keeping service providers.
- The size of the changes in Manawatu wind generation is at times greater than the typical frequency keeping MW band dispatched.
- An improvement in the accuracy of Te Äpiti's two hour forecasts has been observed since January 2005. There have been no improvements in the six and 12 hour forecasts.

In addition to the observed effect on power system frequency, sudden changes in Manawatu wind generation cause changes in power flow across the transmission grid which may cause assets to exceed their stated capability. Inaccuracy in provided forecasts of wind generation reduces the System Operator's ability to manage the power system securely and increases uncertainty for other generators in the planned dispatch of their plant.

It must be noted that some of the observed impacts (e.g. weather condition related sudden large changes and correlation between wind farm outputs) may be unique to Manawatu wind generation and may not occur with wind generation installations in other parts of New Zealand.

[8] Based on an extrapolation of the limited amount of data analysed in this report.

Overall, the current effects of Manawatu wind generation variability on the operation of the power system and the electricity market are manageable using the policies and means available to the System Operator set out in the policy statement in Part C of the EGRs. However, any increase in the amount of Manawatu generation means that the System Operator will have to review the policies and means in the policy statement along with the dispatch rules in Part G.

The System Operator will be identifying and proposing rule changes, where required, as part of the next stage of the Tactical Project so that the impacts of additional wind generation can be managed to ensure the integrity of the power system ahead of any further changes from the WGIP. The process of identifying and proposing any required rule changes is planned to be completed in October 2005 and submitted to the Electricity Commission for processing through its rule change processes.

Appendix B Summary of submissions to the Request For Information of Wind Generation

Purpose

The Electricity Commission's (EC) consultation paper sought information from the industry participants on short-term measures for accommodating wind generation on the New Zealand power system.

The purpose of the consultation was to collect information to assist in the identification of any interim connection and management measures required in the short term to accommodate additional, large scale wind generation.

Summary

Below is a summary of the key points raised by participants:

1. The variability of wind generation output is likely to pose difficulties to power system management. Extra costs incurred in managing additional wind generation (including additional ancillary services procurement) should be recovered from intermittent generators rather than from other users of the system.

2. The nature of wind generation means that other forms of generation will be required to compensate for the natural variability of wind. This has the potential to limit the amount of wind penetration. Options for mitigating the impact of wind variability (e.g. hydro balancing or integrated storage) should be considered.

3. There is a need to improve the forecasting of wind generation. Adapting overseas forecasting models to New Zealand may not be appropriate. There are experts in New Zealand with the capability to develop models and design expert systems to address the short term wind forecasting issue.

4. Wind generation will only be one part of New Zealand's total power generation. All generation plants need to be treated equally, with non-compliance addressed by the "causer pays" principle.

5. Wind generation does not require any changes to be made to Generator AOPOs. The perception is that any non-compliance could be sought via the use of dispensations.

6. The allocation of costs to wind farm generators, such as enforced ramp rate capability and "causer pays" costs will be disincentives to wind farm development.

Submissions Received

The commission invited submissions via a Request For Information in June 05. The paper contained 23 questions which were grouped according to a number of generic factors being considered (see details in the next section). Sixteen respondents made submissions which varied from comments on specific sections only to full feedback on the questionnaire. The respondents represented:

- Five large generators
- Two Lines Companies
- Two direct connects
- Two potential wind generators
- Two wind generation manufacturers
- Two wind generation consultancies
- One industry association

Feedback Received

General

Many respondents support the investigation of technical and market issues associated with wind. They welcome the efforts to facilitate wind energy and appreciate the need to sort out the issues sooner than later. Some Submitters believe that appropriate investigations have the potential to allow the integration of large scale wind energy into the NZ system, through the development of appropriate rules and requirements. The need for revisiting EGRs to accommodate wind generation was also emphasised.

Some respondents have expressed their concerns regarding the content, administration, cost and priority of the project, lack of policy leadership on issues affecting the wind generation integration and the commercial confidentiality of information about future investment plans. Some believe associated costs should be borne by beneficiaries of the investigation. It was also pointed out that proliferation of intermittent generation could adversely affect the economies of investing in base load generation.

Key messages conveyed in general feedback include:

- The variability of wind generation output is likely to pose difficulties to power system management. Extra costs incurred in managing additional wind generation (including additional ancillary services procurement) should be recovered from intermittent generators rather than from other users of the system.

- The nature of wind generation means that other forms of generation will be required to compensate for the natural variability of wind. This has the potential to limit the amount of wind penetration. Integrated storage options will need to be considered for alleviating such issues.

- There is a need to improve the forecasting of wind generation. Adapting overseas forecasting models to New Zealand may not be appropriate. There are experts in New Zealand with the capability to develop models and design expert systems to address the short term wind forecasting issue.

- Wind generation will only be one part of New Zealand's total power generation. All plants need to be treated equally, with non-compliance addressed by the "causer pays" principle.

- Wind generation does not require any changes to be made to Generator AOPOs. The perception is that any non-compliance could be sought via the use of dispensations.

- The allocation of costs to wind farm generators, such as enforced ramp rate capability and "causer pays" costs will be disincentives to wind farm development.

Variability of Wind Output (Q5)

A number of wind farm developers have confirmed the availability of information on real time variability of the output of wind farms in the Manawatu as well as in other regions. This data is not necessarily real time data, in some instances this is historical 10 minute data. The wind farm developers have expressed a willingness to provide this historical information to assist the EC with its studies.

Some of the respondents expressed concern about releasing real time variability data at present due to confidentiality reasons.

Correlation of closely located Wind Farms (Q6-Q7)

Some of the respondents confirmed the availability of information about the degree of correlation:

- between the wind farms in the Manawatu region
- between Manawatu region and some other regions

Submissions indicated a willingness to provide further information to assist the analysis if requested by the EC. Assistance has also been offered to provide an indication of the degree of correlation between wind farms using advanced mesoscale modelling techniques.

Many respondents expect proposed wind farms in the Manawatu region to be highly correlated. As the real time correlation could be higher than the hourly average, the use of an appropriate sampling period when determining correlation would be very important.

Combined Impact on system frequency management (Q8-Q12)

Ramp Control

- Respondents would be happy to share the information on control systems that can be installed to limit the ramp up of wind generation. Some control technologies only allow ramp up rates to be controlled where as certain turbine technologies have also been developed to control both ramp up and ramp down.

- Many respondents would generally support the use of ramp-rate limits only if:
  - there was a potential security issue or risk of frequency excursion as a result of higher ramp rates
  - it was identified as the most effective way of reducing market costs of meeting the System Operator's PPOs
  - it was imposed during the interim period where the need has been demonstrated that the controls are required.

  Some of the respondents oppose the ramp rate control and believe that such measures would constrain the wind farm operators and would be a disincentive to building future wind farms. It is also suggested that the wind farm operators be given the option of choosing whether to balance frequency keeping reserves, install ramp rate equipment or agree an equivalence arrangement.

  A number of respondents are wary of requiring ramp rate limits until the impacts upon frequency keeping are established and would prefer that wind generators face the proper economic costs that their plant imposes upon the power system.

  Generally Submitters do not agree with a blanket requirement for ramp rate control as it would likely lead to additional and perceived unnecessary costs, particularly for small wind farms.

Procurement of resources to manage frequency

- Some submissions have been received suggesting a rule amendment to include wind generators in the allocation of frequency keeping costs and for seeking a transparent process. Support for any alternative ancillary services arrangements for wind generators such as allocating extra frequency keeping costs to the causer ("causer pays" principle) has been expressed. Respondents believe such an approach will provide incentives to develop synergies between wind and hydro generation for frequency keeping.

- Many respondents would not like to see any interim rule changes to accommodate wind generation in the short term. However there is support for alternatives to the current contract conditions to decrease the dependence on the existing providers. The proposed options include:

  - Automatic Generator Control
  - Relaxation (widening) of frequency band
  - Increase of generator droop
  - Cross company frequency keeping (if a greater frequency band was required, moving towards a $/MW offering)

- Wind Generation given priority in load balancing

Changes to the SO's frequency keeping PPOs

Respondents made the following suggestions with regard to the System Operator's frequency management objectives:

- Determination of whether there needs to be changes to the SO's frequency management objectives with respect to wind generation should be included in the long term project.

- An investigation should be carried out to examine the cost-quality trade-off between a reduction in cost due to relaxing the PPOs against the reduction in quality and how that impacts on end-users.

- There should be a reconsideration of some of the frequency management objectives (not specified) as the current objectives are historic and may not be relevant to today's electricity market.

- Status quo should be maintained as the current objectives in terms of the bands in which the frequency is allowed to vary are currently acceptable, and frequency management in New Zealand is considered to be performing to wider tolerances than in other OECD countries.

Other Available Solutions with respect to frequency management in the interim

- Some respondents do not believe that momentary fluctuations as a direct result of variable wind generation would cause any breaches outside of the frequency performance objective. It has been noted that the Procurement Plan allows for +/-25 MW, +/- 50 MW or +/- 75 MW frequency keeping bands and yet the System Operator has not dispatched wider bands than 50 MW.

  Other submissions identify the following options:

  - Procuring additional frequency regulating reserve by increasing the band or by having multiple parties acting as the frequency keeper.
  - Exploring the concept of matching a flexible generator with a variable output wind farm through block dispatch.
  - Formulating short term solutions to accommodate the existing different wind technologies and to enable wind farm operators to implement the most cost effective and efficient solutions for their equipment (without retrofitting).
  - Using demand side management as an interim solution

Forecasting the Output of Wind Generation Stations (Q13-Q16)

Information - Improving Forecasting

- Many wind farm developers are willing to assist the Electricity Commission with providing details about how the forecasting of wind generation output can be improved.

  A number of respondents offer to develop commercial forecasting systems in New Zealand using the real time information from the wind farm and the numerical weather forecast information based on mesoscale atmospheric numerical models and/or weather forecasting models.

Impact on Participants and Interim Measures

- Some participants do not believe that supply-side uncertainty combined with the existing demand side uncertainty will have a material effect on participants since an element of uncertainty is always present. It is felt that additional inaccuracy due to wind generation is unlikely to have any impact.

  An increase in the inaccuracy of the forecasting is predicted to cause an upward movement in wholesale electricity prices as generators would tend to set higher marginal offer prices for all generation plant (either thermal or hydro). This is due to issues such as unit commitment for thermal plants or operating inefficiency for hydro or thermal plants. Some respondents are wary of the price volatility through supply side uncertainty discouraging demand side management initiatives.

- Some submissions are supportive of interim rule change measures designed to improve forecasting data and mitigate the impact of wind generation on price signals in the wholesale electricity market. Yet others do not see that any interim measures are required within the tactical response timeframe as the amount of new wind generation likely to come online in the next two years is limited. Some of the respondents consider that, in principle, inaccuracies in intermittent generation forecasts should be treated in a similar way to inaccuracies in demand forecasts.

  With reference to the interim measures, the respondents made a number of suggestions:

  - There is a requirement for more robust forecasting techniques and a more rigorous forecasting regime
  - Use of price deviation schedules can be used to signal to participants the likely price impact of volatility in the supply curve arising from intermittent generation.

- There should be an investigation into the feasibility of using Hydro generation to cover for the volatility in wind generation (Block Dispatch)
- A decrease in the gate closure period from two hours to a smaller time interval for non-intermittent generators would improve the forecast accuracy
- A disclosure of the wind generator's projected output to market participants would take some of the variability out of the schedules.

Managing Changes in Power Flows on the Power System (Q17-Q18)

Power flows may prove to be a material issue. In anticipation of this, feedback was sought on three possible ways of managing the risk of exceeding power system capability from variations in wind farm output. These include:

- *Option 1 -* applying a margin to the constraints applied by the System Operator in the generation dispatch process to reduce the total generation dispatch from all generators. This would provide a margin to cater for variations in wind generation output
- *Option 2 -* specifically requiring wind generation to reduce output as transmission limits are reached to provide a margin to cater for variations in output
- *Option 3 -* requiring the installation of systems to automatically disconnect or reduce wind generation if transmission limits are about to be breached.

- Five submissions strongly oppose Option 1 and believe Options 2 and 3 are the most efficient way to manage the situation. Whereas one submission acknowledges Option 1 would be a better path even though it may not be appropriate for the tactical wind project timeframe. Another submission favours the System Operator using standard security constraints and dispatch processes, and wind generators act accordingly.

- A number of respondents emphasised that the cost implications of applying Option 2 or Option 3 should be met by the wind generator causing the issue.

Interim Changes to Existing Technical Codes for Intermittent Generation (Q19-Q21)

Generator AOPOs and Technical Codes applied to Intermittent Generation

- Some of the respondents disagree with any rule changes for the interim period and prefer the use of dispensations under Rule 7.3, Section III, Part C as the mechanism for managing perceived inability to meet generator performance requirements. Whereas a similar number of respondents generally support amendments to the rules to accommodate wind generation.

- The current dispensation process has been raised as an issue since some of the respondents believed that AOPOs must be set to a higher standard than required to enable the System Operator to be able to grant dispensations. Submissions have been made with proposals to either relax the AOPOs (based on the assumption that the System Operator can meet its PPOs without all generators being compliant), or to give more certainty to dispensation holders about the length of time dispensations are granted. The submissions also cover the cost recovery processes the holder of a dispensation would be exposed to.

- One respondent indicates that a revision of obligations to wind generators should be extended to the other existing generators. These would cover instances where obligations cannot be met due to physical characteristic limitations and proposes the following AOPOs and technical code be given priority:

  - Frequency obligations
  - Voltage obligations
  - Granting of dispensations

- One respondent suggested the following rule change proposals for Part C:
  - *Section III rule 2.1:* contributions to frequency management: Clearly wind is unable to make a contribution so perhaps a universal exception for intermittent plant would be appropriate.
  - *Section III, rules 3.2.1 & 3.2.2:* Generators are not synchronised as the rule requires; also voltage is often centrally supplied rather than at the generator terminals; Clarity is sought on what is the maximum continuous megawatt measure - is this fuel dependant or on installed capacity?
  - *Tech Code A, rule 5.1:* Requirements for frequency response and control. Some intermittent generation does not synchronise or support frequency. This includes all the speed governor issues, droop, etc.

- *Tech Code A, rule 5.2:* Voltage response and control - Generator units equipped with various equipment to give dynamic voltage control - may not be done at generator units.
- *Tech Code B:* Performance in grid emergencies can not be guaranteed for wind generation.
- *Tech Code C:* Communications: providing generator unit information is inappropriate.

Indications

- Some wind farm owners already use COMIT for data transfer and do not see any problems specific to intermittent generation for using SCADA data for SPD. If SCADA indication requirements are unable to be provided to the System Operator, the ability to provide necessary data via alternate means such as fax, email or telephone is pointed out.

Other Feedback (Q22-Q23)

Other matters that have been raised in the submissions include:

General

- The System Operator receiving insufficient information to accurately assess the effect of intermittent generation on the NZ power system due to commercial confidentiality issues

- The sensitivity of the issues raised to the New Zealand Wind Farm business model and business operation.

Rules and compliance

- The lack of guidelines for acceptable AOPOs for new types of generating plant (such as wind). The EGRs have been written with large hydro and thermal plants in mind.

- The promotion of rules and processes to enable wind generation should not be at the expense of future forms of generation or prevent higher levels of wind penetration

- The need for certainty provided by appropriate rules to make wind generation more economically attractive.

- Rule changes could make wind generation uneconomic in New Zealand and wind power specialists and major players would leave the country

Electricity Market Operation

- The need to improve wind generation forecasting and to mitigate its impact on price signalling.

- Wind generators do not fully face the extra costs they impose on the system.

- How does the Electricity Commission intend to identify and allocate extra costs (frequency keeping and constrained-on) imposed by intermittent generators.

- Wind generation could cause a significant increase in the costs of frequency keeping/ reserves/ constrained–on.

- Wind generators who contribute to the need for frequency keeping should not incur any costs for the service.

- In certain geographical areas balancing wind generation by hydro may be limited.

- Where hydro balancing is not possible, there is a likelihood of higher costs due to less efficient operation of the thermal plant to match a “jagged” demand curve caused by variability of wind power output

- A “jagged” demand curve profile would result in greater coal plant operation (due to its superior flexibility) at the expense of more efficient CCGTs.

- Generator-retailers are exposed to unit commitment risks.

- Supply curve volatility is likely to occur due to wind generators contributing to a weakening of the forecast price signal which causes negative outcomes for the electricity market.

- It is important to consider additional reserve that may be required due to large amounts of wind generation in periods of low demand

Power System Operation

- Line constraints will impact on HVDC transfers and South Island generation if the System Operator reduces line ratings to manage wind power fluctuations.

- Whether the System Operator defines the “loss of multiple correlated wind farms” as a single credible event which may result in cascade failure.