Under Frequency Management

Asset Owner Performance Obligations (AOPO); National Reserve Market Review

System Operator

22/11/2011

SYSTEM OPERATOR

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	Position	**Date**
Prepared By:	System Operator	November 2011
Reviewed By:		

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APPENDICES 1-3 (SEE http://www.systemoperator.co.nz/ufm)

Providing comments to the System Operator

The System Operator requests comments on the findings in this report by Friday 23 December 2011.

Where possible, please provide submissions electronically to *ina.ilieva@transpower.co.nz* with the email title “Submissions on AOPO and National Reserve Market Review” in the subject header. Hard copies can be posted to the following address:

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The System Operator will acknowledge receipt of all submissions electronically.

In the interests of transparency, all submissions will be published on the System Operator’s website. Please discuss any confidential information contained in your submission with the System Operator, prior to sending such information.

1 Executive Summary

The System Operator and Electricity Authority set out to complete an Under-Frequency Management review to determine strategies and measures that offer the most reliable, secure and cost effective frequency management model.

The work was divided into three streams representing the key mechanisms the System Operator employs to achieve its frequency obligations under the Code: management of reserves; use of Automatic Under-Frequency Load Shedding (AUFLS); and the Asset Owner Performance Obligations (AOPO).

This report addresses the appropriateness of the Asset Owner Performance Obligations in the South Island as well as investigates wider system issues such as:

- the management over-frequency events in each Island
- the development of a National Reserve Market

Efficiently maintaining the South Island system frequency within the Principle Performance Obligations (PPO) limits has largely been enabled by the capability of the hydro machines installed. The installations of new generators that are not capable of meeting the AOPOs, known as non-compliant generators, create challenges in efficiently maintaining the PPO requirements.

The System Operator expects most future generation installed in the South Island will be non-compliant. The objective of this report was to investigate the effect of installing non-compliant assets on the frequency envelope in the South Island and outline the issues and options for mitigation.

The investigation found that despite the current level of non-compliance, there is no technical reason for changing the existing AOPOs; nor is there evidence that an economic threshold has been reached that would warrant making a change. However, there will be a point at which the level of installed non-compliant plant may make it impossible to effectively operate the South Island system with the current reserve products available. It is expected that the reason for making a change to counter the effects of non-compliance will, in the first instance, be economic rather than technical.

Historically emphasis has been on under-frequency management. However, with the commissioning of Pole 3 and the system topology changing, the System Operator considers it appropriate to ensure efficient over-frequency management. As such, early industry engagement on this issue is considered important.

The installation of new generation that trips off at 52 Hz also has implications on the management of over-frequency events in the South Island. Currently some generators tripping at 52 Hz benefits the South Island system's response as the units disconnect before the frequency limit of 55 Hz is reached. However, a significant increase in generators that trip at 52 Hz could result in over shedding, and subsequent frequency oscillations potentially leading to cascade failure. The System Operator will continue to monitor the effect of generator capability on the South Island over-frequency response.

Currently, the System Operator procures over-frequency arming on fixed price availability basis and dispatches it according to predetermined power system conditions. The System Operator is investigating the ability to fully model over-frequency events in the same way as it does under-frequency events and will likely implement changes when the current RMT tool is replaced.

After the commissioning of HVDC Pole 3, it will be possible to introduce a national reserve market. A national reserve market has the potential to increase competition amongst a more diverse range of instantaneous reserve providers while considering optimal plant operation. The HVDC controls will be an integral part of a national market. The System Operator believes participants need to be involved in the development of a national market; the form and operation of such market needs extensive industry discussion, preferably prior to Pole 3 commissioning, to ensure that participants have ample opportunity to consider how their assets can contribute or will be affected by the creation of a national market.

The New Zealand power system is getting more sensitive to disturbances as generators with less inertia are installed on the system. The addition of generation connected to the power system with no governor response will adversely affect system performance and result in additional cost to New Zealand consumers. The System Operator will continue to monitor the effect of additional generation on system inertia. However, the solution to this issue is expected to be an industry-lead one. It is therefore recommended the Electricity Authority initiates discussions with industry on the preferred mechanisms and incentives to provide additional inertia.

2 Introduction

Robust under-frequency management plays a significant role in operating a secure and cost efficient power system. Poor management can lead to high procurement costs of frequency management products, inefficient demand interruption, or, in the worst case, cascade failure of the system. The current under-frequency standards are achieved mainly through a combination of mandated generator and HVDC owner obligations, procurement of instantaneous reserves (IR) and mandated automatic under-frequency load shedding (AUFLS) obligations.

Investment in grid infrastructure, in particular HVDC Pole 3 and the new technologies considered in proposed generation investments, further underline the need for a review of the current reserve arrangements and the opportunities to create a national reserve market. In addition, the increasing number of generators with little or no inertial contribution also necessitates a review of the existing operating standards and practices to ensure they are appropriate.

In November 2010, the System Operator and Electricity Authority agreed that the System Operator would review the current under-frequency arrangements. The instantaneous reserve mix and procurement, as well as the assumptions in the Reserve Management Tool (RMT) were reviewed as part of work stream 1. Outcomes from this reserve review were communicated to, and feedback sought from industry participants in August 2011.

The purpose of the Under-Frequency Management review is to determine strategies and measures that offer the most reliable, secure and cost effective frequency management model to provide greater certainty on system integrity during major frequency events, and to operate an efficient market.

The objective of this report is to:

- investigate the effect of installing non-compliant assets on the frequency envelope in the South Island and outline the issues and options for mitigation
- outline the effect and options for managing greater installation of wind generation in the South Island
- review the issues and methods of managing over-frequency events in the North and South Islands
- conduct a preliminary investigation to determine how a national reserve market could function and what limitation can be expected

3 Asset Owner Performance Obligations (AOPOs)

3.1 Introduction

The New Zealand power system is operated to quality and reliability standards that meet the needs of electricity consumers. The standards of quality used by the System Operator are defined in the Principle Performance Objectives (PPO).

The PPOs include a defined system frequency envelope for each island that states frequency limits the island should be managed to and a limit on the number of frequency excursions. Currently the PPO frequency envelope is 47 - 52 Hz in the North Island and 45 – 55 Hz in the South Island.

To meet the under-frequency PPOs the System Operator relies upon a number of products, such as Frequency Keeping, Instantaneous Reserves, Automatic Under-Frequency Load Shedding, and Asset Owner Performance Obligations (AOPO). The AOPOs are a set of common technical standards that the System Operator can rely upon to provide quality of supply and avoid cascade failure.

Generation AOPOs require generators to stay connected at their pre-event output at the low frequencies experienced during credible under-frequency events (known as contingent and extended contingent events, CE and ECE respectively). The AOPOs currently require South Island generators to maintain their pre-event output for 30 seconds if the frequency falls below 47 Hz but not below 45 Hz.

Efficiently maintaining the South Island system frequency within the PPO limits has largely been enabled by the capability of the hydro machines installed. The installations of new generators that are not capable of meeting AOPOs, known as non-compliant generators, create challenges in efficiently maintaining the PPO requirements. Non-compliant generators that are not able to remain connected when the frequency falls below 47 Hz result in the procurement of additional reserves to cover the extended contingent event.

It is expected that most future generation (wind in particular), installed in the South Island will be non-compliant. The objective of this report was to investigate the effect on the frequency envelope in the South Island of installing non-compliant assets and to outline the issues and options for mitigation.

To meet the PPO's the System Operator procures under-frequency reserves to avoid a collapse of the power system. Non-compliant generators have a negative effect on mitigating large under-frequency events, so additional reserves must be procured. The procurement of these additional reserves puts upward pressure on the electricity price paid by consumers.

If the only generation able to be built was compliant generation then it is likely that no wind farms or gas fired plant would be built in the South Island. This would have a significant upward pressure on price and an impact on security of supply to consumers.

The current frequency envelope is 'wide' by international standards and reflects the physical nature of the hydro generation plant that currently dominates the South Island. A wide frequency band enables the System Operation to procure less reserve than would be required for a narrower band.

To optimise the benefits to consumers the System Operator needs to consider both engineering and economic factors. The investigation found that despite the current level of non-compliance, there is no technical justification for changing the existing AOPOs. There is also no evidence to suggest an economic threshold has been reached to drive a change in the AOPOs to provide a net economic benefit. There will be a point, however, at which the level of installed non-compliant plant may make it impossible to effectively operate the South Island system with the current reserve products available. However, it is expected that economic factors will prevail in driving a change before any technical reasons become apparent.

With the current generation and transmission assets in the South Island, the issue of increasing reserve procurement due to non-compliance occurs rarely. However, as the installation of non-compliant generation increases and as power flow from the North Island increases following the commissioning of Pole 3 then the situation is likely to occur more frequently.

Investigations identified the following options that allow the industry to manage the situation:

- Maintain the existing frequency envelope
  - Procure additional reserves to cover non-compliant generation
  - Constrain off non-compliant generation when ECE is binding
  - Constrain back the ECE Risk Setter
  - Increase AUFLS provision
  - Create equivalence arrangements for non-compliant plant
  - Make non-compliant plant technically compliant.
- Change the frequency envelope

At a high level there are two options to manage the situation: to maintain the current frequency envelope specified by the PPOs or change the frequency envelope to enable compliance. Maintaining the current frequency envelope will require selecting one or more methods to address the issues caused by non-compliant assets. These options will be discussed in detail in the next section of the report. The options will be investigated in terms of the potential:

- value at stake
- technical issues
- transaction costs
- implementation issues

Identifying the likely value at stake for each option involved considering the factors that impact the direct cost associated with each.[1] Direct costs are the cost of procuring instantaneous reserve products to manage the frequency within the frequency envelope.

[1] It is noted that there are indirect cost associated with the frequency envelope (i.e. plant maintenance cost and deferred future investment) however it was not sought to quantify these cost.

3.2 Maintain the existing frequency envelope

3.2.1 Procure additional reserves to cover non-compliant generation

Value at stake	Additional cost of reserves
Technical issues	None
Transaction costs	Low (monthly billing)
Implementation issues	Significant set up cost (to establish a method and systems to calculate dispensation cost and allocation for non-compliant parties)

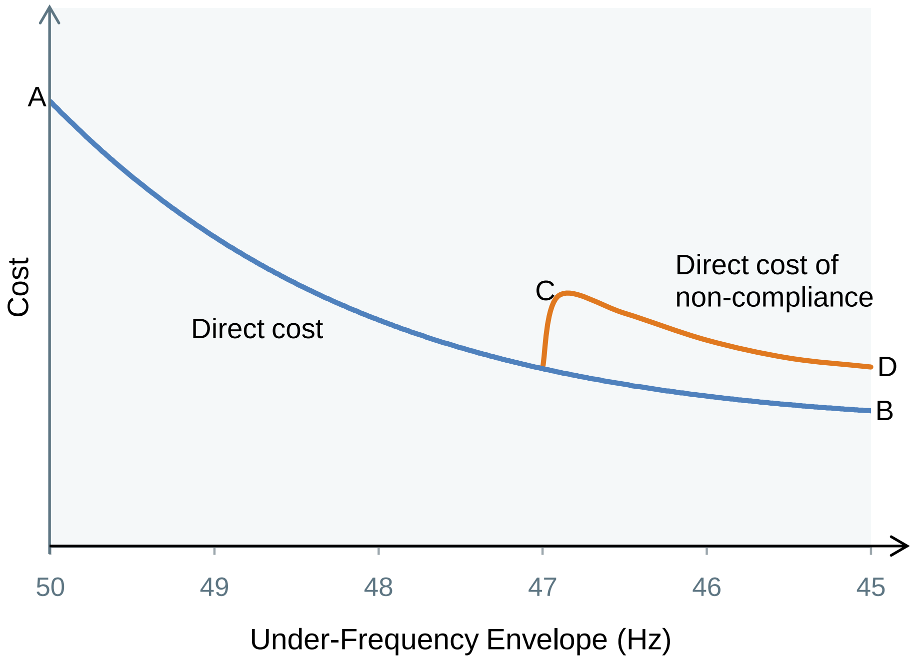

Figure 3-1: Illustration of Under Frequency Envelope Cost Framework

Figure 3-1 illustrates how direct cost change as the frequency envelope changes.

Where a ‘narrow’ frequency envelope exists (i.e. closer to 50 Hz) then more reserves must be procured compared to reserves required for a wider band (i.e. allow a greater range of frequency). Therefore, direct costs decrease as the frequency band widens as illustrated by line AB.

When non-compliant generation is introduced, the System Operator must procure additional reserves for events that take the frequency below the physical limit of the machine. At this point, additional costs are being incurred by consumers as illustrated by the line CD. The amount of additional cost is related to the quantity of non-compliant plant installed and dispatched.

Non-compliant generators must apply for a dispensation from the Code. Dispensations enable the cost of the additional reserves to be borne by the non-compliant parties. However, the System Operator is not currently able to monitor the additional cost of reserves caused by the dispensations and would require the development new tools to address this.

This option would be economically valid while the cost of additional reserves for non-compliant generation was less than the additional cost of reserves for a narrower frequency envelope.

3.2.2 Constraining off non-compliant generation when ECE is binding

Value at stake	▪ Marginal cost of replacement generation ▪ Deter investment in renewable generation
Technical issues	▪ Generation shortfall ▪ Incentivises investment to install at network level (decreases visibility and increases difficulty in managing the system) ▪ Impairs lake level management (increases probability of generation shortfalls during dry years)
Transaction costs	None
Implementation issues	Minor Market System development

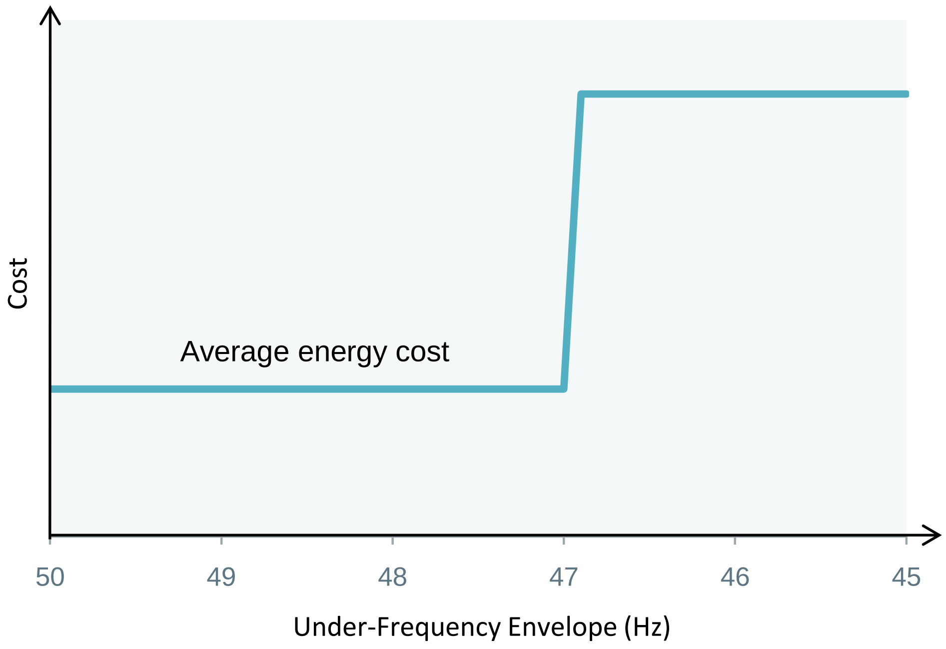

Figure 3-2 Average energy cost as result of non-compliance

Another option for the System Operator is to dispatch off all non-compliant generation when the ECE is binding, which means dispatching compliant generation as a replacement. The compliant generation, which is not generating, will be above the marginal price which will result in an increase in energy cost paid by consumers. Figure 3-2 demonstrates the effect of the frequency envelope and constraining on higher price generation.

In addition, with the increase in non-compliant generation, a shortfall may occur in which there is insufficient compliant generation available to replace the non-compliant generation.

During a dry year, dispatching on compliant South Island hydro can have a significant detrimental impact on the lake levels and increase the likelihood of rationing.

This option would be economically valid while the costs of constrained on generation was less than the additional cost of reserves for a narrower frequency envelope.

3.2.3 *Constrain back the ECE Risk Setter*

Value at stake	▪ Marginal cost of replacement generation (especially high during dry years)
Technical issues	▪ Generation shortfall ▪ Incentivises investment to install at Network level (decreases visibility and increases difficulty in managing the system) ▪ Impairs lake level management (increases probability of generation shortfalls during dry years)
Transaction costs	None
Implementation issues	Minor

Similar to constraining off non-compliant generation, the System Operator may also constrain back the ECE Risk setter to minimise the amount of reserve required. However, such a measure requires dispatching compliant generation which is not generating and above the marginal price. Consequently, there is likely to be an increase in the energy cost paid by consumers.

Again, as the amount of non-compliant generation increases, a shortfall may occur where there is insufficient compliant generation available to replace the non-compliant generation.

During a dry year, dispatching on compliant South Island hydro can have a detrimental impact on the lake levels and increase the likely hood of rationing.

This option would be economically valid while the cost of constrained on generation was less than the additional cost of reserves for a narrower frequency envelope.

3.2.4 *Increasing AUFLS provision*

Value at stake	▪ The value of lost load of additional AUFLS ▪ Restriction of entry into demand side markets (IL)
Technical issues	▪ More prudent to raise trip level of AUFLS to avoid the trip frequency of non-compliant generation ▪ Current AUFLS provision deficient in the South Island

Transaction costs	Low
Implementation issues	▪ Require code change and cost associated ▪ Installation and design cost of new AUFLS scheme

While this is a technically feasible option, there is a certain lack of logic in that for every 1 MW of non-compliant generation the AUFLS quantities must be increased by at least 1 MW.

An increase to the AUFLS quantities counteracts non-compliant generation tripping for a significant under-frequency event. Given that an AUFLS event is almost guaranteed when non-compliant generators trip, then it is more logical to trip less AUFLS at a higher frequency to prevent the tripping of non-compliant generation. Increasing the AUFLS frequency trip setting has the same effect as narrowing the frequency envelope.

Further, AUFLS is currently deficient in the South Island due to the Tiwai Grid Exit Point non-compliance. The obligation to provide additional AUFLS would fall on few remaining providers.

3.2.5 *Create Equivalence Arrangement for Non-Compliant Plant*

Value at stake	▪ Cost of energy and reserves (less reserve availability) ▪ Deter investment in renewable generation
Technical issues	Ability to measure and monitor compliance of equivalence arrangements
Transaction costs	Minor (Contract fees)
Implementation issues	▪ Setup cost ▪ Technical review process cost

This option is similar to procuring additional reserves but it leaves the problem with the non-compliant parties to resolve the impact of their non-compliance. The costs associated with creating equivalent arrangements for non-compliance are comparable to those paid by the System Operator to procure additional reserve products; ultimately these costs get passed to consumers.

Any inability to pass on costs will make generation investment more marginal potentially leaving valuable renewable fuel resources under-utilised.

3.2.6 *Make non-compliant plant technically compliant*

Value at stake	▪ Cost of energy and reserves ▪ Deter investment in renewable generation
Technical issues	▪ Achievability of option unknown ▪ Ability to measure and monitor compliance of equivalence arrangements
Transaction costs	Minor (Contract fees)

Implementation issues	▪ Very high investigation and implementation cost

This is unlikely to be a valid option. The overwhelming majority of generation plant is built to North American or European standards and manufacturers are unlikely to build plant to meet the New Zealand frequency envelope. If plant cannot be procured, then investment will not occur and renewable resources will remain under-utilised.

The System Operator does not know if retrofitting existing non-compliant plant is technically feasible. Enforcing an unobtainable compliance standard would force any investment to be small and 'off grid', perhaps through the excluded generator provisions. If this occurs the System Operator becomes unaware of the amount of generation that may trip for any event and will therefore lose certainty of its ability to arrest the frequency decline and prevent a black out.

3.3 Change the frequency envelope

Value at stake	▪ Cost of energy and reserves (additional reserves) ▪ Increased investment in renewable generation
Technical issues	None
Transaction costs	None
Implementation issues	▪ Require code change and cost associated ▪ Installation and design cost of new AUFLS scheme

This option narrows the frequency envelope to enable the non-compliant generators to become compliant. Narrowing the envelope relieves the pressure of non-compliance cost and so enables future investment of generation that could not currently comply with the wider frequency band.

As demonstrated in Figure 3-1, a 'narrow' frequency envelope (i.e. closer to 50 Hz) means that more reserves must be procured than for a wider band. Therefore, there are the direct costs associated with narrowing the frequency envelope that make such option undesirable. Narrowing the envelope would require re-designing the current AUFLS system to meet the tighter frequency band.

The procurement of the additional reserves required with a narrower envelope makes this option comparatively costly. However, this option would be economically valid when the cost of additional reserves for non-compliant generation is greater than the additional cost of reserves for a narrower frequency envelope.

3.4 Recommendations

In light of the options described above, the System Operator makes the following recommendations:

1. The System Operator will investigate options and preferred methods to operationally manage non-compliance, and publish such methods in the policy statement.

2. The System Operator seeks industry input into the components for an economic threshold test for narrowing the South Island frequency envelope and the timing by which such tests ought to be completed.

4 South Island Wind Generation

The completion of Mahinerangi wind farm in the Clutha region brought the South Island up to 98.6 MW[2] of wind generation installed. There are approximately 480 MW of wind generation projects in the South Island; some of which are under construction; some have received consent; and some are in the course of the consent process[3] (excluding Project Hayes, which is under appeal) for the period 2015-2020.

Most of the current wind technology has been built to international standards and should be able to operate within the 47-52 Hz range. However, due to testing limitations wind generators have been unable to verify their capability to operate within this frequency range. Wind generators still provide the System Operator with their Asset Capability Statement to reflect the designed capability of their machines.

The wind farms which are not excluded (i.e. greater than 30 MW capacity) that cannot meet the required AOPOs can apply for dispensations from the code requirements. The dispensations allow the System Operator to take measures to cover for effect of the non-compliance. However, wind generators that connect via local network companies are also likely to operate to international standards (i.e. operate to 47 Hz) and the System Operator has no visibility of the potential impact this will have on the system.[4]

The System Operator will continue to monitor the amount of excluded wind generation installed in the South Island and seek input from South Island networks of any new wind generation installed.

4.1.1.1 Wind ability to offer reserves

The System Operator considers there to be opportunity to promote greater incentive for wind generation by investigating the ability of wind generators in both islands to offer reserves. The Code does not preclude intermittent generators from providing reserve. However, the manner in which the reserve is to be provided is not specified.

International practice shows that wind generators can be constrained to a certain energy output, with the available capacity offered as reserve. Wind generators may be able to offer Fast Instantaneous Reserves (FIR), which is required at 6 s but it is unlikely a wind generator will be able to offer Sustained Instantaneous Reserves (SIR), which is required at 60 s and must be sustained for 15 min.

The option for wind to provide reserves will necessitate extensive testing, as is current practice for all spinning reserve providers. More detailed information on the technical ability of wind generation to provide reserve, and the respective Code arrangements, can be found in Appendix 1 (Wind Generation and Reserve Offers). It is noted that wind generators would not able to provide reserves for ECE events as the units would trip off below 47 Hz.

[2] Source: NZ Wind Energy Association, http://windenergy.org.nz/nz-wind-farms/operating-wind-farms
[3] Source: Electricity Authority, http://www.ea.govt.nz/industry/modelling/long-term-generation-development/list-of-generation-projects/
[4] According to the NZWEA there is currently 4.6 MW of excluded wind generation installed in the South Island.

Any proposed solution is likely to need EA approval, appropriate industry consultation, and code changes as well as changes in the Reserve Management Tool (RMT) and SPD modelling. The System Operator is seeking feedback from wind generators (nationwide) on whether any are interested in offering into the reserves market.

5 Over-Frequency Issues

5.1 North Island Issues

In the NI, the System Operator procures over-frequency reserve for:

- the loss of the HVDC during high transfer
- the loss of the system electrically North of Henderson

Over-frequency is managed on as-needed basis by ancillary services contracts for over-frequency arming.

The System Operator, as part of this work stream, studied the NI dynamic response as a way of testing the effectiveness of the governor response and over-frequency arming for managing and mitigating over-frequency situations. The study investigated two over-frequency events in the North Island: loss of Northland load on 30 October 2009 and loss of HVDC on 1 August 2009.

The studies concluded that both methods of managing over-frequencies are effective. However, the over-frequency arming is more commercially viable at the moment because it will result in less commercial agreements or changes to the generator governors. The full study report can be seen in Appendix 2 (Over Frequency Arming).

In the past, emphasis has been on the management of under-frequency. However, with the commissioning of Pole 3 and changing system topology, the System Operator is of the view that the industry must turn its attention to the efficient management of over-frequency. Currently, the System Operator procures over-frequency arming on an availability basis and dispatch according to certain power system conditions.

The System Operator is researching the ability to fully model over-frequency events in the same way as it does under-frequency and will likely implement changes as it replaces the current RMT tool.

5.2 South Island Over-Frequency Envelope

Hydro generation is the prevailing type of generation in the South Island. Due to the variability in hydro generation inflows in the South Island, the South Island can either export excess power to the North Island, when hydro inflows are above the average, or import power from the North Island, in dry years, via the HVDC link with the North Island.

The HVDC has a current maximum export of 900 MW which, after the Pole 3 project is complete, will rise to 1200 MW in 2014 and with an ultimate capacity of 1400 MW if an additional cable is purchased (not expected before 2018). The potential exists for HVDC export North to become a significant proportion of total generation in the SI. Under such circumstances there is a risk to South Island system stability if a HVDC bipole failure were to occur.

Losing the HVDC bipole at times of high North transfer and low SI load will result in the rapid increase of SI system frequency. Similar to the under-frequency events, the balance between supply and demand is lost; in this instance supply exceeds demand. If the balance is not restored immediately, the frequency will rise, exceeding 55 Hz causing the uncoordinated loss of generation, which in turn can lead to a shortage of generation and an under-frequency event; a cascading system failure may occur.

The System Operator obligations are defined in the Code; some of its obligations are to maintain the frequency in the normal band, to manage frequency during momentary fluctuations, and to recover quickly from such fluctuations.

To manage over-frequency excursions, the System Operator dispatches over frequency arming when the HVDC transfer is expected to rise above 600 MW and is approximately 50% of the SI generation.

During over-frequency events in the SI, governor response is relatively slow and is insufficient to limit and restore the frequency within a reasonable timeframe. The relatively low system inertia of the SI also contributes to the fast frequency rise following an interruption to HVDC North transfer. These two factors necessitate the procurement of over-frequency reserves to mitigate over-frequency excursions. The System Operator has contracted a number of parties to provide over-frequency reserves (arming).

Under the existing arrangements, some types of generation trips at around 52 Hz. The inability of generation to stay connected above 52 Hz is assisting in the frequency restoration and is beneficial for managing over-frequency events. Therefore, there are no current system security issues arising from the use of these limits, despite the new technology generators, such as wind.

A significant increase in new generation unable to stay connected above 52 Hz could, in the future, have adverse rather than beneficial effects on the power system and compromise the System Operator's ability to meet its PPOs. The over-shedding of generation during an over-frequency event may cause an under-frequency event and system collapse. If this occurs, to support its ability to comply with its PPOs, the System Operator may require protection settings that will lower trip frequency to provide discrimination. For example, a generator may have the capability of staying connected at 52 Hz but would be required to trip at 51 Hz.

To summarise, the System Operator needs to dispatch over-frequency reserves in the SI to mitigate the risk of over-frequency resulting from high HVDC transfer and low SI load. Currently, generation unable to stay connected above 52 Hz has a positive effect on system security because it trips before the 55 Hz limit is reached. Therefore, managing the over-frequency limit to 52 Hz is unlikely to assist system security and will increase the over-frequency reserve procurement costs. Reducing the upper frequency PPO limit, at this stage, has no industry benefit.

Consequently, no change is recommended at this stage.

6 National Reserve Market

Studies have been made in the past to determine the ability of the existing HVDC link to transfer reserves between the islands and preliminary SPD models were analysed. However, the inability of the existing HVDC link to fast and seamlessly change its direction presents a physical limitation for creating and adopting a national reserve market. More information about these studies can be found in Appendix 3 (National Reserves Market, 2004)

The HVDC Pole 3 project will allow power transfer in both directions between the two islands in a seamless uninterrupted manner. The design specifications of Pole 3 include operation in ‘round power’ mode. Round power is when one pole supplies energy in one direction and the other pole provides energy in the opposite direction. Sophisticated controls are designed to respond to frequency deviations and to keep the frequency in both islands constant.

The System Operator conducted a preliminary technical investigation to determine how reserves could be transferred between the two islands and what, if any, limitation can be expected. The work involved a high level simulation of the two islands and the link between them. The existing Reserve Management Tool (RMT) was used for the purpose.

A number of scenarios were studied and for each event, the reserve was provided by the generator in either the North or the South island. The size of the reserve response was changed so that the target frequency of 48 Hz was achieved for CE events for both islands.

The simulations showed that reserves could, in principle, be transferred from one island to the other. However, because of the different generation mix, and consequently the different response to the same size of a frequency disturbance, the simulations could not confirm, with sufficient confidence, that reserve quantities from one island could fully cover an event in the other island. Specific settings and parameters for the HVDC controls to provide the required functionality have not yet been determined and therefore no firm proposal for a National Reserve Market can be offered.

Further, the simulations demonstrated that while SIR can easily be shared between the two islands, FIR is not so straightforward. More accurate studies with the actual HVDC Pole 3 controls have to be conducted once Pole 3 is commissioned.

The simulations concluded that a national reserve market is technically possible but the modalities of achieving it – legal framework, technical capability, and economic viability - are yet to be explored and formulated. The System Operator wishes to take the opportunity to engage the industry participants in a discussion for developing a national reserve market strategy and approach.

7 Recommendations

The work to-date outlined in the Under-Frequency Management review highlighted the necessity for changing the way in which reserves are calculated and procured. The report identified the areas that need further monitoring and studies and those which can be modified as a consequence of the system evolving.

The following conclusions and recommendations are made in addition to those set out in the Reserves review.

It is recommended that:

- The South Island AOPOs relating to the frequency envelope should remain unchanged
- The options and preferred methods to operationally manage non-compliance are identified and published in the policy statement by the System Operator
- Industry input into the components for consideration of an economic threshold and the timing to complete is actively sought by the EA and the System Operator to determine the appropriate cost-benefit analysis for narrowing the South Island frequency envelope
- Further work is undertaken to facilitate the offering of reserves by wind generators (subject to appropriate code and software changes)
- Industry discussion is facilitated by the EA and the System Operator about a future national reserve market given that reserve market rules will require changes based on the HVDC control system
- Industry discussion is facilitated by the EA and the System Operator on the implementation of more sustainable over-frequency arrangements including system modelling and market arrangements similar to those that exist for under-frequency reserves