Wholesale Advisory Group

National Frequency Keeping Market Recommendations Paper

By the Wholesale Advisory Group

May 2014

Note: This paper has been prepared for the purpose of making recommendations to the Electricity Authority Board. Content should not be interpreted as representing the views or policy of the Electricity Authority.

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Electricity Authority request

The Electricity Authority (Authority) has requested input and advice of the Wholesale Advisory Group (WAG) to determine the potential for developing a national market for frequency keeping (FK).

1 Introduction

1.1.1 In October 2013 the Authority asked the WAG to consider the benefits of developing a national market for FK and if feasible to develop arrangements to give effect to it.

1.1.2 The Authority had previously identified that a national FK market (NFKM) could contribute to the Authority's statutory objective by:

a) ensuring that the most efficient providers available nationally are selected in each trading period

b) improving the operational efficiency of the service by reducing the overall quantity of FK that is required.

1.1.3 This paper presents the WAG's recommendations following its investigations.

2 Conclusion and recommendations

2.1.1 The WAG concludes that implementing an NFKM would result in a substantial net economic benefit (section 5) and that doing so would be consistent with the Authority's statutory objective and Code amendment principles (Section 3).

2.1.2 The WAG therefore recommends the Authority should progress the NFKM as a priority project. The WAG considers this project should be developed in parallel with the national reserves market initiative. The WAG recognises that of the two projects, the NFKM has a wider technical scope of work, and as a consequence would be commissioned following the introduction of the national reserves market.

2.1.3 The WAG endorses the investigation work initiated by the Authority in engaging the system operator to identify the best options for implementing an NFKM in more detail. The WAG agrees that the Authority and the system operator jointly are best placed to complete this work as it is technical in nature but the WAG would like to remain involved in the following key aspects of the NFKM design:

a) The method of frequency keeper selection - The WAG accepts advice from the secretariat that full co-optimisation with energy and reserves is the preferred method and would not introduce unintended pricing consequences, but subject to the condition that the Authority carry out an independent review to confirm that this is definitely the case, and that an appropriate investigation process has been undertaken. If any complications are found, the method of selection should be referred back to the WAG for further consideration.

b) Technical representation – The WAG requests it be invited to nominate a member to represent the WAG on any technical group established by the Authority to support this work.

c) Regular updates- As provided for in the advisory group charter and the WAG terms of reference, the WAG specifically seeks regular updates, particularly in the event that the Authority proposes to make a substantial change, or approaches a significant milestone.

2.1.4 The WAG notes that key aspects of the NFKM design include:

a) the extent to which enabling Code provisions for an NFKM are centralised in part 13 of the Code to create alignment between the energy, reserves and FK markets

b) the extent to which the new HVDC bi-pole control system functions including round-power and FKC[1] can be utilised to support an NFKM.

2.1.5 Additionally, the WAG notes that it has an interest in pursuing the future FK cost allocation work that the Authority has already identified as a project following on from the development of an NFKM.

3 Problem definition

3.1 Authority's statutory objective and Code amendment principles

1.1.1 The Authority's statutory objective is to promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers.

1.1.2 Principle 2 of the Authority's Code amendment principles states that the Authority and its advisory groups will only consider using the Code to regulate market activity when either:

a) it can be demonstrated that amendments to the Code will improve the efficiency of the electricity industry for the long-term benefit of consumers

b) market failure is clearly identified, such as may arise from market power, externalities, asymmetric information and prohibitive transaction costs

c) a problem is created by the existing Code, which either requires an amendment to the Code, or an amendment to the way in which the Code is applied.

3.2 Current market inefficiencies

3.2.1 The WAG identified three areas of inefficiency in the current FK market:

a) competition in the island-based FK markets is limited[2]

b) the selection of frequency keepers is not co-optimised with energy and reserves in the market clearing software (SPD) and constrained on/off payments for frequency keepers in the energy market arise as result

c) the MW quantity of island-based FK procured by the system operator is larger than would be required if FK was co-ordinated nationally.

3.3 Improvements in efficiency possible

3.3.1 An NFKM would improve the overall efficiency of the FK market by:

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1 FKC is a modulation control on the HVDC link which effectively locks the North and South Island frequencies together to form a strongly coupled national power system.

2 The related Multiple Frequency Keepers Project addresses this inefficiency on an intra-island basis only by reducing barriers to entry for smaller FK providers such as load aggregators. The project provides for central co-ordination of FK so that the MW band required can to be split and allocated across multiple providers in the same trading period.

a) increasing the productive efficiency of the market by allowing FK to be purchased from the lowest cost providers in a national pool rather than in two separate island-based pools

b) increasing the allocative and productive efficiency of the market by co-optimising the selection of energy, reserves and FK to allow the lowest overall cost selection of alternatives

c) increasing productive efficiency of the market by reducing the MW quantity of FK required to regulate frequency on the power system

3.3.2 An additional dynamic efficiency gain can be obtained in the energy market by deferring investing in peaking capacity as a result of any reduction in the MW quantity of FK purchased.

4 Current arrangements

4.1 Procurement

4.1.1 In accordance with the frequency principal performance objective (PPO) in part 7 of the Code, the system operator is required to act as a reasonable and prudent system operator with the objective to maintain system frequency in each island between 49.8 Hz and 50.2 Hz - the normal band.

4.1.2 The objective to maintain frequency in the normal band is a quality based objective intended to achieve the optimal trade-off between quality and the cost. The system operator acts to achieve this quality objective by procuring FK services from providers in half-hour markets separately in each island. Providers are currently generating companies[3] that have sufficiently responsive plant and adequate spare capacity to be able to vary their output to maintain island frequency within the normal band, for normal demand/supply imbalances.

4.1.3 The two island power systems presently operate as independent a.c. systems loosely coupled by the stabilising influence of the HVDC link. The link effectively transfers a degree of balancing and reserve between the islands, but this benefit is neither recognised nor paid for under the current procurement arrangements for FK or instantaneous reserves.

4.1.4 Procurement arrangements in the North and South Islands differ while a transition is taking place from single FK (SFK) to multiple FK (MFK). The North Island MFK market started on 1 July 2013 and MFK is scheduled to be introduced to the South Island late 2014.

4.1.5 The respective arrangements in the two islands can be summarised as follows:

North Island – MFK

a) providers offer up to 5 FK bands, each between 4 MW and 50 MW in size

[3] A recent Code amendment permits demand side participation of FK

b) the system operator selects the lowest cost combination of offers to make up a cumulative band of 50 MW and dispatches the providers

c) the system operator controls frequency using a central frequency controller which issues raise/lower set point controls to dispatched providers every 2 s.

South Island – SFK

a) providers offer up to 5 FK bands of at least 25 MW

b) the system operator selects the lowest cost offer of 25 MW or more and dispatches a single provider

c) the dispatched single provider controls frequency using its own local station or area based frequency control system

d) responsibility for frequency control moves from one provider to another whenever there is a dispatch change.

4.1.6 At present, only four generating companies meet the system operator's technical requirements for MFK and SFK:

a) Mighty River Power Limited using the Waikato hydro block (North Island)

b) Genesis Energy Limited from four Huntly thermal units, the Tokaanu hydro station, and the Waikaremoana hydro block (North Island)

c) Contact Energy using two Stratford thermal units and the Clutha hydro block (North Island and South Island)

d) Meridian Energy Limited using the Waitaki hydro block and the Manapouri hydro stations (South Island).

4.2 Payment and cost allocation

4.2.1 MFK and SFK providers dispatched by the system operator are currently paid the following:

a) the provider’s offer price (the availability fee)

b) to-the-band constrained on or off compensation, if required, to move the frequency keeper from its natural dispatch point so that its control maximum or control minimum operating points are not exceeded within the dispatched FK band

c) in-band constrained on or off compensation, if required, to compensate the provider for any difference between actual and dispatched quantities of output, for example:

i) if a generator produces a lower energy output than its dispatched quantity (to compensate for an increase in system frequency) when the energy price is above its energy offer price, it receives a constrained off payment

ii) if a generator produces a greater energy output than its dispatched quantity (to compensate for a decline in system frequency) when the energy price is below its energy offer price, it receives a constrained on payment

d) in addition, providers are paid in the energy market for any generation produced at the final price, although this is not treated or reported as part of the FK costs.

4.2.2 FK ancillary service costs are allocated monthly to purchasers (those parties that purchase energy through the spot market from the clearing manager). The total cost of FK for each trading period of the previous month is pro-rated to purchasers according to the quantity of electricity purchased in each trading period. The allocation is carried out on a national basis even though the service is procured separately in each island. A degree of cross-subsidisation arises because of the price diversity and procured quantity difference between islands.

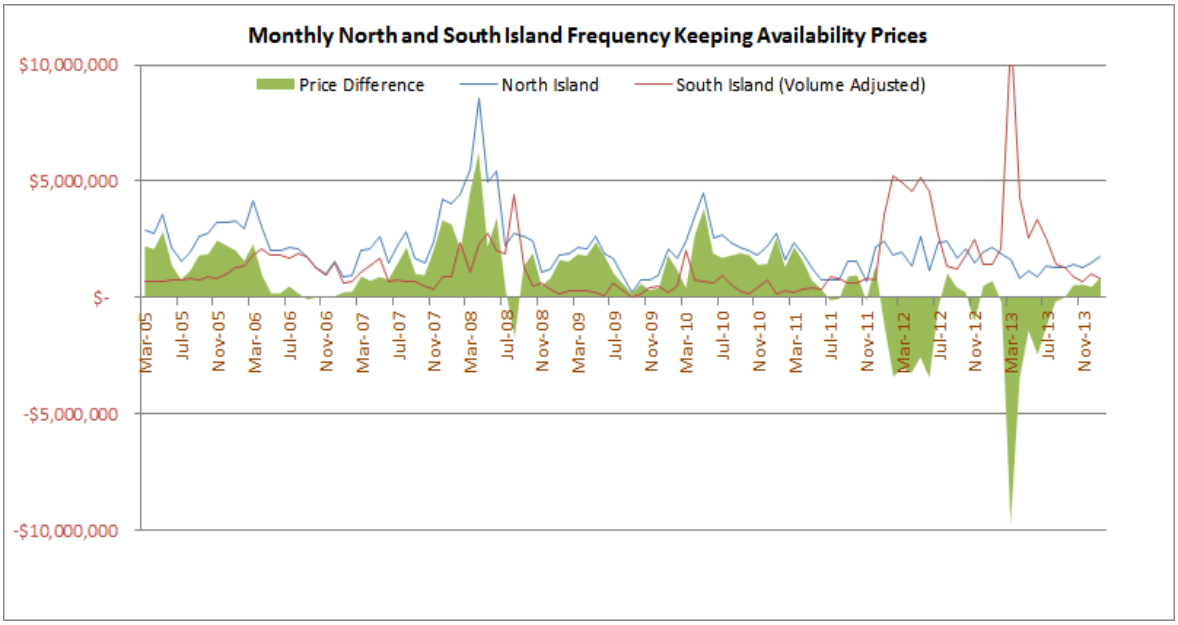
5 Cost benefit analysis of implementing an NFKM

Economic Benefits

5.1 Price diversity between islands

5.1.1 FK prices include a significant energy cost component that has a degree of inter-island diversity. This is evident in the historical FK price differences between the North and South Islands. Since 2005, South Island prices (adjusted for the volume difference between the two islands[4]) have averaged about 64% of North Island prices. The historical price differences since this time are represented by the green area shown in Figure 1.

Figure 1 - Price diversity between islands



5.1.2 For the purposes of analysing the economic benefit that could be achieved by selection of FK in an NFKM, the historical pay-as-bid block offers ($ per 25 MW or $ per 50 MW band) were assumed to reflect the marginal cost of production. As this is generally not the case due to the pay-as-bid design of the current market, the analysis set out below represents the upper bound of cost reduction that could be achieved through selection in an NFKM.

[4] Between 2006 and 2012 the system operator progressively reduced the quantity of FK purchased in the South Island from 50 MW to 25 MW.

5.1.3 The Authority simulated NFKM selection using a modified version of its vSPD model of Transpower's SPD clearing engine software. The Authority carried out the analysis using both unmodified block offer prices and block offer prices converted to equivalent uniform offer prices ($ per MW). The converted uniform offer prices were analysed to measure improvements possible in the run time of the solver software.

5.1.4 The Authority used a set of historical FK offers in the simulation taken after the introduction of Multiple FK in the North Island in July 2013 to capture a period when the most recent market arrangements have been in effect.

5.1.5 The upper bound cost reduction over the 6-month simulation period was assessed to be $4 m, or $8 m annually.

5.2 Reduction in frequency keeping quantity

5.2.1 The system operator's current practice is to purchase FK bands of +/- 25 MW in the South Island and +/- 50 MW in the North Island. The bands are sized to cover:

- the impact of non-dispatchable generation
- the intra-trading period variability of load
- errors in forecast load
- generation not exactly meeting its dispatch target.

5.2.2 Under an NFKM market, it is expected that the total national FK band requirement is expected to reduce to less than +/- 75 MW due to increased inertia and load diversity between the two islands. The system operator requires operational experience to determine the extent of the band size reduction, but a conservative estimate is a reduction of 10 MW.

5.2.3 The Authority's vSPD simulation identified a cost reduction of $1.5 m over the 6-month simulation period, or $3.0 m annually for a quantity reduction of 10 MW (accepting the limitations of this analysis described in paragraph 5.1.2)

5.3 Co-optimisation of FK with energy and reserves

5.3.1 FK selection can have an impact on energy prices. For example, if a generator that is dispatched for FK is constrained on or off to provide the dispatched FK band, the cleared price of energy may change.

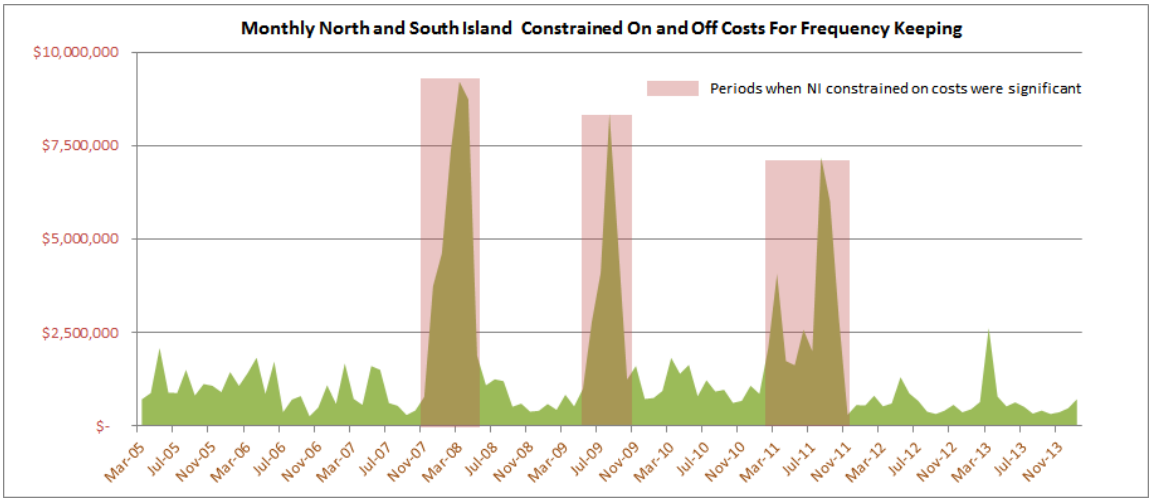
5.3.2 While the constrained on and off costs are taken in the current FK selection algorithm, no optimisation is carried out in SPD to minimise the total cost of:

- FK availability cost
- FK constrained on and off costs
- energy cost
- *rese*rves costs.

The inefficiency of the current selection of FK, energy and reserves is evident in the

magnitude of constrained on and off payments made to frequency keepers. Historical constrained on and off payments are shown in **Figure 2**[5].

Figure 2 Constrained on and off costs for frequency keeping



5.3.3 Full co-optimisation as proposed under an NFKM inherently offers efficiency gains by minimising the constrained on and off payments made to frequency keepers, and additionally minimising the effect of FK selection on energy prices. The Authority's vSPD simulation identified a cost reduction of $1 m over the 6-month simulation period, or $2 m annually.

5.3.4 The WAG notes that full co-optimisation carries a potential risk of unintended pricing consequences at times when system capacity becomes scarce or constrained. The WAG suggests the Authority carries out additional modelling work to assess this risk and reviews any studies completed to date on this subject.

5.4 Deferred investment in peaking capacity

5.4.1 Reducing the band requirement for FK by 10 MW would make some contribution to meeting North Island capacity requirements and allow investment in peaking capacity to be deferred (or allow existing capacity to be retired earlier) - thus providing an additional economic benefit.

5.4.2 The WAG assessed a similar benefit in relation to the national instantaneous reserves market to the extent that a national reserves market also allows investment in peaking capacity to be deferred. While New Zealand is currently in a period of limited demand growth, it is expected that new peaking capacity may be needed from around 2018 assuming demand increases in line with the long term rate of growth. Peaking capacity is assumed to cost approximately $145/kW per year.

[5] FK providers found ways to exploit the FK selection algorithm in 2008, 2009 and 2011 when constrained on payments rose to high levels. The system operator and the Authority have progressively improved the selection algorithm to the extent that such exploitation has not re-emerged since 2011 when the last changes were made. Only recent offers between July and December 2013 when constrained on costs were in the 'normal' range were used in the vSPD simulation to calculate cost reductions.

5.4.3 A 10 MW reduction in the FK band would not always contribute 10 MW to peaking capacity in the North Island. The reduction would occur over both islands and exporting additional capacity from the South Island to the North Island is subject to a number of constraints such as the HVDC capacity and water storage.

5.4.4 As a conservative estimate, a 10 MW reduction in the FK band nationally is assumed to avoid the need for approximately 5 MW of North Island peaking capacity investment.

5.4.5 The economic benefit of the NIRM (through deferral of capacity investment) is therefore estimated as $700 k per year, or $5 m PV over 20 years (using an 8% discount rate).

5.5 Summary of economic benefits

5.5.1 The economic benefits assessed above are summarised in Table 1 below in both annual and 20-year PV terms using an 8% discount rate.

Table 1: Economic benefits of implementing an NFKM

Item	Annual Value	Present Value
Price diversity between islands	$8 m (upper limit)	$59 m
Reduction in FK quantity	$3 m	$22 m
Co-optimisation of energy and reserves	$2 m	$15 m
Deferred investment in peaking capacity	$0.7 m (from 2018 onwards)	$4.7 m
Total	**$12.7 m (before 2018) $13.4 m (from 2018)**	**$101 m**

Costs

5.6 Market systems

5.6.1 The technology platform required to co-ordinate and control FK in a single market spanning both islands has been provided within the scope of the Multiple Frequency Keepers Project and Transpower's new HVDC bipole control system.

5.6.2 The main costs to develop an NFKM that utilises this technology platform are associated with the changes to the system operator and NZX market systems to accommodate a new form of FK offer and to carry out FK selection in SPD. The system operator has investigated these costs and the results are summarised in Table 2 below.

5.7 Changes to FK provider systems

5.7.1 FK providers would need to modify their trading systems to accommodate a new form of FK offer and would need to familiarise staff with new market arrangements. This cost is expected to be in the order of $0.5 m per provider or $2.0 m in total.

5.8 Code amendments

5.8.1 Enabling Code provisions and changes to the procurement plan and the system operator's ancillary services contract are required to support an NFKM. The cost of this regulatory work is estimated to be in the order of $0.15 m

5.9 Summary of costs

5.9.1 The economic benefits assessed above are summarised in Table 1 below in both annual and 20-year PV terms using an 8% discount rate.

Table 2: Cost of implementing an NFKM

Item	Cost
System operator and market system changes	$5.2 m
Changes to FK provider systems	$2 m
Code, procurement plan and ancillary services contract changes	$0.15 m
Total	**$7.35 m**

6 Approach to the project

6.1 Process followed by the WAG

6.1.1 The WAG met three times between October 2013 and February 2013 to discuss the NFKM. The WAG recognised that the Authority has already developed the Multiple Frequency Keepers Project as an enabler for an NFKM. The technical and market solution options for an NFKM are necessarily limited by this pre-cursor project.

6.1.2 The WAG considered publishing a discussion paper to seek feedback from the wider industry. However, it decided to proceed directly to making its recommendations to the Authority on the basis that the project has substantial net benefits and is largely uncontentious. In addition, the project, if approved, would require the Authority to seek feedback from the wider industry as part of the Code amendment process to finalise and confirm the detailed design elements, and create enabling regulatory provisions.

6.1.3 The next stage of the project will be technical and, in the WAG's view, can best be progressed by the Authority working in conjunction with the system operator. However, the WAG would like to be kept informed of progress with the project.

6.1.4 The WAG is of the view that implementing an NFKM is feasible and endorses the work already started by the Authority to investigate market designs, costs and timelines.

6.2 Proposed solution

Selection of NFKM providers

6.2.1 The system operator has advised the Authority that the performance of the existing FK selection tool is barely adequate to support island-based MFK. Accordingly, it will need to be replaced as part of any NFKM implementation.

6.2.2 It is proposed to extend the current co-optimisation of energy and reserves in SPD to include FK, i.e. to perform the selection of frequency keepers in SPD. The cost benefit analysis in section 5 indicates full co-optimisation using SPD has an additional present benefit of
$15 m.

6.2.3 The FK band is currently fixed (50 MW in the North Island and 25 MW in the South Island) but the national band requirement could be made variable in each trading period depending on dispatched generation and load. In such a case, SPD would allow a scheduled quantity of FK to be dispatched in the same way that the reserve products are scheduled and dispatched

Offers and pricing

6.2.4 Under the current market arrangements, providers are paid as offered, and FK is cleared in discrete bands. Frequency keepers are also paid constrained on and off costs and these costs must be added to offer prices to determine total offer costs.

6.2.5 Under selection in SPD it is proposed to adopt a uniform island $/MW enablement price for NFKM with part bands permitted to be cleared.

HVDC controls and interaction with national reserves market

6.2.6 The grid owner completed commissioning of its new HVDC bipole controls on Pole 2 and Pole 3 at the end of 2013. Besides standard HVDC stability controls, the new control system includes a FK and reserves sharing controller (FKC).

6.2.7 The fast acting FKC controller is designed to minimise the absolute frequency difference between the North and South Islands. It allows both national FK and national fast instantaneous reserves to be sourced in either a.c. island by controlling the HVDC link to behave much like an a.c. link.

6.2.8 Whenever FKC is enabled, it transfers FK and reserves between the a.c. islands, regardless of whether island-based or national markets are introduced. In the absence of national markets, free FK and free reserves would be transferred across the link.

6.2.9 Operation of an NFKM is dependent on the ability to transfer FK between the a.c. islands using the HVDC link. While FKC is not the only control option for an NFKM, it is the default option because FKC is a requirement for the related national reserves market initiative.

HVDC round power

6.2.10 The HVDC link has a minimum transfer level in either direction on the HVDC, which would constrain the link's ability to transfer FK (and reserves) between the islands whenever the link is scheduled at low power transfer levels.

6.2.11 It is possible to reduce this constraint by using round power, where power is transferred in opposite directions on the two poles. Transpower is currently investigating how to offer the round power capability of the HVDC link to the market in order to maximise the number of trading periods when national FK (and national reserves) can be transferred between the islands.

7 Next steps

7.1.1 If the Authority agrees with the WAG's recommendations, it should progress the NFKM project as soon as possible. This is expected to involve working jointly with system operator regarding system design and development, market design, enabling Code development, and consultation with stakeholders.

7.1.2 The WAG undertakes to make itself available to provide advice to the Authority as required through the course of the Authority's future work on the NFKM.

7.1.3 The WAG requests the Authority to keep it updated with progress on this project.

Appendix A Frequency keeping optimisation – Authority report