



# **RELIABILITY PANEL**

## **Frequency operating standards**

### **Determination**

**September 2001**

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**National Electricity Code Administrator Limited  
ACN 073 942 775**

# TECHNICAL AND ECONOMIC REVIEW OF FREQUENCY STANDARDS

## 1 EXECUTIVE SUMMARY

Power system frequency is crucial to the management of power system security. Standards for frequency are set by the Reliability Panel, on the advice of NEMMCO, as part of the power system security and reliability standards under clause 8.8 of the National Electricity Code.

The Panel initiated a review of the standards following interconnection between Queensland and New South Wales and to assess the potential better to incorporate economic criteria into the management of frequency and the associated ancillary services. The Panel published a discussion paper in December 2000 and a draft determination in July 2001.

The Panel conducted a public forum to discuss the draft on 27 August. After considering submissions from interested parties NEMMCO amended aspects of its advice to the Panel. The Panel now determines revised frequency operating standards which in summary:

- ◆ relax the normal frequency band from 49.9 - 50.1 Hz to 49.85 - 50.15 Hz;
- ◆ create a probabilistic tolerance for the normal band of 99 percent of time;
- ◆ amalgamate the standard for load disturbances with the standard for single generator disturbances;
- ◆ increase the maximum time to stabilise frequency following multiple contingencies;
- ◆ establish a uniform base standard when a contingency event may result in separation of parts of the network and provide for a Jurisdictional Co-ordinator to advise NEMMCO of a relaxation of this requirement;
- ◆ tighten the standards that apply to island operation in the absence of disturbing events; and
- ◆ amend the allowable time error from 3 seconds to 5 seconds.

No change is made to the frequency levels relating to generation loss, network contingency events or multiple contingency events.

The tolerance on the normal band will allow NEMMCO to reduce the level of ancillary services and to enhance the scheduling process to, within limits, vary the amount of ancillary service in response to market price.

The additional flexibility for the effect of network separation will reflect better the variation in social, technical and economic circumstances across the network.

The determination is to apply on and from **30 September 2001**.

## **2 BACKGROUND**

Power system frequency control is crucial to the quality and security of electrical power systems. The Reliability Panel determines standards for frequency in the national market as part of the power system security and reliability standards, with advice from NEMMCO. NEMMCO then controls power system frequency in accordance with those standards.

Prior to the start of the national electricity market, the Panel set standards that were similar to those then being used by the utilities in each state. These were later confirmed after a review of customer needs subject to a further examination after two years of market experience. A minor change to the standard for Queensland prior to interconnection with other regions was incorporated during 2000.

In 2000, NEMMCO advised that it would be appropriate to review the standards in the light of growth in the size of the power system and in particular with Queensland region now interconnected with the other regions of the market. The Panel has also undertaken to review the potential for inclusion of direct economic criteria in the standards to reflect the market environment in which the standards operate. The initial scope of the review has been expanded to consider a more general treatment of events that result in separation of parts of the network from the rest.

## **3 DISCUSSION PAPER & DRAFT DETERMINATION**

The Reliability Panel issued a discussion paper in December 2000. The paper presented a discussion of technical issues prepared by NEMMCO, and also considered the economic impact of the standards and options to enhance these arrangements.

Submissions were received from TransGrid, Powerlink Queensland, Hazelwood Power and Ergon Energy.

NEMMCO's analysis of the comments received in the submissions was published with the draft determination.

In July 2001 the Panel published a draft determination which took into account matters raised in submissions to the discussion paper. Submissions on the draft determination were received from Powerlink Queensland, Tasmanian Treasury, VENCORP Victoria and the South Australian Electricity Supply Industry Planning Council.

Copies of submissions to the discussion paper and draft determination are available from the NECA website. NEMMCO's advice is available on the NEMMCO website.

## **4 INTRODUCTION**

In an alternating current power system, the supply frequency is a common characteristic of the voltage at all locations, but varies over time as system conditions change. Many items of electrical equipment, especially rotating machinery, rely on a steady frequency for safe, effective and efficient operation, and are designed to tolerate minor short lived fluctuations. If frequency deviates too far from its nominal level, which is 50 Hz in Australia, the operation of consumer and generating equipment can be impaired and, in the extreme, damaged.

Excursions of frequency from the nominal level are caused by both gradual changes and spontaneous events that disturb the balance between load and generation. Ancillary services are scheduled by NEMMCO to restore the balance and so restore frequency to the nominal level. If a disturbance is large, restoration may not be achieved before some plant and equipment malfunctions and disconnects from the power system. This can exacerbate the excursion. It is therefore crucial that appropriate frequency standards are set and frequency is maintained within those standards. Further information about how system conditions affect frequency is provided in Attachment 1.

## **5 FRAMEWORK FOR FREQUENCY STANDARDS**

### **Role of standards**

Variations of frequency away from the nominal value of 50 Hz can cause equipment connected to or supplied from the power system to malfunction. Wider variations can lead to equipment damage. Malfunction of generation equipment may increase frequency deviation and lead to cascading malfunctions. This could rapidly lead to total collapse of the power system, with major financial loss to the industry and the community.

Frequency must be managed on a second by second basis, far faster than any market mechanisms can deliver. Accordingly, as part of its security obligations, NEMMCO is charged with central management of frequency to the defined standards. These should be set so that appropriately designed equipment does not malfunction and will not be damaged.

### **Economic impact of frequency control**

Power system frequency is essentially determined by the rotational speed of large generating units, which can be controlled by changing their mechanical power input or their electrical power output. NEMMCO meets its responsibility under the Code for frequency control principally by using ancillary services provided by Generators or provided by Market Customers. Some of these services are provided as commercial ancillary services and some are mandated under the Code. Mandated services include customer load shedding and may have zero direct costs but significant indirect cost, including community cost. In addition, to obtain the necessary level of ancillary service, the energy market dispatch may need to be constrained, with the effect of increasing energy prices. Total direct costs for the commercially acquired frequency

control ancillary services in the national market have been of the order of \$150 - 200 million per annum. A spot market is soon to replace the existing contract basis for purchase of these services. One of the objectives of this review is to ensure that the format of the standards does not constrain the efficiency of the ancillary service regime.

The task of setting frequency standards is largely a matter of making a trade-off between quality, security and cost. The appropriate balance depends on the impact on consumers' equipment (such as loss of production or operating efficiency), its impact on generation equipment (such as consequential failure), the cost of ancillary services and the impact of any constraints imposed on the energy market.

In a market environment, an appropriate process for setting standards would be to quantify the supply cost and service impact for various levels of standard, and find the level at which these match. That is, find the level of service that the industry and consumers are prepared to pay for. However, none of these service impacts and costs is sufficiently well known or able to be determined in advance in a manner that would allow standards to be set to achieve an ideal cost-effective outcome for the industry and our consumers.

The substantial difficulty of accurately determining the service impacts and costs of frequency standards can be addressed in two ways:

- ◆ by considering the likely changes to service impacts and costs for a proposed incremental change in the standards, and adopting that change if it shows a net benefit; and
- ◆ by setting standards that contain flexibility to allow further economic evaluation of what is known near the time of dispatch.

### **Location factors**

In an interconnected alternating current power system, system frequency is essentially the same at every location. Frequency standards apply globally and have the potential to affect the performance of all equipment connected to the power system. To determine appropriate standards the service impacts and costs should therefore be assessed on a global basis for the whole of the interconnected system. However, if parts of the power system are separated or connected only through direct current (d.c.) circuits, then the separate parts will have different frequencies, and the service impacts and costs should be considered for each part. Different service impacts and costs could then result in separate parts having different standards. This may need to influence the future design of ancillary service cost recovery arrangements.

## 6 SUMMARY OF CURRENT STANDARDS

The following table applies to the fully interconnected network:

Condition	Containment	Stabilisation	Recovery
normal (none of the following)	49.9 to 50.1 Hz		
unplanned load change	49.75 to 50.25 Hz	49.9 to 50.1 Hz within 5 minutes	
single generating unit loss	49.5 to 50.5 Hz		49.9 to 50.1 Hz within 5 minutes
other single credible contingency event	49 to 51 Hz	49.5 to 50.5 Hz within 1 minute	49.9 to 50.1 Hz within 5 minutes
multiple contingency event	47 to 52 Hz	49.5 to 50.5 Hz within 1 minute	49.9 to 50.1 Hz within 10 minutes

The following table applies while there is system separation and an electrical island has formed:

Condition	Containment	Stabilisation and Recovery
Normal (none of the following)	49 to 51 Hz	
Unplanned load change	49 to 51 Hz	
Single generating unit loss	49 to 51 Hz	
Other single credible contingency event	49 to 51 Hz	
Multiple contingency event	47 to 52 Hz	49 to 51 Hz within 1 minute

The allowable time error is 3 seconds.

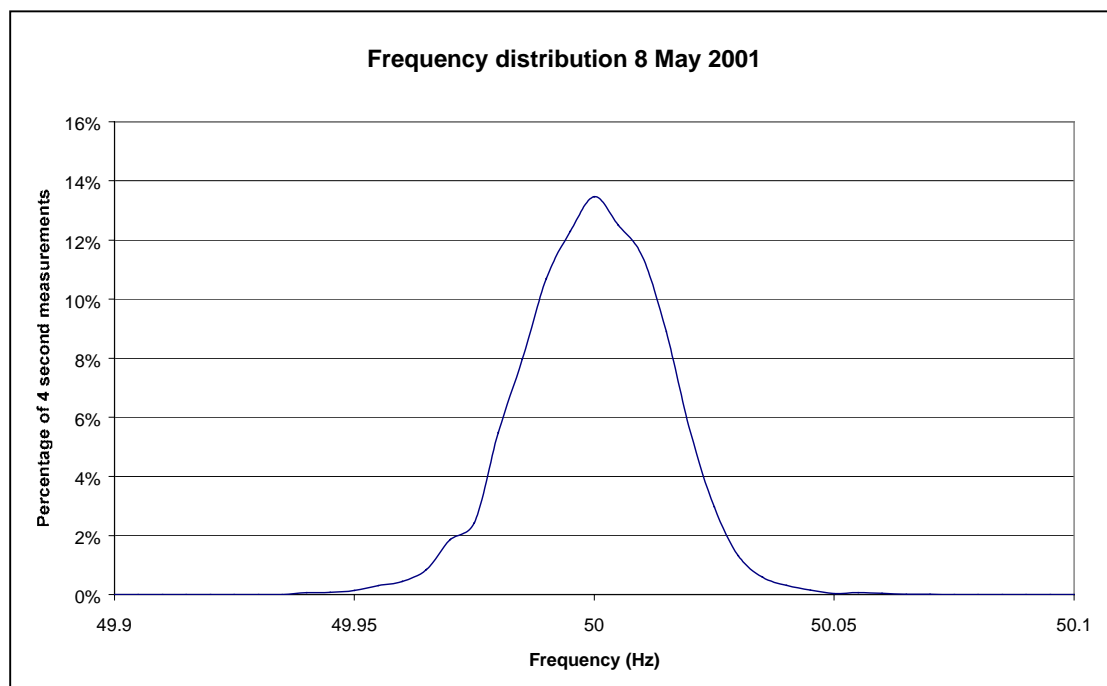
## 7 DISCUSSION AND PROPOSAL FOR AMENDMENT

### Normal frequency band

**Technical performance:** The purpose of the normal band is to provide stability of frequency in the absence of disturbances, that will allow efficient and predictable operation of generation, networks and consumers' equipment, and predictable excursions as a result of contingency events.

Minor variation in frequency around 50 Hz occurs continually as a result of normal fluctuations in consumer demand and generating unit performance. NEMMCO's dispatch process forecasts demand and establishes a linear path for generating units every five-minute dispatch interval. However, consumer demand does not vary linearly between five-minute dispatch cycles, and the imbalance between generation and demand causes frequency to vary even without contingency events. The regulating ancillary services are used to correct such frequency variations within each five-minute period. The limits of the normal band therefore determine the amount of regulating ancillary service required, and consequently its cost.

NEMMCO usually keeps system frequency well within the normal band to minimise the possibility that it will be exceeded in the absence of major load changes or contingency events. For example, a typical statistical distribution of system frequency over 24 hours is shown in the figure below.



Keeping the frequency so close to 50 Hz has several benefits:

- ◆ it provides reasonable certainty for the starting point for any disturbance, allowing the amount of contingency services to be determined on the assumption that frequency is close to 50 Hz prior to the incident;

- ◆ it minimises the chance that frequency will exceed the normal band for simultaneous occurrence of minor load and generation changes;
- ◆ time error is much easier to keep within specified limits if it is not usually being accumulated; and
- ◆ keeping the frequency close to 50 Hz and within the governor deadband permitted by the Code (+/- 0.05 Hz) minimises wear of governor systems and therefore generation costs.

**The quality-cost balance:** In the 2000 calendar year, the regulating ancillary services had the highest cost of all ancillary services, more than \$90 million, and its highest weekly cost exceeded \$9 million.

A survey of international sources undertaken for the Reliability Panel in 1998 showed that even the most sensitive equipment is generally able to operate satisfactorily if the frequency is normally within 0.3 Hz to 0.5 Hz of nominal. A similar study in South Africa identified that IEEE Standard 446-1995 and BS EN50160:1995 state that a maximum of +/-0.5 Hz frequency variation is used as a tolerance for major end-use equipment.

Nationally and internationally, the normal band for frequency control in the National Electricity Market is amongst the most conservative. The equivalent standard in Queensland was 49.85 to 50.15 Hz prior to interconnection, is 49.85 to 50.15 Hz in Tasmania, and is 49.8 to 50.2 Hz in Western Australia and the Northern Territory. Normal practice in the United Kingdom, Ireland and New Zealand is 49.8 to 50.2 Hz. South Africa is proposing to change their standard from 49.95 to 50.05 Hz to 49.85 to 50.15 Hz (with a 95% probability). It should be noted that the United Kingdom does not use an automatic regulating service like ours, but relies on manual control and governor action. South Australia operated similarly before interconnection with Victoria and had a wider frequency band. Given:

- ◆ the substantial cost of maintaining frequency within the existing normal frequency band;
- ◆ the cost savings available from reducing the system requirement for regulating ancillary services;
- ◆ the low probability that a small widening of the band would affect either consumers' equipment or generation equipment; and
- ◆ the more relaxed standard in other states and countries that would have comparable generation and consumer equipment,

NEMMCO has recommended that the normal frequency band be relaxed slightly.

In the submissions on the discussion paper, Ergon Energy and Powerlink Queensland supported the concept of some dispatch flexibility. Hazelwood Power expressed concern about the lack of information about consumers' preferences for quality and that any discernible reduction in supply quality could be used "as evidence that the market is flawed". NEMMCO considers that the weight of Australian and international experience and standards support a widened normal band.

As with the contingency services, the requirement for regulating service is offset by the amount of load relief provided by system demand. Load relief is the characteristic of load inherently changing with frequency. NEMMCO estimates that the

requirement could be reduced by 30 MW for every 0.05 Hz of widening of the normal band, which is 10% of the present requirement of 300 MW. This would easily achieve a reduction of more than 10% in the cost of regulating ancillary services or more than \$9 million based on calendar year 2000 costs although new market arrangements will affect future costs. Given the very high cost paid for the last few MW of service in a very small number of dispatch intervals, the saving could be much higher than this.

A consequence of a widening of the normal band is that the amount of fast contingency service may need to be increased by the same amount as any reduction in regulating service requirement to meet the same minimum frequency requirement for contingency events. This point was emphasised in VENCORP's submission on the draft determination. Contingency services have generally been cheaper than regulating services. An additional 30 MW of fast raise and lower service is estimated to cost about \$3.8 million per annum based on calendar year 2000 costs. A widening of the normal band would allow NEMMCO greater scope to schedule the optimum mix of different services able to meet the different aspects of the standard. NEMMCO also proposes to examine the possibility of adjusting the amount of generation to be dispatched in the energy market for load relief provided by customer load. This would be on the basis that the energy market is expected to balance demand and generation at nominal frequency, rather than at any other frequency. This would achieve a further slight reduction in the requirement for regulating services and therefore a slight reduction in its cost.

**Dispatch flexibility and economic criteria** The present firm definition of the normal band, to be achieved despite a wide range of power system changes, means that NEMMCO must necessarily be conservative in its dispatch of ancillary services. Many load and generation changes do not fall within the conditions of the load change and generating unit contingency bands, and the regulating ancillary services available to control frequency within the normal band are slow to operate compared with the speed of load and generation changes. NEMMCO must set the requirement to cover any generation-load imbalance that does not fall within the conditions of the other bands, allowing for the slow operation of the regulating ancillary services.

If the normal band could be expressed with a statistical tolerance, to allow occasional limited deviations beyond a specified level NEMMCO would require less regulating ancillary service. Moreover, a statistical tolerance in the Panel's standard would allow NEMMCO to consider economic factors, such as the prevailing market cost of ancillary services, at the time of dispatch. This would model a consumer's choice to adjust its purchase in response to price. Within the defined limits, less ancillary service could be purchased when the market price was high, resulting in an increased probability of entering the tolerance range at that time. More could be purchased when the price was low, leading to a lower probability of entering the tolerance range at those times. The levels would be set so that over an evaluation period the probability was as specified in the standard. NEMMCO would need to develop and consult on new dispatch procedures and extend aspects of the scheduling process. A preliminary assessment of this is given in Attachment 2. The Panel looks to NEMMCO to utilise the full opportunity to optimise market efficiency afforded by these changes through appropriate enhancement of the despatch process.

**Determination** The normal band for frequency be widened and defined on a statistical basis. Except following defined events, frequency should be contained

within the range 49.85 to 50.15 Hz for 99 per cent of the time and otherwise within the range 49.75 to 50.25 Hz.

The range of 49.85 to 50.15 Hz is the same as the range that existed in Queensland until recent times, and no less stringent than comparable ranges elsewhere in Australia and more stringent than the ranges in New Zealand, Ireland and the United Kingdom. The range of 49.75 to 50.25 Hz is presently the load change band, and so occasional operation within this band will not adversely impact on equipment operation. NEMMCO considers that such new limits are most unlikely to affect consumers' or Generators' equipment and are likely to achieve significant savings in contingency ancillary service costs. The submission from the SA ESIPC called for inclusion of a time period over which the statistical tolerance should operate. This is included in the detail of NEMMCO's advice at 30 days.

### **Contingency bands**

The purpose of these bands is to contain the impact of contingency events in order to minimise malfunction and damage of consumers' and producers' equipment, and to minimise the possibility that one contingency event causes other failures, leading to significant load shedding and possibly system collapse. In the 2000 calendar year, the contingency ancillary services cost more than \$60 million. As any one of the hundreds of events during that period could have led to major disruption, if not system collapse, failure to procure and dispatch these services would have impacted the community in a very significant manner, suggesting the value of these services is very high.

#### **The load change frequency band (49.75 Hz to 50.25 Hz)**

Currently the upper limit of this band (50.25 Hz) determines the amount of lower frequency control ancillary services required to cover disconnection of large, typically industrial, loads, for example aluminium smelter potlines. The lower limit (49.75 Hz) presently has little effect on ancillary service requirements because the corresponding raise requirement is less than that required to cover single generating unit loss.

Since market commencement, there has been only one instance of load changes causing the frequency to exceed the applicable load change band. However, there were about 240 occasions when load changes caused the frequency to exceed the applicable normal band. Many of these involved coincident multiple load changes.

A key issue is whether this band really needs to be as restrictive and specifically restricted to "sudden and unplanned" changes of system demand. If the power system can withstand frequency rising to 50.25 Hz for an unplanned disconnection, it can withstand the same frequency rise for a planned disconnection. This band was previously more important in the smaller Queensland power system prior to interconnection. For Queensland, it was originally 49.5 Hz to 50.5 Hz, but widened to 48.5 to 51 Hz in July 2000. NEMMCO considers that the need for a separate level for unplanned load changes is now obsolete. If it were amalgamated with the single generating unit band it would reduce the requirement for fast lower services by about \$4 million per annum based on calendar year 2000 costs. As all generating units are (or should be) capable of operating continuously in this band, NEMMCO does not expect there to be any adverse impact on equipment or power system security. None of the submissions to the draft determination addressed the proposal to delete the load change band.

**Determination:** The load change band be deleted.

**The single generating unit band (49.5 Hz to 50.5 Hz).**

The lower limit of this band determines the amount of raise frequency control ancillary service required to cover disconnection of single generating units. Connection of generating units at the time of synchronisation causes frequency to rise, but not significantly, so the upper limit currently acts only as a limit on over-correction of frequency through excessive control action (such as load shedding).

This band is also used to set the standard for the time within which frequency must be recovered following more severe disturbances. All generating units must readily accept system frequency between the upper and lower limits of this band but are at increasing risk if frequency moves outside the band. To minimise the risk of generating unit trips following a severe excursion of frequency, the standards specify a relatively short time to recover to this level.

Since January 1999, there have been about 200 generating unit trips in Queensland and the interconnected regions. The relevant single generating unit band was not exceeded for any single generating unit trip. This is an indication that sufficient ancillary services had been scheduled.

A key issue is whether single generating unit loss needs to be treated differently from other single credible contingency events. In a submission on the discussion paper, TransGrid has suggested that the addition of a separate band for single generating unit contingencies into the frequency standards had no economic justification and that traditionally the limit for single generating unit loss was 49.0 Hz. However, the National Electricity Code derogations for many Victorian generating units provide that they only need to operate continuously following single generating unit loss if the system frequency remains above 49.5 Hz. While such derogations are in force, a relaxation of this frequency band would increase the probability that loss of a single generating unit would lead to total system collapse. NEMMCO believes it would be appropriate to retain the present frequency limits for generation loss at least while these derogations remain in place. This point was highlighted by the VENCORP submission on the draft determination.

In its submission on the discussion paper, Powerlink argues that while the normal band could provide some flexibility, the contingency and emergency bands should remain fixed.

**Determination:** No change be made to the frequency limits for generation loss.

**The (other) credible contingency band (49.0 Hz to 50.0 Hz)**

The upper and lower limits of this band determine the amount of additional frequency control ancillary service that needs to be dispatched during transmission outages that leave amounts of generation and load at risk from a single credible contingency event.

Since January 1999, there has been one occasion when a single credible transmission contingency led to a frequency excursion outside this band. That was on 23 October 1999 when the interconnection between Victoria and South Australia was severed leaving South Australia as an electrical island. The multiple contingency band allows the frequency to fall to 47.0 Hz under these circumstances.

It should be noted that the Code requires that the under-frequency load shedding has frequency settings between 49.0 and 47.0 Hz, and accordingly any relaxation of this band would allow load shedding as a consequence of single credible contingency events (unless the settings were changed).

**Determination:** No change be made to this band for the interconnected network. Provision for variations for specific island conditions is considered below.

### **The multiple contingency band (47.0 Hz to 52.0 Hz)**

The principal purpose of this band is to set frequency levels at which Generators, Network Service Providers and Customers can disconnect their equipment to prevent damage. It plays no part in the scheduling of frequency control ancillary services. The band limits would only be reached in a calamitous situation following a major disturbance. By the time the frequency reaches the lower end of the range, under-frequency relays would have interrupted a large percentage of consumer load in an attempt to avoid total shutdown. If the disturbance is so severe that frequency reaches 47.0 Hz, it is better to allow collapse and then rebuild, using system restart ancillary services procured for this purpose. This band has not been exceeded in the national market. As this band is largely determined by the capability of generating units, any relaxation would require upgrading of plant, which would be unrealistic to impose. Also, there is no obvious benefit of tightening the band.

There have been several instances where the recovery of frequency from between the other credible contingency and multiple contingency bands following multiple contingencies could not be achieved within the times specified in the current standards. NEMMCO considers that the recovery requirement is too tight for multiple contingencies. The time allowed for recovery to 49.5 Hz is 60 seconds for a single credible contingency event or a multiple contingency event. NEMMCO dispatches sufficient ancillary service to achieve this. However, NEMMCO does not dispatch frequency control ancillary services to cover multiple contingencies, and relies on ancillary service dispatched for single contingencies plus mandatory load shedding provisions. In recognition of this, the current standard allows twice the usual time to recover frequency to the normal band, but the same time to recover to 49.5 Hz for single and multiple contingencies. Under these circumstances, it would be reasonable to allow more time to recover for multiple contingencies to the 49.5 Hz level. The Code also requires that NEMMCO act to restore the power system to a satisfactory operating condition, or no more than 0.25Hz away from 50Hz unless the standards allow otherwise, as soon as practicable. If a disturbance is severe enough to result in a frequency of 47 Hz all ancillary services will be fully utilised and load shedding will be occurring. The power system will be at risk of cascade failures of the remaining generators and load and it is therefore critical for frequency to be recovered rapidly. The rate of that recovery will be heavily dependent on the level of load shedding as well as the performance of the remaining generation and load in the particular circumstances. This is consistent with the Code requirement to restore a satisfactory operating state as soon as practicable. None of the submissions on the draft determination addressed the multiple contingency band.

**Determination:** No change be made to the frequency levels for multiple contingencies, but the recovery time to the 49.5 Hz level be extended from 1 minute to 2 minutes.

### **Time standard**

Currently, NEMMCO must use reasonable endeavours to keep the time error less than 3 seconds. In practice, NEMMCO usually keeps the time error less than 2 seconds, but contingency events cause the error to increase. For example, a single credible contingency event other than a generating unit trip could cause a time error change of about 2.3 seconds if frequency is just maintained within the present standards. Multiple contingency events could cause even greater time error. NEMMCO considers that to keep time error normally within say 0.7 seconds or less to leave allowance for such contingency events is impractical and would probably unnecessarily increase the cost of regulating services.

In their submissions on the discussion paper, Hazelwood Power argues that the standard should remain tight, TransGrid argues that any change should be to tighten it but also that errors as high as 1 minute should not be of concern to consumers. Powerlink proposes that the standard could allow the limit to be exceeded if ancillary services costs were "too high" at the time. NEMMCO does not separately dispatch regulating service for time error correction, and considers that cost should therefore not be an issue. NEMMCO has therefore recommended that the maximum time error be increased to 5 seconds.

When parts of the national market are operating as separate islands time error will be different in each island. The current standards do not address management of time error upon re-connection. The Panel endorses NEMMCO's recommendation that the standards incorporate a provision to reset electrical time rather than delay reconnection purely to allow time error in the separate parts to be aligned.

**Determination:** The time error allowance be increased to 5 seconds and specific provision be made to allow NEMMCO to write off time errors after islands are reconnected such that they again have a common frequency.

## **8 ELECTRICAL ISLANDS AND ASYNCHRONOUS SECTIONS OF THE NETWORK**

Electrical islands are formed when connection between parts of the interconnected network is broken. An island may comprise an entire region if an interregional link is out of service or only a part of a region, for example the north of Queensland or west of South Australia. Power system frequency in the separated parts will be independent of the other(s). In islands formed from larger sections of the network there will often be some capability to control frequency. Smaller islands may have to rely on manual control.

There are similar considerations for d.c. links. Although energy can readily be transferred between parts of a network connected only by a d.c. link the frequency either side of the link can be separately or asynchronously controlled. Unless frequency control ancillary services are transferred across a d.c. link, separate provision must be made either side of the link. It may therefore be appropriate for standards, particularly under contingency conditions to differ either side of a d.c. link,

especially when a small network is interconnected to a larger network through a d.c. link. This is likely to be the case with Tasmania.

An event that causes separation into islands is currently treated as a multiple contingency event. In general, a single credible contingency will not cause separation unless one or more adjacent lines are open before the event. The effect of this provision means that NEMMCO does not need to dispatch frequency control ancillary services to cover separation events, even those caused by single credible contingency events. This was incorporated as part of the standards in recognition of the significant cost burden frequency control was placing on South Australian participants when the interconnection to Victoria was reduced to a single contingency during maintenance or lightning activity. A similar double circuit interconnection has now been established between Queensland and NSW. The Panel believes it is now appropriate for the standard to more generally address the frequency within any electrical island within the NEM, at the instant it forms.

There is a range of social, technical and economic factors, which influence the degree to which it is appropriate to provide full security of supply for contingencies. In the design of transmission networks all load can generally be supplied when a single credible contingency occurs when no other related line is out of service. Some exceptions exist in remote areas. It is also common for supply interruptions to result from contingencies in distribution networks. Security of supply within the interconnected network of the national market due to frequency excursion is broadly similar to that for transmission systems. This means that there is generally no call for the under-frequency relays required under the Code to disconnect consumers for single credible contingency events. There are however significant exceptions, particularly where a single event can cause separation into electrical islands.

The effect of separation will depend on the demand within each part and the direction of electrical transfer immediately before the event. For example if the islanded area was importing power before the contingency frequency will fall as the island forms, but rise if the area was exporting. If the contingency results in frequency falling below 49.0Hz, the other credible single contingency level of the current standards, the under-frequency relays will operate and shed load in the affected area. The extent of shedding will depend on the size of the excursion. Where they are deployed, ancillary services can mitigate the impact. Cost of the ancillary services and the indirect effect in the energy market is exacerbated by the need to deploy sufficient ancillary services entirely within the islanded area.

Although it is possible to predict the formation of particular islands, for example, Queensland and South Australia, and in the future Tasmania, where connection is through only two lines, there are a large number of other potential electrical islands.

Larger islands can be self-sufficient in terms of frequency control and readily achieve the full standards, in particular in the bulk of the network after a smaller section has separated. A balance should therefore be struck to widen the requirements for frequency control for smaller separated sections and continue to regard the larger sections as if full interconnection has been maintained. NEMMCO has therefore amended its recommendation to identify an island as a section of the network containing less than half the generation of two regions of the market. This approach would need to be revisited if market regions are to change, and possibly to allow the Panel to establish standards for Tasmania. In any event a minimum of 12 months notice is required before boundaries can be changed and a number of other standards

would also need to be revisited, for example the Panel's reliability standard and associated reserve requirements.

The broader community consequences of widespread interruption is a matter of legitimate interest to jurisdictions in a similar manner to the level of reserve required before reserve trading contracts are arranged. The Panel therefore believes that it would be appropriate for it to establish a uniform standard applicable:

- ◆ to the normal interconnected condition, that is where an island will not form from a single credible contingency event. Under the Code, this will require NEMMCO to recruit sufficient ancillary services to provide full security to all load seeking to be supplied; and
- ◆ a wider, reasonable endeavours, boundary for frequency within an electrical island as it forms and after it has stabilised. Wherever it is physically possible, the standard should ensure the same security of supply to load that applies to the interconnected power system. The standard should recognise that the outcome will be strongly dependant on the network configuration of the particular island;

A new provision should be made for the Jurisdictional Co-ordinator to advise NEMMCO of lesser alternative requirements for frequency within particular island sections of the network within that jurisdiction, for the limited occasions where an island may form.

The draft determination discussed the possibility that the advice could address more than just frequency. It suggested the level of customer load at risk, network limitations and ancillary service costs might be covered by the advice. It was envisaged that NEMMCO and a Jurisdictional Coordinator would need to agree on the form of any advice that would effect NEMMCO's operational processes.

NEMMCO already has a basic obligation to seek economically to optimise market operation within physical constraints. Where the SPD algorithm model is sufficiently comprehensive this is achieved on a 5 minute basis for example the energy market treatment of generation, demand side, network losses and constraints and the prescribed levels of each ancillary service. Where the SPD despatch algorithm does not fully model a cost, procedures or decision processes in the software are used. For example, the optimisation does not assess the benefit of reducing interconnector flow where this might have reduced the need for FCAS. Under the current procedures FCAS is purchased ahead of consideration of reduced interconnector flow. Where the FCAS requirement is a single network wide requirement this is adequate. If a local requirement is specified, for example because of the potential to form an island, it may not be the optimum result. Network constraints used in the process are provided by TNSPs. Their primary purpose is to manage network loading, and abnormal conditions for example lightning, but on some occasions they are designed to limit the effect of low frequency due to an event which creates an island and indirectly impose a partial optimisation between interconnector flow and ancillary service requirements. There is therefore scope for the overall dispatch arrangements to be enhanced and the MSORC process is reviewing the arrangements for setting those limits for overall system operation, particularly those, which have a system wide effect. These matters are wider than management of frequency and affect a number of parties and regulatory processes.

It is therefore not appropriate for the frequency standards to be the mechanism to influence the wider optimisation process or the source of advice about network limits.

In these circumstances the standards should therefore allow for a Jurisdictional Coordinator to provide advice of a wider multiple contingency frequency band – this will be directly related to the amount of load at risk of interruption by operation with frequency relays.

The means to achieve the standard should be fully integrated with the market scheduling arrangements developed by NEMMCO with appropriate consultation with market participants.

Under the existing standards, when islands have formed, the normal, load change and single generating unit contingency bands all widen to the (other) credible contingency band (49.0 to 51.0 Hz). This was designed to require good control where it was possible but recognised that this may not always be the case. For example, the requirement to satisfy the other credible contingency band meant that, whenever it was possible, frequency within the island would need to be controlled much closer to 50 Hz.

NEMMCO has recommended that the standards be tightened to improve system security under such circumstances without significant adverse effects on cost. In particular, that the normal band within an island be tightened to 49.5 to 50.5 Hz – noting that only a section of the network containing less than half the generation of two regions will be regarded as an island. This aligns with the range that all generating units are required, under all circumstances, including derogations, to operate continuously. Recovery to this level while islanded and stable will generally be achievable, because frequency control ancillary service can be dispatched in each island or, if there is insufficient available, Generators can be directed to control units manually for frequency control. This arrangement would impose a 0.5 Hz margin between the normal band and the level at which automatic under-frequency load shedding would commence. In many, but not all, circumstances this will be sufficient to prevent loss of customer load following a further single generating unit loss or single load reconnection even under these difficult circumstances.

While the proposed revisions to the standards do not specifically cover the inclusion of Tasmania into the National Electricity Market, the structure will readily accommodate amendment for an asynchronous island. The appropriate levels will need to be considered after the final technical and administrative arrangements for Basslink have been determined. Derogations have been proposed for Tasmania, which will allow for the Tasmanian Reliability Panel standards to be applied until specific provision is included in the NEM standards.

## 9 DETERMINATION

The Reliability Panel now determines the frequency operating standards to be:

### **PART A SUMMARY OF THE STANDARDS**

The *frequency operating standards* set out in Part B below are summarised in the following tables for convenience. To the extent of any inconsistency between these tables and Part B below, Part B prevails.

The following table applies to any part of the *power system* other than an *island*:

<b>Condition</b>	<b>Containment</b>	<b>Stabilisation</b>	<b>Recovery</b>
<i>Accumulated time error</i>	5 seconds		
<i>no contingency event or load event</i>	49.75 to 50.25 Hz, 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
<i>generation event or load event</i>	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	
<i>network event</i>	49 to 51 Hz	49.5 to 50.5 Hz within 1 minute	49.85 to 50.15 Hz within 5 minutes
<i>separation event</i>	49 to 51 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
<i>multiple contingency event</i>	47 to 52 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

The following table applies to an *island*:

<b>Condition</b>	<b>Containment</b>	<b>Stabilisation and Recovery</b>	
<i>no contingency event, or load event</i>	49.5 to 50.5 Hz		
<i>generation event, load event or network event</i>	49 to 51 Hz	49.5 to 50.5 Hz within 5 minutes	
<i>the separation event that formed the island</i>	49 to 51 Hz or a wider band notified to NEMMCO by a relevant Jurisdictional Coordinator	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
<i>multiple contingency event including a further separation event</i>	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes

## **PART B THE FREQUENCY OPERATING STANDARDS**

For the purposes of Chapters 4, 5 and 10 of the National Electricity Code, the *frequency operating standards*, forming part of the *power system security and reliability standards*, are:

- (a) except in an *island*, the *accumulated time error* should not exceed 5 seconds;
- (b) except as a result of a *contingency event* or a *load event*, *system frequency* should not exceed the applicable *normal operating frequency excursion band* and should not exceed the applicable *normal operating frequency band* for more than five minutes on any occasion and not for more than 1% of the time over any 30 day period;
- (c) as a result of a *generation event* or a *load event*, *system frequency* should not exceed the applicable *generation and load change band* and should not exceed the applicable *normal operating frequency band* for more than five minutes;
- (d) as a result of any *network event*, *system frequency* should not exceed the applicable *operational frequency tolerance band* and should not exceed the applicable *generation and load change band* for more than one minute or exceed the applicable *normal operating frequency band* for more than five minutes;
- (e) as a result of any *separation event*, *system frequency* should not exceed the applicable *island separation band* and should not exceed the applicable *generation and load change band* for more than two minutes or exceed the applicable *normal operating frequency band* for more than ten minutes; and
- (f) as a result of any *multiple contingency event*, *system frequency* should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable *generation and load change band* for more than two minutes while there is no *contingency event* or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no *contingency event*.

## **PART C APPLICATION OF CODE TERMS**

For the purposes of these *frequency operating standards* and Chapters 4, 5 and 10 of the National Electricity Code, a term shown in Column 1 of the following table has the corresponding range shown in Column 3 of the table for an *island* and has the corresponding range shown in Column 2 of the table otherwise.

<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>
<b>Term</b>	<b>Normal range (Hz)</b>	<b>Island range (Hz)</b>
<i>normal operating frequency band</i>	49.85 to 50.15	49.5 to 50.5
<i>normal operating frequency excursion band</i>	49.75 to 50.25	49.5 to 50.5
<i>operational frequency tolerance band</i>	49.0 to 51.0	49.0 to 51.0
<i>extreme frequency excursion tolerance limits</i>	47.0 to 52.0	47.0 to 52.0

## PART D DEFINITIONS

Words and phrases shown in Italics in this document have the meaning given to them in the following table:

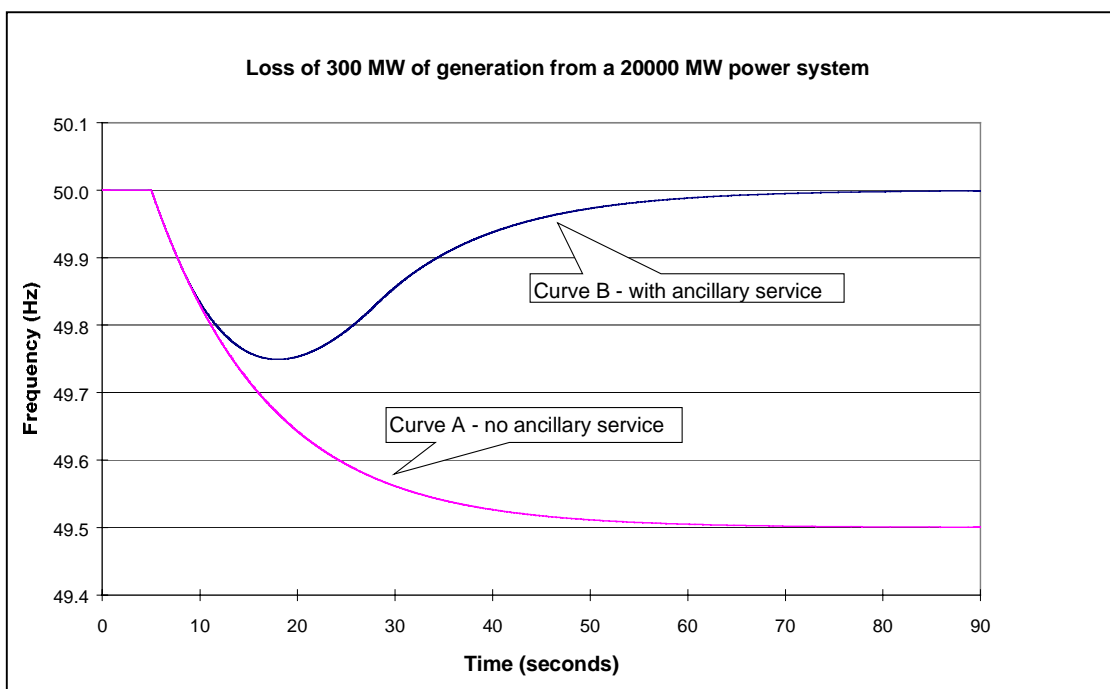
<b>Term</b>	<b>Meaning</b>
<i>abnormal frequency island</i>	means a part of the <i>power system</i> that includes <i>generation, networks</i> and <i>load</i> for which all of its alternating current <i>network</i> connections with other parts of the <i>power system</i> have been disconnected, provided that the part does not include more than half of the <i>generation</i> of each of two <i>regions</i> (determined by <i>available capacity</i> before disconnection).
<i>accumulated time error</i>	means, in respect of a measurement of <i>system frequency</i> that NEMMCO uses for controlling <i>system frequency</i> , the integral over time of the difference between 20 milliseconds and the inverse of that <i>system frequency</i> , starting from a time <i>published</i> by NEMMCO.
<i>available capacity</i>	has the meaning given to it in the National Electricity Code.
<i>connection point</i>	has the meaning given to it in the National Electricity Code.
<i>contingency event</i>	has the meaning given to it in the National Electricity Code.
<i>credible contingency event</i>	has the meaning given to it in the National Electricity Code.
<i>electrical island</i>	means a part of the <i>power system</i> that includes <i>generation, networks</i> and <i>load</i> , for which all of its <i>network</i> connections with other parts of the <i>power system</i> have been disconnected, provided that the part does not include more than half of the <i>generation</i> of each of two <i>regions</i> (determined by <i>available capacity</i> before disconnection).
<i>extreme frequency excursion tolerance limits</i>	has the meaning given to it in the National Electricity Code.
<i>frequency operating standards</i>	has the meaning given to it in the National Electricity Code and are the standards set out in Part B of this document.
<i>generating unit</i>	has the meaning given to it in the National Electricity Code.
<i>generation</i>	has the meaning given to it in the National Electricity Code.
<i>generation and load change band</i>	means the frequency range of 49.0 to 51.0 Hz in respect of an <i>island</i> and the frequency range of 49.5 to 50.5 Hz otherwise .
<i>generation event</i>	means a <i>synchronisation</i> of a <i>generating unit</i> of more than 50 MW or a <i>credible contingency event</i> in relation to a single <i>generating unit</i> , not arising from a <i>network event</i> , a <i>separation event</i> or a part of a <i>multiple contingency event</i> .
<i>island</i>	means either an <i>electrical island</i> or an <i>abnormal frequency island</i> .
<i>island separation band</i>	means: <ul style="list-style-type: none"> <li>(a) in respect of a part of the <i>power system</i> that is not an <i>island</i>, the <i>operational frequency tolerance band</i>;</li> <li>(b) in respect of an <i>island</i> that includes a part of the <i>power system</i> to which no notice under paragraph (c) applies, the <i>operational frequency tolerance band</i>; and</li> <li>(c) otherwise in respect of an <i>island</i>, the frequency band determined by the most restrictive of the high limits and low limits of frequency ranges outside the <i>operational frequency tolerance band</i> notified by <i>Jurisdictional Coordinators</i> to NEMMCO with adequate notice to apply to a nominated part of the <i>island</i> within their respective jurisdictions.</li> </ul>

<b>Term</b>	<b>Meaning</b>
<i>Jurisdictional Coordinator</i>	has the meaning given to it in the National Electricity Code.
<i>load</i>	has the meaning given to it in the National Electricity Code.
<i>load event</i>	means an identifiable connection or disconnection of more than 50 MW of customer load (whether at a <i>connection point</i> or otherwise), not arising from a <i>network event</i> , a <i>generation event</i> , a <i>separation event</i> or a part of a <i>multiple contingency event</i> .
<i>multiple contingency event</i>	means either a <i>contingency event</i> other than a <i>credible contingency event</i> , a sequence of <i>credible contingency events</i> within a period of 5 minutes, or a further <i>separation event</i> in an <i>island</i> .
<i>NEMMCO</i>	has the meaning given to it in the National Electricity Code.
<i>network</i>	has the meaning given to it in the National Electricity Code.
<i>network event</i>	means a <i>credible contingency event</i> other than a <i>generation event</i> , a <i>separation event</i> or a part of a <i>multiple contingency event</i> .
<i>normal operating frequency band</i>	has the meaning given to it in the National Electricity Code.
<i>normal operating frequency excursion band</i>	has the meaning given to it in the National Electricity Code.
<i>operational frequency tolerance band</i>	has the meaning given to it in the National Electricity Code.
<i>power system</i>	has the meaning given to it in the National Electricity Code.
<i>power system security and reliability standards</i>	has the meaning given to it in the National Electricity Code.
<i>publish</i>	has the meaning given to it in the National Electricity Code.
<i>region</i>	has the meaning given to it in the National Electricity Code.
<i>separation event</i>	means a <i>credible contingency event</i> in relation to a <i>transmission element</i> that forms an <i>island</i> .
<i>synchronisation</i>	has the meaning given to it in the National Electricity Code.
<i>system frequency</i>	means the frequency of a part of the <i>power system</i> , including the <i>frequency</i> of an <i>island</i> .
<i>transmission element</i>	has the meaning given to it in the National Electricity Code.

## ATTACHMENT 1

### MANAGEMENT OF POWER SYSTEM FREQUENCY

The frequency of an alternating current power system is essentially determined by the rotational speed of its generating units. If the amount of electrical load provided by the many consumers' loads is increased rapidly, the extra energy required by them is drawn from the rotors of the generating units and they therefore slow down, thus reducing system frequency. The consumer load and associated network losses inherently changes slightly with frequency, and if the generation is not changed, frequency will settle to a lower value where the load reduction due to frequency of the load exactly offsets the initial load increase. This is shown by curve A in the figure below. A similar result occurs for loss of generation, but a loss of load or an increase in generation will cause frequency to rise in a similar way.



Continuing with this example of a load increase, in order to restore the frequency to the nominal level of 50 Hz, the generation needs to increase by the same amount as the load initially increased. For large sudden changes, this generation increase needs to be fast initially to arrest the decline of frequency and then sustained to restore system frequency back towards its nominal value. For small and gradual changes, the corresponding generation change can be slower. In the market environment, these responses are provided as contingency and regulating ancillary services respectively. This is shown by curve B in the figure above.

For a very large change in system frequency, such as arising from a multiple contingency event, generating unit response alone may not be enough and may not be reliable. To avoid market failure that could lead to further frequency decline to the point where generating units cannot operate reliably, Customers (including retailers) are required under the Code to make 60% of their load available for shedding by under-frequency relays. The Code requires that this load shedding only be used if the frequency falls below 49 Hz.

## ATTACHMENT 2

### PRELIMINARY CONSIDERATIONS OF ECONOMIC DISPATCH OF REGULATING SERVICES

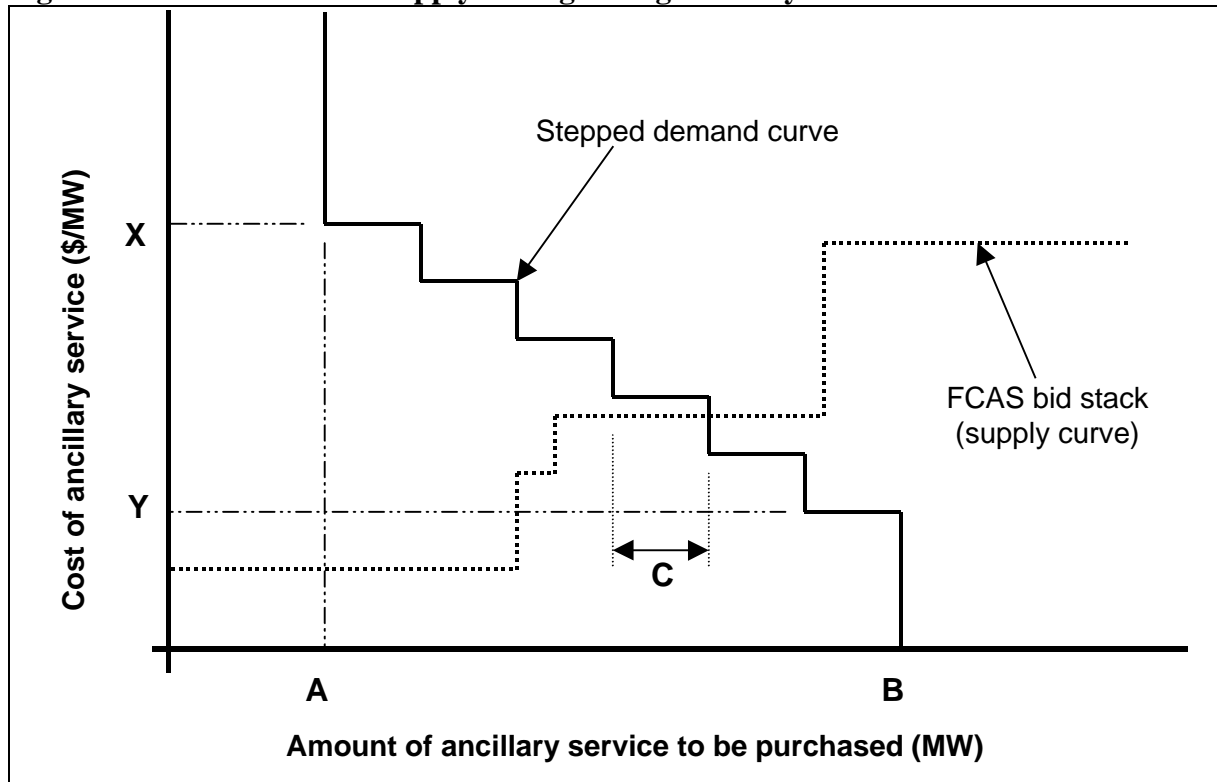
The concept of economic dispatch of regulating ancillary service is based on the following:

- (a) the Reliability Panel establishes a probabilistic approach for the normal band requiring NEMMCO, in the absence of specific events, to keep frequency within a “narrow performance band” for a certain percentage of time but always within a “wider performance band”;
- (b) NEMMCO establishes a “typical price band” within which it generally expects to be able to procure sufficient ancillary to maintain frequency (at least) within the wider performance band; and
- (c) the amount of regulating ancillary service dispatched for any interval will be based on both performance and price – regulating ancillary services will only be dispatched at a price above the upper end of the typical price band if necessary to keep frequency within the wider performance band.

The following issues would need to be resolved before such a concept could be implemented:

- (a) Dispatch algorithms would need to be modified to implement a stepped demand "curve" for regulating ancillary service as shown in Figure 1 in order to be solved by the linear programming algorithm used in NEMMCO's dispatch facility.

**Figure 1: Demand and supply for regulating ancillary service**



The intersection of the demand curve and the (shifting) FCAS bid stack would determine the amount of regulating ancillary service to be procured for each interval.

- (b) Processes would need to be established to calculate the parameters A, B, C, X and Y, where:
- A represents the minimum amount of regulating ancillary service to be dispatched to maintain the wider performance band;
  - B represents the level of regulating ancillary service beyond which increased dispatch creates a degree of frequency control that is not valued by the market;
  - C represents a consistent step size in the stepped demand curve; and
  - X and Y represent the upper and lower limits of the typical price band within which sufficient ancillary to maintain frequency (at least) within the wider performance band can generally be procured.
- (c) The processes established will need to be auditable, transparent and repeatable so that all parameters can be reviewed on a regular basis to take account of changes in market dynamics.

The changes outlined above would constitute an amendment of the existing dispatch algorithm, and NEMMCO would need to carry out a Code consultation process to seek endorsement from the market of specific calculation methods.

Whilst the concepts outlined are relatively straightforward, some work remains in establishing robust methodologies for the calculation of parameters A, B, C, X and Y:

Determination of amounts A and B require further refinement of NEMMCO's existing process for determining how much regulating ancillary service needs to be dispatched to keep the frequency within particular limits. NEMMCO may need to conduct tests to clarify the relationship between the amount of service and the performance it delivers.

Determination of prices X and Y represent some challenges in a market environment where offer prices can change daily and amounts of service corresponding to the prices can change at any time.

Determination of the size of step C is straightforward – to be consistent with other aspects of the dispatch process, the demand curve would have 10 'bands' and the size of C will be  $\frac{1}{10}$  of the difference between A and B.

At this time, NEMMCO considers that these changes are achievable and implementable.