SYSTEM OPERATOR

Common Quality Advisory Group

Instantaneous Reserve Monitoring Survey Results

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Contents

Executive Summary

This report summarises the Instantaneous Reserve (IR) monitoring technology and cost survey undertaken by the System Operator on behalf of the Common Quality Advisory Group (CQAG), and discusses the monitoring options available moving forward.

IR is important because it is fundamental to the System Operator avoiding cascade failure following an under frequency event. Without reliable IR, a contingent event could cause the tripping of AUFLS load or worse an Extended Contingent Event (ECE) could cause a total cascade failure of the power system.

Monitoring IR is important because it helps demonstrate that the System Operator is acting as a reasonable and prudent operator under the rules. Given the consequence of not having sufficient reserve, it is critical for a reasonable and prudent System Operator to monitor appropriately.

Five responses were received from the monitoring survey covering a wide array of monitoring technologies and costs. These responses were complemented by a special report from BECA covering another two lower cost options and the Grid Owners SCADA system.

There is little benefit in improving the monitoring requirements for all SIR providers (currently 10s or better) or for FIR Generation providers (currently 6s or better).

The System operator has to have confidence in FIR performance, especially IL. FIR IL providers require a further control to be added. A number of options are discussed as possible options for a way forward.

1) Leave things as they are now. Ensure responsibilities are clear and there is a culture of compliance. Liability for non-compliance should be set high to reflect the reward providers receive in the market and the potential costs to NZ if they do not comply (ie system collapse). Possibly look at the GO SCADA system in the future and investigate reserve margins during the proposed National reserve market project.
2) Go with a high quality monitoring system now at least for FIR IL providers. The total cost on the industry will be approximately 800k one off cost plus interrogation costs
3) Develop and install a purpose built low cost option. This is the lowest cost option that meets the requirements for FIR IL. There is little benefit in implementing a low cost option for SIR because SCADA can do this as well as the low cost options. One low cost option can provide a sampling rate of 300ms. This will require a detailed development study but it is likely that this could provide a viable solution with a total cost on industry of 500k. The best option to pursue with development work is estimated to cost in the order of 10k.
4) Introduce another control on FIR IL providers such as a requirement to submit an ACS and or repeat the initial capability tests every 2 years.

5) There are combinations of the options above such as providers having the option to either provide accurate monitoring (2 or 3) or to have more regular testing (4).
6) There could be some recognition for compliance costs for smaller IL providers and the relative risk they impose on the system.

The best solution may be a monitoring/testing standard that reflects the greater system risk for larger load blocks on a single relay. Smaller blocks of IL that would require multiple logging units could have less onerous monitoring/testing requirements.

1. Introduction

Background
At the 6 July meeting of the Common Quality Advisory Group (CQAG), the System Operator undertook to provide further information on Instantaneous Reserve (IR) monitoring technologies and costs to CQAG. This request was part of a wider review of IR monitoring generally, with a view to help determine future monitoring standards for New Zealand.

Purpose
The purpose of this report is to summarise the Instantaneous Reserve monitoring technologies and cost survey undertaken by the System Operator. This survey was undertaken to help assess the possible technologies and costs of IR monitoring systems.

Our aim of the survey was to determine the cost of "imposing" varied monitoring standards. For example if the cost of imposing a standard requiring a higher sampling rate compared to a 6s sampling is negligible, then it is reasonable to implement a higher standard without the need for a full cost benefit analysis. A full cost benefit analysis is more complex and will be undertaken if the cost of imposing the higher standard is "material".

The current standard (as per the Ancillary Services Procurement Plan) requires FIR monitoring at a sampling rate of 6s or better and 10s or better for SIR reserve. The CQAG will use this report as an input to considering the monitoring standards for future procurement plans. The future specifications will depend on the cost at each level and whether there is a material cost difference between them.

The structure of this report is as follows:
- Section 1: Introduction
- Section 2: Context of Instantaneous Reserve
- Section 3: Controls and RPO considerations
- Section 4: Instantaneous Reserve
- Section 5: Future Monitoring Requirements
- Section 6: Survey Response
- Section 7: Discussion
- Section 8: Conclusion

Survey Documents

The documentation used by the System Operator to receive information on technologies and costs, is provided in Appendix A. It consists of:
a) A short specification to provide a starting point to estimate IR monitoring costs
b) A standard form to provide information in a standardised format.

2. The Context of Instantaneous Reserve

The importance of Instantaneous Reserve to the System Operator arises out of the Principal Performance Obligations under the Electricity Governance Rules and Regulations. In particular, the System Operator has specific obligations relating to maintaining frequency within prescribed bands.

What is the Under Frequency PPO?

The System Operator under-frequency PPO requires under-frequency excursions to be limited to 47 Hz in the North Island and 45 Hz in the South Island. The system is managed so that the frequency will just reach these minimum limits under the most extreme "**Extended Contingent Event**" (ECE).

In addition to the minimum limits, the System Operator is required to limit the rate of occurrence of under-frequency excursions below other frequencies, as illustrated in Figure 2.1.

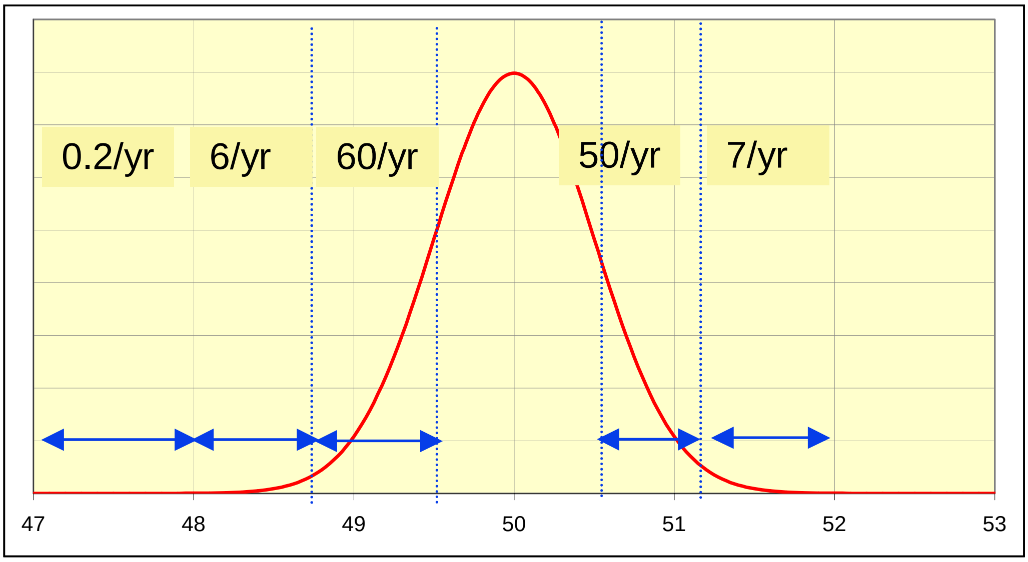

Figure 2.1: PPO limits on frequency excursions

To achieve a 1 in 5 year probability of frequency excursions below 48 Hz (0.2/yr in the graph above), the System Operator aims to limit frequency excursions to 48 Hz following single "**Contingent Events**" (CE). In terms of under-frequency management, a contingent event is normally the loss of a generation unit or a pole of the HVDC.

In NZ, large frequency drops are caused by losses in large generation stations or outages of the HVDC. They may also be caused by transmission circuit outages, which island part of the power system. The number of under frequency events where the frequency dropped below 49.25 Hz in 2002 and 2003 was 7 and 4 respectively. This is shown graphically in figure 2.2.

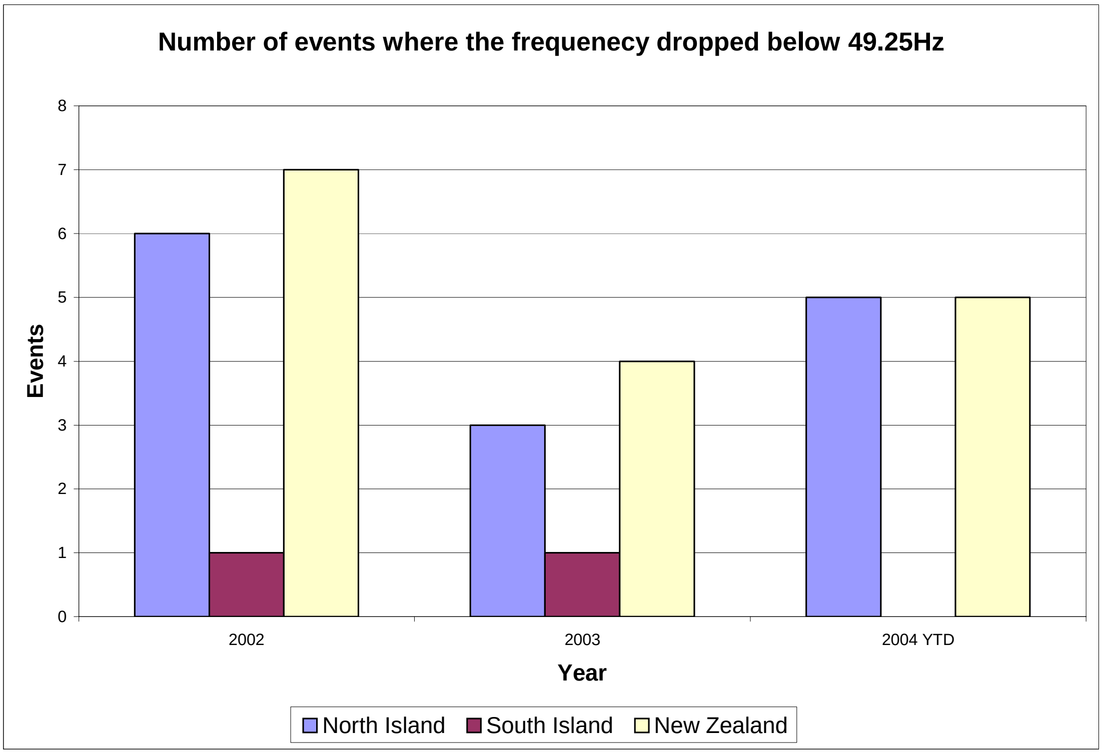

Figure 2.1: PPO limits on frequency excursions

How is the Under Frequency PPO Achieved?

The management of under frequency events in the New Zealand electricity system poses a significant challenge due to the considerable size of the generating units and HVDC Inter-Island link compared to the size of the system. Specifically, frequency excursions following a loss of generation or transmission are relatively large and rapid.

Under-frequency management is extremely important, as the consequence of poor management is cascade failure of the entire system. The under-frequency PPO is achieved through a combination of the following three building blocks:

- **Generator AOPOs**
  Generators are required to remain connected for specific periods at various frequencies down to 47 Hz (in the North Island). They are also required to maintain pre-event output following a frequency excursion; although there is virtually an automatic dispensation, with cost allocation, available for generators that are unable to meet this.

- **Automatic Under-Frequency Load Shedding (AUFLS) AOPOs**
  Distributors and the Grid Owner are required to have two 16% blocks of AUFLS load as a backstop to cover multiple or extended contingencies (such

as failure of both poles of the HVDC). Exemptions (in part or whole) are possible where it can be demonstrated that AUFLS costs are excessive.

- **Instantaneous Reserves (IR)**
  The System Operator procures additional IR via the EGR spot market according to the System Operator Policy Statement and Ancillary Services Procurement Plan as agreed by the industry annually. IR can be provided by generation as partly-loaded spinning reserve (PLSR) or tail water depressed reserve (TWD). In addition, demand can provide interruptible load (IL).

3. Controls and RPO considerations

Reasonable and Prudent Operator (RPO) Considerations
For each of the three building blocks in Section 2 above, there are controls in place to maintain confidence that the power system is being prudently managed in order to avoid cascade failure.

Generator AOPOs controls:
- There is a clear responsibility on Generators to submit an up to date ACS
- Generators will need to meet the requirements of the agreed Asset Test Plan.
- The System Operator models each significant generator and confirms stability and capability

Distributors and the Grid Owners AUFLS AOPOs controls:
- There is a clear responsibility to submit an up to date ACS.
- Distributors and Grid Owners will need to meet the requirements of the agreed Asset Test Plan. This requires an updated AUFLS profile every year[1].

Reserve Provider Controls:
- Generator reserve providers must meet the AOPO requirements above.
- Generator and IL providers must undertake initial tests confirming their ability to meet the required performance levels. Note there is no current requirement in the Asset Test Plan to repeat these tests.
- All reserve providers must provide the System Operator with their individual reserve responses following an under frequency event, upon request. The sampling rate is 10s of better for all SIR[2] providers and 6s or better for all FIR providers.

[1] There may be some benefit in all AUFLS relays being installed in the Grid Owner substations. This is because relay management becomes a lot simpler and the AUFLS load can be SCADA summated which could allow for real-time reserve optimisation. The disadvantage is that AUFLS load selection is a lot coarser and may disadvantage some connected parties.
[2] Section 4 provides a definition of SIR and FIR.

4. Instantaneous Reserve Specification

All reserve quantities are assessed against a standard under-frequency curve
There are two classes of reserve as per the table below;

Reserve Type	**Use**	**Measured**	**Monitoring (Procurement Plan)**
Fast Instantaneous Reserve (FIR)	To arrest the frequency decay	*Generation* • 6 seconds after the event *Interruptible Load* • 1 second after the frequency falls to 49.2 Hz.[3]	Sampling rate of 6 seconds or better
Sustained Instantaneous Reserve (SIR)	Return the frequency above 49.25 Hz within 1 minute and then sustain for at least another 14 minutes	Average increase in reserve over the first minute	Sampling rate of 10 seconds or better

There are currently in the order of 50 IL sites that need to be monitored. Of these, about 20 have contracts (ASPCs) allowing them to offer into the FIR market. In terms of generation sites, we need to monitor outputs either at a unit or summated level. Assuming all generation stations are summated at a station level, the number of sites to be monitored is 32, of which the vast majority have contracts to offer in both the SIR and FIR markets.

[3] The difference between generation and IL measurements is because the generation response is continuous while the IL response tends to be discrete. Waiting up to 6 seconds for IL to respond is not prudent because the frequency can fall to unacceptable levels in 6 seconds

5. Future Monitoring Requirements

As discussed in section 3 above, monitoring of reserve providers is one of three controls to check Reserve providers. There are four types of reserve providers to be monitored or be considered for future monitoring.

- SIR IL and
- SIR Generation reserves[4].
- FIR Generation reserves
- FIR IL

The extent to which of these need monitoring, and the sampling rates required are discussed below:

SIR Monitoring – both generation and IL

Neither type of SIR needs to be sampled more frequently than the current requirement. A standard of around 6-10s for SIR is sensible, and there is no justification for imposing a tighter standard than the current 10s monitoring standard. It seems reasonable to require providers to synchronise there SIR actual response against the start of the under frequency event. Because of the low sampling rate, the synchronisation only needs to be accurate to about 5s.

FIR Generation monitoring

Our main concern with monitoring FIR providers is that there is no record of whether IR providers responded in the time required by the specification. Generation has significant controls and a monitoring level of 4-6s (in line with the GO SCADA specification seems appropriate). Again it seems reasonable to require providers to synchronise their FIR generation actual response against the start of the under frequency event

FIR IL monitoring (and Hybrid generation – see footnote below)

There are two major differences between generation and IL reserves;

- There are fewer controls on IL reserve than generation reserve because generators must meet AOPOS requirements and provide ACSs.
- IL response tends to be discrete whereas generation response is continuous. We need confidence that IL will respond quickly after an event because the frequency can fall to unacceptable levels in 6 seconds

For these two reasons, there is merit in implementing a further control on this type or reserve. The question we need to consider is what is the net benefit in adding an another control, such as tighter monitoring requirements, on FIR IL?

At this point, it is worth considering the quantity of FIR IR cleared in Market. Figure 5.1 shows the average quantity of reserve procured for each trading period over 26 months. The following points can be made:

- SIR requirements are greater than FIR due to RMT modelling assumptions
- The total amount of FIR required is almost constant at 200 MW.

[4] There is also Hybrid type providers that change governor settings as a result of a relay action. TWD providers are a type of this class. These are included in the generation reserve numbers discussed in section 4 of this report. Because these act discretely at a set frequency, these providers should have the same monitoring requirements as IL. The total number of Hybrid type stations offering in the FIR IL market is in the order of 12.

- The total amount of FIR IL is about 30% of the FIR market. This gives some relative weighting on the monitoring requirement of FIR IL.

It is difficult to identify the actual cost to New Zealand of having inaccurate monitoring of FIR IL reserve. There is no explicit margin added to RMT to account for this uncertainty. However, from historical events, we know that at times we have had more reserve than required due to a number of possible sources such as HVDC reserve sharing functionality. The proposed *National Reserve Market* project may be a good time to fully investigate all sources of reserve inaccuracy.

Although FIR IL reserve only represents about 30% of the FIR market, when a severe event occurs, it is clearly important that the majority of the reserve will respond.

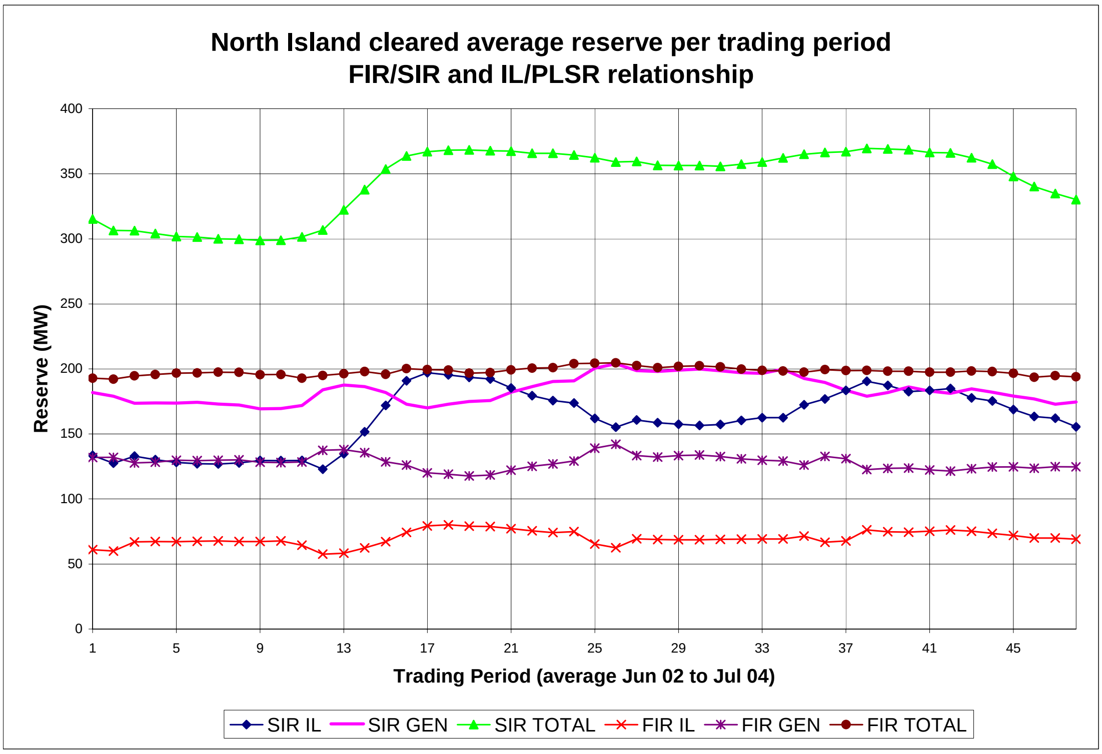

Figure 5.1: Reserve cleared per Trading Period

6. Responses

The System Operator received five responses to its specification (see Appendix A). These are summarised in Table 6.1. The completion of a special report was commissioned from BECA covering another two lower cost options. These options along with the Grid Owners SCADA system has also been added to the table for comparison. In aggregate terms the responses can be divided into four types of different solution proposed.

Power Quality Meters (options a and b)
Power Quality meters are specifically designed for power quality analysis. These typically detect a transient disturbance within 130 microseconds and time stamp each record to an accuracy of 1ms. Fast and secure access to the data can be made via Internet communications to a central server. Typical recording resolution is from 20ms for 65s to 4s for 16minutes. The Australian market uses a Power Quality meter to monitor reserve providers.

Transient Disturbance recorders (options c and d)
These are at the high end of monitoring and recording equipment. They are designed to be able to record time-stamped transient waveforms for fault analysis. Typical recording resolution is from 50 microseconds for 30s to 2s for 30minutes.

Low Cost Options / Panel Indicating Meters (options e, f and g)
A low cost option was proposed by a NZ company based on a data logging based proposal that could be promising but requires some further development (option e).

The completion of a special report was commissioned from BECA covering two lower cost options. These options are at the lower end of monitoring and recording equipment. They have limitations with time accuracy, which could be overcome by recording the frequency trace as well.

A high level summary of the BECA report is as follows:
BECA carried out a search for equipment that was low cost and able to meet the draft criteria for measurement of reserve quantities. The low cost criteria was set at equipment with a capital cost of less than $8k and preferably less than $5k. The search was carried out by contacting likely suppliers of this type of equipment using their knowledge of local and international equipment suppliers. Searches were also carried out via the Internet for new suppliers.

Three options were investigated in further detail. The first option was discounted mainly because it required an additional pulsing meter to provide pulses to a remote meter reading device. The cost of this additional pulsing meter (with high resolution) was expected to rule this option out.

Two future options, both costing approximately $2000 were investigated further. One is a datalogger, which can store up to 100,000 readings but only at a fixed sampling rate of 3s (barely faster than the current monitoring requirement). The final option, a multifunctional power meter, can sample at a 300ms rate and appears a reasonable alternative for FIR monitoring. Both the future options do not have accurate time synchronisation facilities. It will be best to also monitor frequency and use this to calibrate an event across the system – noting that the system frequency is close to constant within an island.

Grid Owner SCADA
Currently the SCADA typically polls the RTUs at a rate of between 4 and 6s. In a few sites there are communication bottlenecks that limit the polling rate to 10s. Increasing the current base polling rate to 2s was discussed briefly with the Grid Owner. The current communication capacity of the system can not handle the increased data

transfer. It is also a major additional requirement on the SCADA system over and above what its primary purpose is.

The Grid Owner is proposing, in the long term, to move to new “generation” RTUs with greater on site storage capability of important information. This will allow substantially faster interrogation rates.

Costs Summary

The following table summarises the costs of the various options (all figures in $k)

	Power Quality Meters		Transient Disturbance Recorders		Low cost options			SCADA
Model	a	b	c	d	e	f	g	h
Cost per unit	11	11	16	29	1-2 (+5k)	2	2	0
Installation	10	10	10	10	10	10	10	0
Central Server	3	3	3	3	3	3	3	0
GPS unit cost	No GPS, need a 2nd channel for frequency							SCADA time stamp
Cost per Site	24	24	29	42	15	15	15	0
Cost: 20 FIR IL only	480	480	580	840	300	300	300	0
Cost: 32 FIR and Hybrid sites	770	770	930	1340	480	480	480	0
Cost: All 80 total sites	1920	1920	2320	3360	1200	1200	1200	
Sample rate	20ms/ 4s	50 ms	20ms/ 5s	10ms +	1s	3s	300ms	
Duration at sampling rate (one channel)	65s/16 min	15 min	10s/40 min	1min	30s	continuous 4 days of history	30min	4-6s continuous

Assumptions

- *Existing CV and VTs are available*
- *Installation cost includes design, drawings, installation costs, no cabinet included, no meter certification required. These estimated costs are significant and tend to make the option costs similar.*
- *Central server cost per provider. Total cost of 15k but divided by 5 to get a cost per site. This assumes a provider on average has 5 stations / GXPs to monitor.*
- *GPS cost per unit is estimated as 10k, which is significant. It will be easier to record the frequency trace as well as the reserve quantity. The frequency trace can be used to calibrate the response against time (as long as islanding hasn’t occurred)*
- *The cost per event to download data is assumed to be low in all cases*
- *SCADA costs are marginal costs, noting that there are some download costs*

7. Discussion

SIR Monitoring – both generation and IL

As discussed earlier, the System Operator considers that a standard of around 6-10s is sensible, and there is no justification for imposing a tighter standard than the current 10s monitoring standard.

FIR Monitoring – both generation and IL

Our main concern with the current monitoring of FIR providers is that there is no record of whether IR providers responded in the time required by the specification.

FIR Generation

Generation has significant controls and a monitoring level of 4-6s (in line with the GO SCADA specification seems appropriate). It seems reasonable to require providers to synchronise their FIR generation actual response against the start of the under frequency event

FIR IL monitoring (and Hybrid generation)

There are a number of options that can do better than our current monitoring standard of 6s or better for IL reserve. In all these cases it is assumed that the frequency trace will be monitored as well because this will remove the need for a relatively expensive GPS clock.

A reasonable monitoring requirement for FIR IL sites is perhaps 1s sampling for 30-60s. Although ultimately it comes down to the extra confidence we gain from adding the control. The following options are possible ways forward.

1) Leave things as they are now. Ensure responsibilities are clear and there is a culture of compliance. Liability for non-compliance should be set high to reflect the reward providers receive in the market and the potential costs to NZ if they do not comply (ie system collapse). Possibly look at the GO SCADA system in the future and investigate and adjust reserve margins during the proposed National reserve market project.
2) Go with a high quality monitoring system now at least for IL providers. The total cost on the industry will be approximately 800k one off cost plus interrogation costs. This assumes that all FIR IL (and Hybrid generators) providers are required to install monitoring systems.
3) Develop and install a purpose built low cost option. This is the lowest cost option (other than SCADA). There is probably no benefit in implementing a low cost option for SIR because SCADA can do this as well as the low cost options. One low cost option can provide a sampling rate of 300ms. This will require a detailed development study but it is likely that this could provide a viable solution with a total cost on industry of 500k. The best option to pursue with development work is option g, which is estimated to cost in the order of 10-15k.
4) Introduce another control on FIR IL providers such as a requirement to submit an ACS and or repeat the initial capability tests every 2 years.
5) There are combinations of the options above such as providers having the option to either provide accurate monitoring (2 or 3) or to have more regular testing (4).
6) There could be some recognition for compliance costs for smaller IL providers and the relative risk they impose on the system.

8. Conclusions

Five responses were received from the monitoring survey covering a wide array of monitoring technologies and costs. These responses were complemented by a special report from BECA covering another two lower cost options and the Grid Owners SCADA system.

There is no benefit in improving the monitoring requirements for all SIR providers (currently 10s or better) or for SIR IL providers (currently 6s or better).

The System operator has to have confidence in FIR performance, especially IL. FIR IL providers require a further control to be added. A number of options are discussed as possible options for a way forward. The total cost of implementing a 1s monitoring standard on FIR IL (and Hybrid generators) is between 500k and 800k for low cost and higher cost options respectively.

The best solution may be a monitoring/testing standard that reflects the greater system risk for larger load blocks on a single relay. Smaller blocks of IL that would require multiple logging units could have less onerous monitoring/testing requirements.

Appendix A

A1: Specification for Monitoring Instantaneous Reserve

Background

Monitoring of IR is required by the NZ Electricity Industry to:

- Ensure providers are meeting their obligations (compliance)
- Enable the System Operator to optimise the reserve being procured by improved calibration of the RMT tool
- Reduce the overall uncertainty of frequency management
- Enable future optimisations of the reserve market. A national reserve market will require a tighter control on dispatched reserve.

Providers of Reserve

Reserve providers include generators, distributors and retailers:

- Generators provide partly loaded spinning reserve (PLSR) and Tail Water Depressed reserve (TWD). The reserve is offered by unit or by station.
- Distributors and retailers provide interruptible load and this is always offered at a GXP.

Channels to be monitored

Generators:

- The output of the generation providing reserve measured at the generator terminals (this needs to be provided on a unit basis in all cases and also summed if the reserve is delivered at a station or block-basis).
- The data must be time-stamped using a GPS clock

Load:

- The load at a GXP or at a lower level if it is required to adequately isolate and measure the IL response
- The data must be time-stamped using a GPS clock

Data Storage and transfer

For SIR, the channels must be stored for a period from 6s before and 15min after an event that causes frequency to fall to or below 49.25Hz (under frequency event). For FIR, the channels must be stored for a period from 6s before and 1min after an event that causes frequency to fall to or below 49.25Hz. The data files need to be downloaded electronically and forwarded to the System Operator following each under frequency event upon request. This is expected to be less frequently than once per month. Records must be made digitally and stored in a computer file format suitable for analysis using commercial spreadsheet software.

Accuracy

Overall accuracy of the measurement system (including CT, VT, and metering) is to be 2% or better. Data needs to be provided to 0.5MW or 1% resolution (whichever is the lower). The measurements must have a settling time of less than 250ms (to 99% of final value after a step change from zero)

Sampling Rate

The fastest required sampling rate envisaged is 250 ms, being for FIR Interruptible Load. It is envisaged that FIR generation and SIR will be sampled at 1 second and 6 seconds respectively. However the final specifications will depend on the cost at each level and whether there is a material cost difference between them.

If there is a material cost difference in providing a slower sampling rate then this will be considered as required.

Inertia
The Generation reserve measured will be distorted by the inertial response of the generator. The System Operator will compensate for this effect when assessing reserve response compliance.

A2: Standard Form: Instantaneous Reserve Monitoring Costs

Please use the following table to provide cost estimates.

A) Base Costs – Current Procurement Plan requirements

	Types of	Monitoring timeframe	Sampling Rate	Cost Estimate – per unit but based on 20 units			
				Material (per unit)	Installation (per unit)	Download (per unit)	On going Maint. (per unit)
FIR Monitoring	"interruptible load" - monitoring at GXP level or finer if required	(-6 to 60s)	6s (12 samples)				
	Partly loaded spinning reserve or "Tail Water Depressed"		6s (12 samples)				
SIR Monitoring	"interruptible load" - monitoring at GXP level or finer if required	(-6 to 15min)	10s (92 samples)				
	Partly loaded spinning reserve or "Tail Water Depressed"		10s (92 samples)				

B) Possible/Maximum Procurement Plan requirements

	Types of	Monitoring timeframe	Sampling Rate	Cost Estimate – per unit but based on 20 units			
				Material (per unit)	Installation (per unit)	Download (per unit)	On going Maint. (per unit)
FIR Monitoring	"interruptable load" - monitoring at GXP level or finer if required	(-6 to 60s)	250ms (242 samples)				
	Partly loaded spinning reserve or "Tail Water Depressed"		1s (62 samples)				
SIR Monitoring	"interruptable load" - monitoring at GXP level or finer if required	(-6 to 15min)	6s (152 samples)				
	Partly loaded spinning reserve or "Tail Water Depressed"		6s (152 samples)				

C) Alternative proposed requirements

	Types of	Monitoring timeframe	Sampling Rate	Cost Estimate – per unit but based on 20 units			
				Material (per unit)	Installation (per unit)	Download (per unit)	On going Maint. (per unit)
FIR Monitoring	"interruptable load" - monitoring at GXP level or finer if required						
	Partly loaded spinning reserve or "Tail Water Depressed"						
SIR Monitoring	"interruptable load" - monitoring at GXP level or finer if required						
	Partly loaded spinning reserve or "Tail Water Depressed"						

Please attach any supporting information.