



South Island Under Frequency Event 1 August 2009

System Operator
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1. Introduction and Purpose

On the 1st August at 04:30:52 the HVDC link between the North and South Islands tripped with a loss of 270 MW of power to the South Island. This resulted in a low frequency of 47.72 Hz in the South Island followed by a high frequency of 52.05 Hz.

The event is considered significant because:

- The frequency fell below that planned for or expected for a contingent event (the standard under frequency curve), that
- The frequency fell to within 0.2 Hz of activating AUFLS and
- The frequency rose to above 52 Hz were we expect some types of generation to automatically disconnect.

The intention of this report is to inform interested parties as to the nature of the event and the findings from subsequent investigation. It seeks to ask and answer a number of questions that participants may have in relation to the event It proposes a number of options around mitigating some of the issues raised.

It should be noted however that the report is not intended to be a full description of all of the technical issues investigated or identified. Much of the technical language has been simplified to make this report more accessible to a wider audience. It is also not intended to identify or assess individual generator compliance.

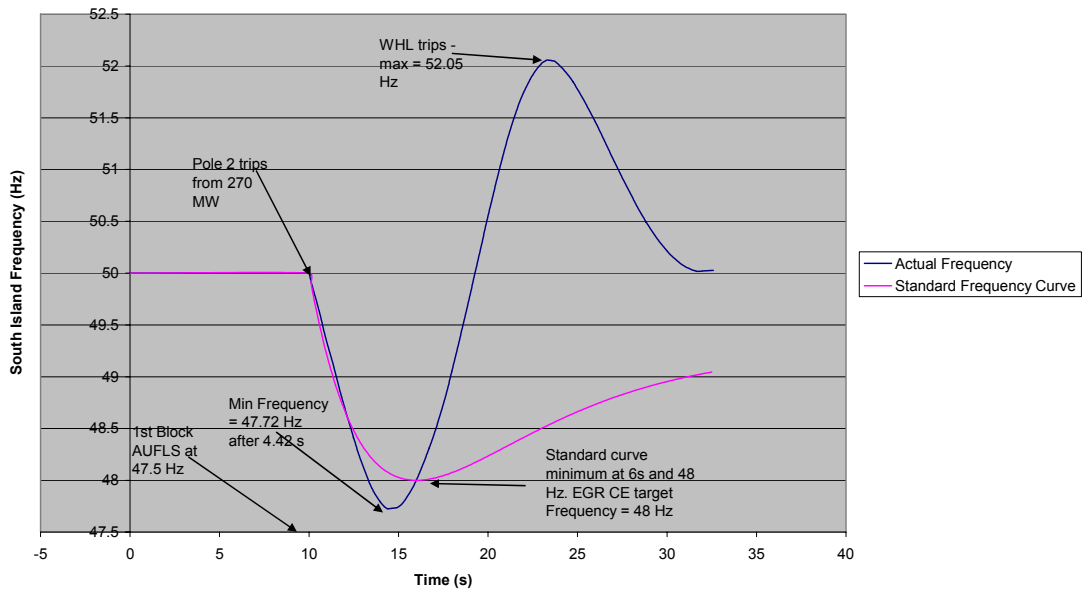
2. Event overview

At 04:14 on 1 August 2009 the System Operator instructed the Grid Owner to select HVDC Pole 2 to reduced voltage mode to correct high voltages in the Upper South Island.

While switching was occurring, in order to comply with this instruction one Pole 2 filter automatically switched out while the other filter was being manually switched. The resulting lack of filtering caused an immediate trip of Pole 2.

The tripping of Pole 2 was a loss of 270 MW of power injection into the South Island as a result the frequency fell to 47.72Hz followed by a high frequency of 52.05 Hz. The low frequency was below that planned for a contingent event and was within 0.2 Hz of activating AUFLS as highlighted in diagram 1 below.

Frequency Curve for DC tripping 1/8/09 04:30:52



3. Investigation

The System Operator has and continues to undertake a thorough investigation into this event, with the intent of understanding **why the frequency in the South Island fell below 48 Hz** and why it rose above 52 Hz.

In this regard the following issues have been considered and are discussed in this report:

- RMT performance. Did the Reserve Management Tool (RMT) perform as expected?
- Generator performance. Was the response from generation plant as expected when compared to test data and the actual frequency?
- Models. Were the models used by the System Operator sufficiently accurate?

While the primary focus of the investigation has been to understand and secure the system from similar events having the same or worse consequences, there is also a requirement to investigate from a compliance perspective.

4. Investigation outcomes

4.1. Reserve management tool (RMT)

RMT is a tool used by the System Operator to calculate ex-ante the effect on the frequency of the loss of the largest generator or the HVDC. It is then able to determine how many MW of fast reserve (FIR) are required to arrest the decline in frequency for every MW of risk.

To do this RMT uses:

- Offer data submitted by generators,
- Schedule data from PDS/SDS schedules.
- Models created by the System Operator based on Asset Capability Statement (ACS) data submitted by generators and test data collected by the System Operator.

As a mathematical solver RMT will iterate toward a solution with a **target minimum frequency** of 48 Hz for a contingent event. Given the other more significant variables and the additional time to reach a perfect solution it is not considered a requirement for RMT to solve to exactly 48Hz. The solution used in dispatch for this event had solved for 48.09Hz. Therefore this factor could be discounted as contributing to the under-frequency issue.

RMT contains a **load model** which divides the load into load having inertia and load that does not. Load with inertia will assist in arresting the fall of frequency. Therefore there is an inherent risk that if the load with inertia is overestimated reserves can be under procured. In this event the load with inertia was underestimated, therefore this too could be discounted as contributing to the event.

RMT assumes the **loss to be instantaneous**. In this case the loss was over approximately 0.03 seconds, which is near instantaneous. Therefore this factor could be discounted as contributing to the under-frequency issue.

There is a block of generation modelled in RMT as ungoverned to represent non dispatched **embedded generation**. This is modelled as tripping at 47.95 Hz. In accordance with the SCADA data none of this generation tripped. Therefore this factor could be discounted as contributing to the under-frequency issue.

AVI and ROX 220 TWD was not being translated correctly into the RMT file. The values were not coming through so RMT only saw PLSR dispatched to this station. The effect of this was to reduce the frequency modelled from 48.09 Hz to 48.01 Hz.

The cause of the fault was found to be a missing data flag and this was rectified with an update to the system on the 12th August.

The System Operator is currently investigating this from a **compliance** perspective.

4.2. The under frequency event

4.2.1. Division of the causes of the low frequency

The System Operator has identified a number of interrelated issues which cumulatively resulted in the frequency dropping to 47.72 Hz. These are discussed further in the preceding sections however the best way of illustrating the effects of the problems identified is by using RMT to calculate their effect on the target frequency. The results are in the table and graph below.

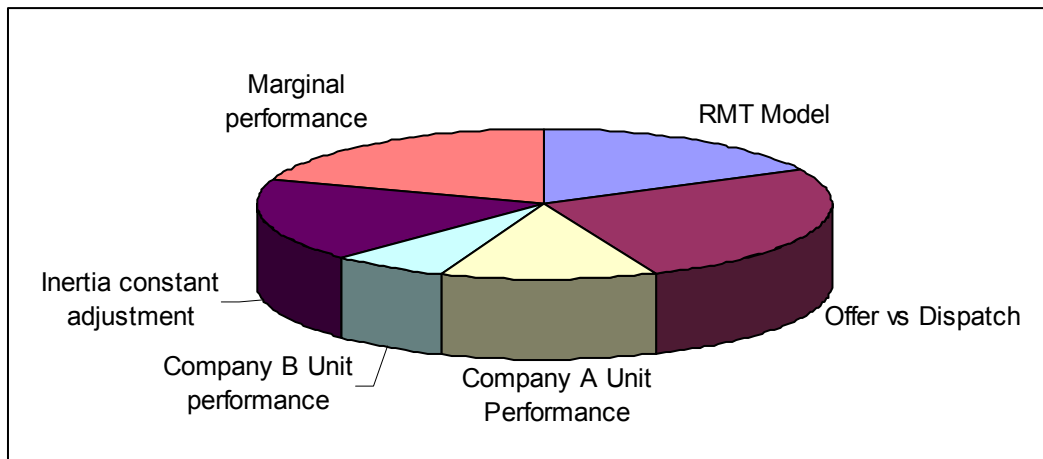
Cause	Change in frequency (Hz)
Original	(48.09)
RMT model of AVI & ROX	-0.08
Offer Vs Dispatch issues	-0.120
Company A unit performance	-0.056
Company B unit performance	-0.030
Inertia constant adjustment	-0.082
Marginal performance	-0.090
Total	0.378

Note: - 1) The trip occurred when frequency was 50.1 Hz.

2) No allowance has been included for modelling inaccuracies or inherent mechanical delays which may have been masked by the data sampling.

Graph 1 showing proportions of the cause of the frequency under performance

The graph is representative only. Data accuracy prevents these figures being anything else.



4 2 2. Offer vs Dispatch

There are a number of disjoints between testing and dispatch that create the opportunity for issues to arise. This comes down to some activities needing to happen at a unit level, some at a station level and some at the block level. These different activities are discussed below.

Notable in this event was that there was in reality less reserve provided by TWD than RMT calculated using the offer data, which means there were fewer units connected to the system with the result that the **system inertia was less than RMT scheduled**.

Reserves are an ancillary service, Providers must be tested and approved before they can provide that service. **Testing** is done on a product and type basis by unit i.e. FIR/SIR by TWD/PLSR for each generating unit.

Generators **offer** reserve as either:

- FIR-TWD (Fast Instantaneous Tail Water Depressed)
- FIR-PLSR (Fast Instantaneous Partially loaded Spinning Reserve)
- SIR-TWD (Sustained Instantaneous Tail Water Depressed)
- SIR-PLSR (Sustained Instantaneous Partially loaded Spinning Reserve)

The TWD and PLSR information is only used so that RMT can calculate the amount of inertia on the system.

Instantaneous reserves are **dispatched** to generators as either FIR (fast) or SIR (sustained). Dispatch instructions are issued at a block level, however how generators distribute the reserves amongst the stations in a block is up to them so long as the units it is provided from are approved through testing.

Compliance from a dispatch instruction perspective is measured at a block level by comparing the response of the block dispatch group to the dispatch value and considering the nature and extent of the event.

There are a number of options that could be used to address the issues arising from these disjoints including:

- Removing reserves from block dispatch
- Increasing the under frequency target,
- Dispatching a PLSR/TWD ratio,
- Extending the AGC implementation to include reserves,
- A mix of the above.

All of these mitigations can have real costs to the efficiency of generators or to the reserve market so they need careful consideration by the industry to ensure the effectiveness and costs of the options are understood.

4 2 3. Generator performance

In looking at the performance of individual machines and their response to the event we must examine how the machine performed in testing and how the machine performed for the actual event.

Quality of data

The biggest issue in investigating this event has been the quality of the data available to the System Operator. The issue of data has been in the industry for some time and there was a proposal in the Procurement Plan to improve data quality. This was looked at by the Common Quality Advisory Group (CQAG) and it was found that there was no economic justification to improve the current situation.

Quality in this regard has 3 components:

- Accuracy (how good)
- Sample rate (how many measurement per sec)
- Time stamping (knowing very accurately when each value was measured)

The System Operator receives 4 sec data via Transpower's SCADA system, however this provides very low quality when used to evaluate events that last 6 seconds.

Meridian and Contact Energy both provided data with a higher sample rate however the time stamping created a margin of error.

Meridian had sites with Ion meters which provided high quality in all aspects.

Unit response

A number of issues were identified with units providing reserves from **TWD** where reserve response was slower than expected. The System Operator has been working with the generators to understand why units performed in such a way and making changes where necessary. Where there is concern regarding performance, units have been either withdrawn from the market by the owner or other appropriate mitigations have been put in place to work around the potential for under performance.

Any **contract compliance** issues are being worked through between the System Operator and the generator concerned.

Generators are required to submit to the System Operator certain technical information in the ACS. It is vital that this information is accurate specifically regarding the **governor response**. The System Operator is reviewing ACS data against event data and test data to ensure it is accurate.

The System Operator has two sets of information regarding **inertia constants** that which is derived from tests and that which is submitted with the ACS. RMT currently uses test data which is more optimistic than the ACS data. This is being reviewed.

The investigation has focussed on performance of Fast Instantaneous reserves (FIR) as the event was effectively over before we would expect to see any Sustained Instantaneous reserve (SIR). However at two sites issues with **station control systems** arose that lead us to conclude that the provision of SIR from these sites may not have been possible. Changes to these systems are underway and **contract compliance** issues are being worked through between the System Operator and the generators concerned.

4.3. The high frequency event

In the South Island the frequency rose above 50 Hz to a maximum of 52.05 Hz. (One generator tripped at 52 Hz as expected.)

4 3 1. Reserve quantity

The purpose of FIR is to arrest the fall of the frequency at or above 48 Hz. TWD takes some time to react to a falling frequency therefore is applied at a time when the frequency has already fallen quite some way (~1Hz). The further the frequency falls before FIR is applied the more FIR is required to arrest the fall.

In this event a large amount of the scheduled reserve was being supplied by TWD and therefore approximately 400MW of FIR reserve was needed to manage the 270 MW risk.

It is inherent in these circumstances that the frequency will rise above 50 Hz.

4 3 2. Control Systems

TWD machines revert to generate at a predetermined frequency. Many have a 'Feed Forward' control system that increases the machines output at a high rate of change until the frequency has recovered to just below 50Hz. At this point they revert to governor control.

On governor control the increase in output of the machine in response to an under frequency event is proportional to the degree of under frequency. With a large number of machines coming off TWD, the ability of governor control to stop the rising frequency prior to it exceeding 50 Hz was simply not sufficient and they simply over reached. This situation was likely exacerbated by the slow TWD response.

It is possible to use over frequency arming to manage this type of event however this requires caution as so as not to set up another under frequency oscillation especially where AUFLS activation could be involved.

5. Testing

Prior to a generator providing an ancillary service the System Operator will carry out tests with that generator to determine their capability.

For the provision of FIR/SIR via TWD this testing traditionally has involved the injection of the standard under frequency curve into the TWD control relay.

This investigation has highlighted latencies in associated systems that are not currently tested and that would warrant the use of other, sometimes more invasive tests which would be more 'end-to-end' in nature.

This can be done by:

- Carrying out a system test (bump test) where the power system frequency is reduced.
- Injecting the under frequency curve into the frequency measuring device.
- Placing high quality meters on units and observing their response to naturally occurring under frequency events.
- A mix of the above where high quality meters are placed on units but, if events do not naturally occur then subjecting units to tests.

In this way we are able to observe the complete reaction to under frequency events and then these effects can then be better accounted for in the models.

Where the System Operator has carried out tests there is usually an issue of repeatability where if a test is done several times on the same unit we tend to get different responses. Currently this effect is averaged out. This practice needs to be reviewed.

6. Q&A

Q1 Could this event happen again?

The most significant effect in this event was block dispatch issues, which remain unresolved, however there has been significant progress in resolving unit issues. In addition modelling issues have been identified and once these are resolved we would have a high degree of confidence that under these same circumstances a repeat of this event would not occur.

This however should not give false expectations, as there are still a number of outstanding variables that under different circumstances could produce a similar event including higher level of HVDC south transfer with similar proportions of TWD.

Q2 How can the identified issues with Block Dispatch be resolved?

There are a number of options that could be used to address the issues arising from block dispatch including:

- Removing reserves from block dispatch
- Increasing the under frequency target,
- Dispatching a PLSR/TWD ratio,
- A mix of the above.

All of these mitigations can have real costs to the efficiency of generators or to the reserve market so they need careful consideration by the industry to ensure the effectiveness and costs of the options are understood.

Q3 What would have happened had AUFLS been triggered?

It is natural to extrapolate the events of 1 August into a series of oscillations between high and low frequency that results in a loss of supply, there has not been sufficient work done to fully understand this scenario or answer the questions that arise. The System Operator has a work stream to investigate a broad range of issues to do with AUFLS and this need to be considered as part of that workstream.

In parallel to this the System Operator, is increasing (through investment and training) its ability to undertake dynamic studies and those looking at transient issues.

Q4 What does this event mean for the North Island?

Many of the issues covered in this report are equally valid for the North Island, including data quality, testing, block dispatch etc. The North Island system however is quite different in nature due to the different mix of generation, the presence of Interruptible Load reserve (IL) and free reserves.

IL has a positive effect in that a large quantity of reserve is made up of this type which activates very quickly. This can however also have a negative impact in that a resulting over frequency is quite common but not to the extent seen in the South Island on 1 August.

TWD reserve is less common in the North Island and historically is used during drier periods when there is usually a higher commitment of thermal plant. The large number of modern thermal units and wind farms in the North Island creates a risk in that we stand to lose larger quantities of generation for over frequency events.

The historic practice of accounting 'free reserves' in the North Island needs examination. While not fully investigated indications are that had this practice been used in the South Island the event may have been worse.

Q5 What work needs to be done ?

The System Operator intends to hold a series of workshops in November, and it will be using this event as a talking point to raise a number of issues with participants including:

- Investigations process
- Dispatch issues
- Data quality standards
- Testing
- Modelling
- Free reserve
- Controls on governor changes
- AUFLS

7. Appendix 1 Chronology of data quality discussion,

- 1 **2003** The issue of resolution and accuracy of data used in the monitoring of instantaneous reserve was discussed by the PPWG under the Grid Security Committee in 2003.

- 2 **2004** The System Operator acted on these discussions and proposed in the first EGR Procurement Plan a standard higher than what what some parties at the time provided (6 seconds was proposed instead of the 10 seconds) - The EC agreed and approved the move to 6seconds.

- 3 **2004** As part of the 2004 Procurement Plan the EC asked M-co as the Market Administrator to carry out a cost benefit analysis for reducing the monitoring time form 10seconds to 6 seconds. The benefits for changing the monitoring requirements to a higher quality (milliseconds) for fast instantaneous reserves and slow instantaneous reserves was seen as less urgent by the EC and was added to the future development work to be undertaken by the Common Quality Advisory Group

- 4 **2004** (June - August) CQAG requested the System Operator prepare several reports for the CQAG on IR monitoring. The System Operator also completed a technology survey (14Oct 04 - Ray Hardy) as there were concerns that increasing the monitoring resolution might come at a cost that resulted in IR providers withdrawing from the market.

- 5 **2005** The System Operator proposed in the drafting of the Procurement Plan a move to 1 second monitoring. Submissions from IR providers opposed the higher resolution of data arguing it would place additional costs on existing providers and create a barrier to entry for new providers. The EC agreed with submitters and rejected the proposed change and referred the issue back to the System Operator and CQAG for future consideration.

- 6 **2006 - 2007** The System Operator proposed in the Procurement Plan for IR service providers ,who had higher resolution data, should be obligated to supply this to the System Operator. The System Operators view was that the service providers should be willing to demonstrate their performance. The issue of IR providers having higher resolution data but not supplying it for compliance analysis was highlighted by a large provider of IR 'stripping' their 1 second data back to 6 second data as that was all that was required in the EGRs (basically creating a larger grey area) . The proposed change was rejected by the CQAG as it was felt it would disadvantage certain IR providers who had 1 second data recording.
The System Operator strongly disagreed with the CQAG reasoning for not progressing this change.