High spring washer price situation of 20 June 2013

Market performance enquiry

23 October 2013

Version control

Version	Date amended	Comments
1.0	17 October 2013	1st draft
2.0	23 October 2013	Incorporating legal comments

Investigation stages

An in-depth investigation will typically be the final step of a sequence of escalating investigation stages. The investigations are targeted at gathering sufficient information to decide whether a Code amendment or market facilitation measure should be considered.

Market Performance Enquiry (Stage I): At the first stage, routine monitoring results in the identification of circumstances that require follow-up. This stage may entail the design of low-cost ad hoc analysis, using existing data and resources, to better characterise and understand what has been observed. The Authority would not usually announce it is carrying out this work.

This stage may result in no further action being taken if the enquiry is unlikely to have any implications for the competitive, reliable and efficient operation of the electricity industry. In this case, the Authority publishes its enquiry only if the matter is likely to be of interest to industry participants.

Market Performance Review (Stage II): A second stage of investigation occurs if there is insufficient information available to understand the issue and it could be significant for the competitive, reliable or efficient operation of the electricity industry. Relatively informal requests for information are made to relevant service providers and industry participants. There is typically a period of iterative information-gathering and analysis. The Authority would usually publish the results of these reviews but would not announce it is undertaking this work unless a high level of stakeholder or media interest was evident.

Market Performance Formal Investigation (Stage III): The Authority may exercise statutory information-gathering powers under section 46 of the Electricity Industry Act 2010 to acquire the information it needs to fully investigate an issue. The Authority would generally announce early in the process that it is undertaking the investigation and indicate when it expects to complete the work. Draft reports will go to the Board of the Authority for publication approval.

The outcome of any of the three stages of investigation can be either a recommendation for a Code amendment, provision of information to a Code amendment process already underway, a brief report provided to industry as a market facilitation measure, or no further action.

From the point of view of participants, repeated information requests are generally concerned with Stage II; trying to understand the issue to such an extent that a decision can be made about materiality.

Executive summary

On 20 June 2013, during trading period 41 (20:00 – 20:30), the final spot electricity price at Lichfield (LFD1101 and LFD1102) and Kinleith (KIN1101) reached $8,318/MWh and $6,466/MWh respectively due to a binding transmission security constraint.[1] The system operator applied the high spring washer price resolution process, which marginally reduced prices in the region.

Carter Holt Harvey has generation and load at the Kinleith substation and requested the Authority consider the conditions and events in and around the central North Island that contributed to this high spring washer event. The Authority evaluated the issues raised in Carter Holt Harvey's request and considered some of these issues warranted further consideration as part of an enquiry.[2]

The Authority's analysis indicates that a number of contributing events resulted in the binding transmission security constraint and increased prices at Lichfield and Kinleith on 20 June 2013. These events included:

(a) a temporary grid reconfiguration that involved closing the Arapuni bus split from 28 May 2013 to 25 June 2013

(b) planned outages of the KIN_TRK2.1 and KIN_TRK2.2 circuits

(c) the HVDC link being unavailable during trading period 41 due to an unplanned outage starting in the previous trading period and continuing through into trading period 41

(d) the reduced availability of the Kinleith co-generator due to an unplanned outage of the co-generator in the previous trading period

(e) high North Island demand due to cold weather.

The Authority's analysis also indicates that the high spring washer process was correctly triggered and operated as designed. This process indicated that the high prices in the Tokoroa region were not sensitive to minor adjustments to the constraint limits. Furthermore, the transmission security constraints that bound in final prices also bound during real time reflecting the transmission constraints importing power into the Lichfield and Kinleith nodes.

One of the issues that Carter Holt Harvey raised was the process followed by Transpower when closing the Arapuni bus split on 28 May 2013 and the engagement of parties impacted by this reconfiguration. The Authority considered Transpower's application of the net benefit test to temporarily close the Arapuni bus split from 28 May 2013 to 25 June 2013. The Authority's analysis confirms that there was no generation benefit in keeping the split open from 26 May 2013 to 25 June 2013. This was due to reduced availability of Arapuni generation over that period as a result of a transformer outage at the power station. Closing the split increased security to Kinleith.[3] The

[1] This was after applying the high spring washer resolution process. The provisional prices at Lichfield and Kinleith (before the high spring washer resolution process) were $8,336/MWh and $6,479/MWh respectively.

[2] A copy of Carter Holt Harvey's letter and the Authority's response is available at http://www.ea.govt.nz/industry/monitoring/enquiries-reviews-investigations/2013/#highspringwasher

[3] Had the in-service Kinleith-Lichfield-Tarukenga circuit tripped during the adverse weather conditions on 20 June 2013, the supply to Kinleith and Lichfield would have been maintained under the reconfigured grid (with the Arapuni bus split closed). This might not have been the case had the Arapuni split been kept open under the same

Authority's analysis also indicates that while the closing of the Arapuni bus split was one of the contributing factors to the high spring washer prices in the Tokoroa region during trading period 41 on 20 June 2013, there were other contributing factors that were also necessary to produce the high prices, as indicated above. However, the Authority is concerned at the lack of engagement and notification of affected parties that Transpower was undertaking this net benefit assessment and that Transpower was closing the split. The Authority will further consider these issues as part of its review of Part 12 of the Electricity Industry Participation Code 2010 (Code).

The Authority considered the impact of the assumptions for the calculation of transmission circuit limits on the high spot prices. For spot prices to provide the correct economic trade-offs, some consideration should be given to how accurately the circuit limits used to determine the price signal reflects the actual limits during that time. The Authority estimates that had the limits of the transmission circuits involved in the binding security constraint been based on more reflective ambient temperatures during that time, there would have been at least a 20% increase in these limits. [4] This would have avoided the high spring washer price situation in the Tokoroa region with prices at Lichfield reducing to $441/MWh (from $8336/MWh) and prices at Kinleith reducing to $452/MWh (from $6479/MWh).

This experiment illustrates the sensitivity of spot prices to the assumptions used to determine the circuit ratings. The Authority considers that for the spot prices to provide the correct economic trade-offs between supply-side and demand-side alternatives, the assumptions used to determine the circuit ratings should be more representative of actual conditions. One approach to facilitate this accurate trade-off would be to enable the adjustment of constraint limits based on more reflective ambient conditions as part of the high spring washer price resolution process. This has the benefit of ensuring that spot prices more accurately reflect the constraints on the system particularly when the prices are sensitive to these constraints. However, this approach increases the divergence between forecast, real time and final prices and therefore should only be considered as an interim solution. Ideally a more dynamic rating of transmission circuits is needed in all schedules.

Transpower has indicated to the Authority that it is looking at extending its interim variable line rating project, which would adjust circuit ratings based on more historical conditions more reflective of the time of day and year. Transpower has also indicated that it will undertake a dynamic line rating trial this year, but this would not feed into the market system.

The Authority notes that Transpower gained substantial experience in the use and benefits of dynamic line rating from trials it undertook in the late 90s. It is concerning that Transpower has not made progress in deploying dynamic line rating methods in the intervening fifteen years, particularly given the substantial benefits to grid users, and the comprehensive deployment of the technology in other locations, such as Tasmania. The Authority would be interested to hear from Transpower what issues have prevented deployment being feasible.

Finally, the Authority considered whether there were any roadblocks in the Code currently preventing Transpower agreeing with designated transmission customers on

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conditions as it is uncertain whether the Arapuni generators supplying Kinleith would be able to successfully form an electrical island.

[4] Transpower provided the circuit rating calculator for its circuits.

adjusting the rating on circuits based on more representative conditions. This does not appear to be the case, and the Code appears to permit such a process subject to some conditions.[5]

[5] See clause 12.128 of the Code.

Contents

Tables

Figures

1 Introduction

1.1 On 20 June 2013, the provisional price for electricity in the wholesale spot market reached $8,336/MWh at Lichfield and $6,479/MWh at Kinleith during trading period 41.[6] These prices were the result of a binding transmission security constraint in the central North Island. The relevant transmission security constraint was developed to protect the Kinleith-Lichfield-Tarukenga 110kV circuit in the event of a trip of the Hamilton-Whakamaru 220kV circuit.

1.2 The price at Lichfield exceeded the highest unconstrained cleared offer price by a factor of greater than 5, resulting in the pricing manager issuing a notice of a high spring washer price situation. After the system operator applied the high spring washer resolution process, the price at Lichfield reduced marginally to $8,318/MWh. Figure 1 illustrates the price heat map for trading period 41 showing the concentration of the high prices in the Tokoroa region.

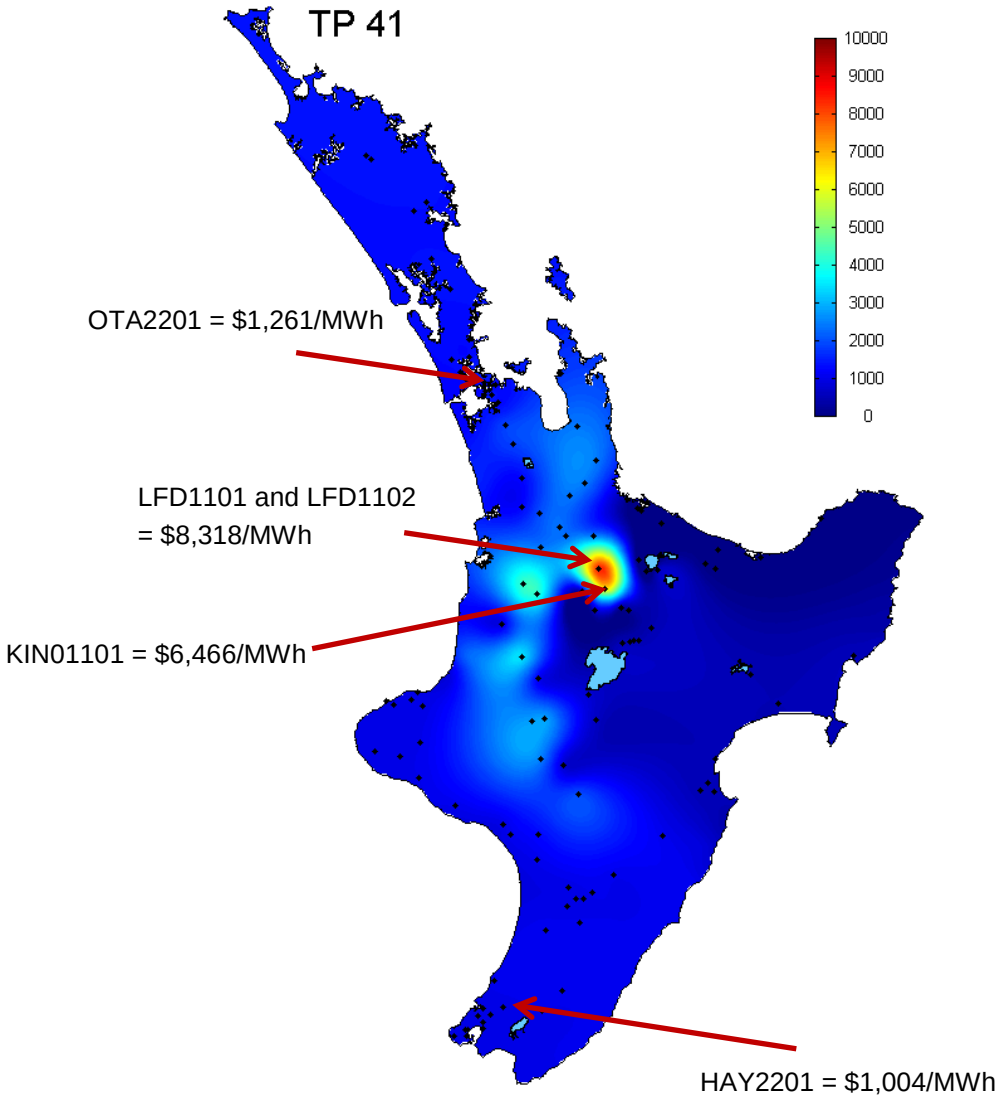
1.3 Carter-Holt Harvey (CHH) is a direct connect consumer of electricity in the Tokoroa region that was affected by these high spot prices. CHH requested the Authority consider a review of the underlying events of this situation. The Authority agreed that some of the issues raised by CHH warranted further analysis.[7]

1.4 This enquiry report considers issues relating to, and contributing factors for, this high price event.

[6] These prices refer to LFD1101 (Lichfield) and KIN1101 (Kinleith).

[7] See http://www.ea.govt.nz/industry/monitoring/enquiries-reviews-investigations/2013/ for further details.

Figure 1 Price heat map for 20 June 2013, trading period 41



Source: Electricity Authority

Notes: 1. Prices shown are those after the high spring washer resolution process

2 Closing the Arapuni split increases security of supply to Kinleith substation

2.1 On 29 September 2011, Transpower New Zealand Limited (Transpower) implemented a permanent bus split at Arapuni to relieve transmission constraints preventing increased output from the Arapuni power station. Transpower reassessed the benefits of the split on 1 October 2012 following the commissioning of the new transmission line between Whakamaru and Auckland and concluded that the split should remain in place and be reviewed when the Wairakei-Whakamaru C line and Tarukenga replacement transformers were in place.

2.2 During grid emergency conditions, Transpower can and have reconfigured the Arapuni bus (by closing the split) to improve security in the Tokoroa region. An example of this was on 9 July 2013 when a generation outage at Arapuni resulted in the system operator declaring a grid emergency and closing the Arapuni bus split during the period of the grid emergency condition.[8]

2.3 Under clause 12.116AA of the Code, Transpower can also temporarily reconfigure the grid. On 28 May 2013, Transpower temporarily reconfigured the Arapuni bus by closing the split. This decision was made following the unplanned outage of transformer T1 at the Arapuni power station resulting in the unavailability of four Arapuni generating units. The grid owner reviewed the net benefit test of the Arapuni bus split and determined that the majority of the benefits of having the split no longer existed with the indefinite unavailability of four generating units at the Arapuni power station. Closing the split increased security to the Kinleith substation, which outweighed the benefits of maintaining the split for reduced transmission losses.

2.4 On 28 May 2013, Transpower issued a customer advice notice (CAN) at 16:29 informing market participants that the split would be temporarily closed at 16:30 until the end of the Arapuni T1 outage with a summary of the net benefit test available from its website on 29 May 2013. A copy of the CAN and the net benefit assessment summary is shown in Appendix B.

2.5 The Authority has carried out its own analysis on the temporary closing of the Arapuni split using transmission outage history data, discussions with CHH and simulating the market dispatch using its vSPD model with and without the Arapuni split in effect over the period from 28 May 2013 to 25 June 2013. This analysis indicated that over the period from 28 May 2013 to 25 June 2013 the closing of the Arapuni bus split did not constrain back the available Arapuni generation. The market dispatch simulations illustrates that the Arapuni bus split provided no benefit in terms of additional generation dispatch with the reduced availability of Arapuni generation from 28 May 2013 to 25 June 2013.

2.6 The split bus configuration at Arapuni does, however, reduce security to loads at Kinleith and Lichfield. This is due to the risk that, with the Arapuni bus split open, all the Arapuni generators connected to the Arapuni south bus (connected to the Arapuni-Kinleith circuits) are unable to successfully island if there is an unplanned outage of both Kinleith-Lichfield-Tarukenga circuits.

2.7 The Authority has access to transmission outage history data from July 1999 to 2013. In this outage data, there is no record of both the Kinleith-Lichfield-Tarukenga circuits tripping simultaneously or in succession over this 13.5-year period. However, this does not mean that such an event cannot occur, and in this instance, the Authority assumed that the Kinleith-Lichfield-Tarukenga circuit is similar to the median which has one simultaneous outage of both circuits over the 13.5-year historical period.

2.8 CHH provided outage cost information to the Authority from which an expected cost of $840k per outage was calculated. The Authority used the average load to the Kinleith town, a value of lost load (VoLL) of $20,000/MWh and an expected

[8] See Appendix A for further details.

outage time of 0.5 hours to determine the interruption cost of other loads supplied from the Kinleith substation.[9]

2.9 The expected interruption cost for Kinleith for the period from 28 May 2013 to 25 June 2013 was calculated as follows. Expected cost = (1/13.5) * (28/365) * ($870k+$100k) = $5.5k.[10]

2.10 The outcome of the Authority's analysis is consistent with Transpower's decision to close the Arapuni bus split over the period from 28 May 2013 to 25 June 2013. While the outcome of the net benefit process for the temporary grid reconfiguration is plausible, the Authority has concerns about the level of engagement of affected parties in the application of the temporary grid reconfiguration process in place at the time.[11] Transpower only consulted Mighty River Power, who provided information on the unavailability of Arapuni generating units 1 to 4 for the indefinite future.

2.11 The Authority is also concerned about the amount of notice given to participants. According to time stamping records on the Customer Advice Notice (CAN), it appears that the CAN was provided one minute before the temporary reconfiguration was expected to take place on 28 May 2013. This provided no opportunity for participants to consider the implications of these actions.

2.12 While the temporary grid reconfiguration process in effect during May 2013 did not require a formal consultation, it is recommended that some engagement with affected parties be considered as part of this process going forward. This will improve the transparency when there is a potential temporary grid reconfiguration being assessed. Such engagement was undertaken during the low Southland hydro storage condition in early 2013 when temporary grid reconfigurations were considered. This engagement included teleconferences with participants requested to provide inputs into the process. This provided greater clarity to participants of the potential issues and potential reconfigurations. It is also recommended that, going forward, the temporary grid reconfiguration process consider provisions to ensure that adequate notice is given to participants of upcoming reconfigurations. This would allow parties to consider the implications of these reconfigurations and take the necessary actions. The Authority will consider these issues as part of its review of Part 12 of the Code.

3 Several contributing factors for the high spring washer scenario of 20 June 2013

3.1 The Authority's analysis indicates that several factors contributed to the binding transmission security constraint causing the high spring washer price situation in

[9] Transpower has indicated that in the event of a loss of supply due to an outage of both the Kinleith-Lichfield-Tarukenga circuits, the supply to Kinleith substation could be restored within 30 minutes with the closing of the Arapuni bus split.

[10] This corresponds to an expected cost of $72k per year which is greater than the expected cost of $40k per year calculated by Transpower in its net benefit assessment. Transpower used a one event in 20 year likelihood for a double circuit outage as compared to the one in 13.5 year likelihood used by the Authority. Transpower calculated cost per interruption for Kinleith load as $800k as compared to the $970k calculated by the Authority.

[11] This is at the time of assessing closing the Arapuni bus split in May 2013.

trading period 41 on 20 June 2013. The Authority's analysis further shows that each of these factors was required for the high spring washer prices to occur. These contributing factors were as follows:

(a) Transpower closing the Arapuni bus split from 28 May 2013 to 25 June 2013, which created a parallel path for power flow between the 220kV and 110kV network through Kinleith.

(b) Planned outage of the KIN_TRK2.1 and KIN_TRK2.2 circuits from 18 to 21 June 2013, which increased the flow on the KIN_TRK1.1 and KIN_TRK1.2 circuits for contingencies on the parallel 220kV network.

(c) High North Island demand on 20 June 2013 due to cold weather.

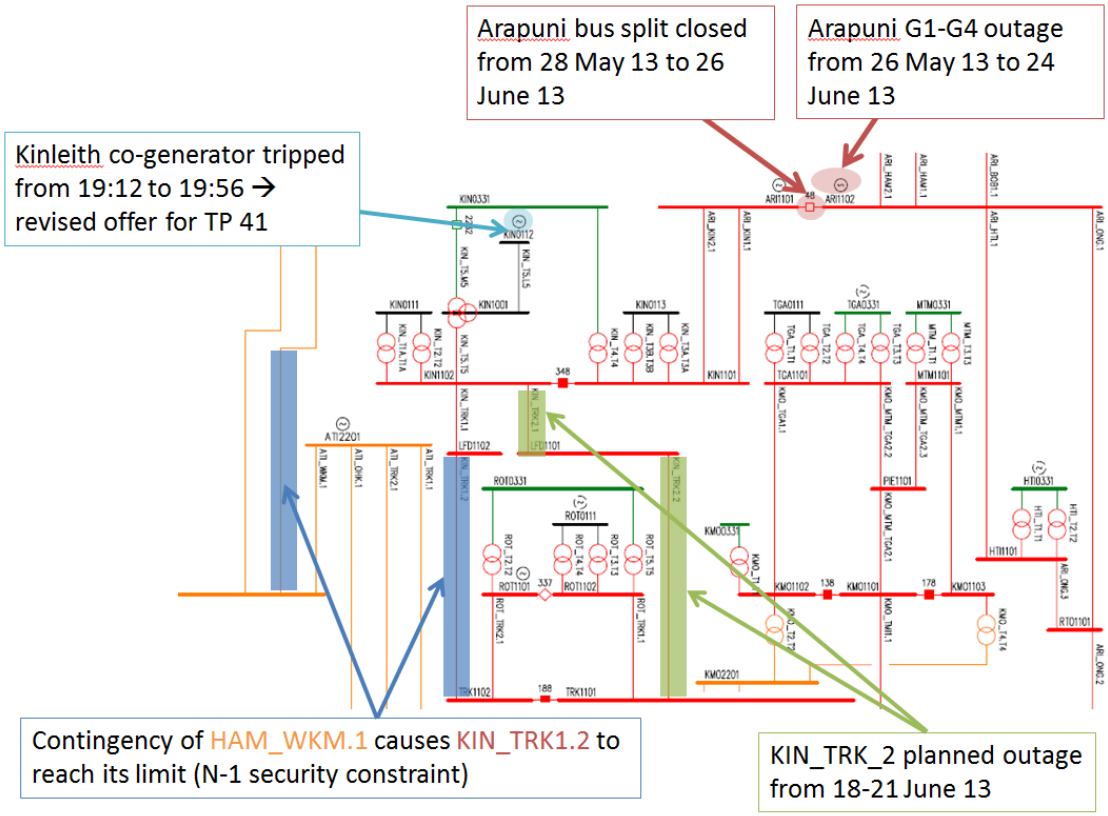
(d) Unplanned outage of the HVDC bipole link during trading period 39.

(e) Tripping of CHH's co-generation at Kinleith during trading period 39 with reduced energy offers submitted for trading period 41.

3.2 Figure 2 shows the affected network in the Tokoroa and surrounding region on 20 June 2013, highlighting the different contributing factors. The constraint to protect the KIN_TRK1.2 circuit if the HAM_WKM.1 circuit was to trip was the binding constraint that resulted in the high spring washer prices.

3.3 The first contributing factor occurred on 28 May 2013. At this time, Transpower reconfigured the grid at Arapuni following the extended unplanned outage of generators 1 to 4 at Arapuni power station due to a transformer outage. This reconfiguration involved closing the Arapuni bus split (ARI_CB_48), which resulted in the 220kV (Wairakei-Whakamaru-Hamilton) and the 110kV (Tarukenga-Kinleith-Arapuni-Hamilton) networks being operated as parallel networks. This parallel operation implied that contingencies on the 220kV network could result in increased flow on the parallel 110kV circuits, thus creating the potential loop-flow effect required for high spring washer price situations.

Figure 2 Configuration of network in the Tokoroa and surrounding region



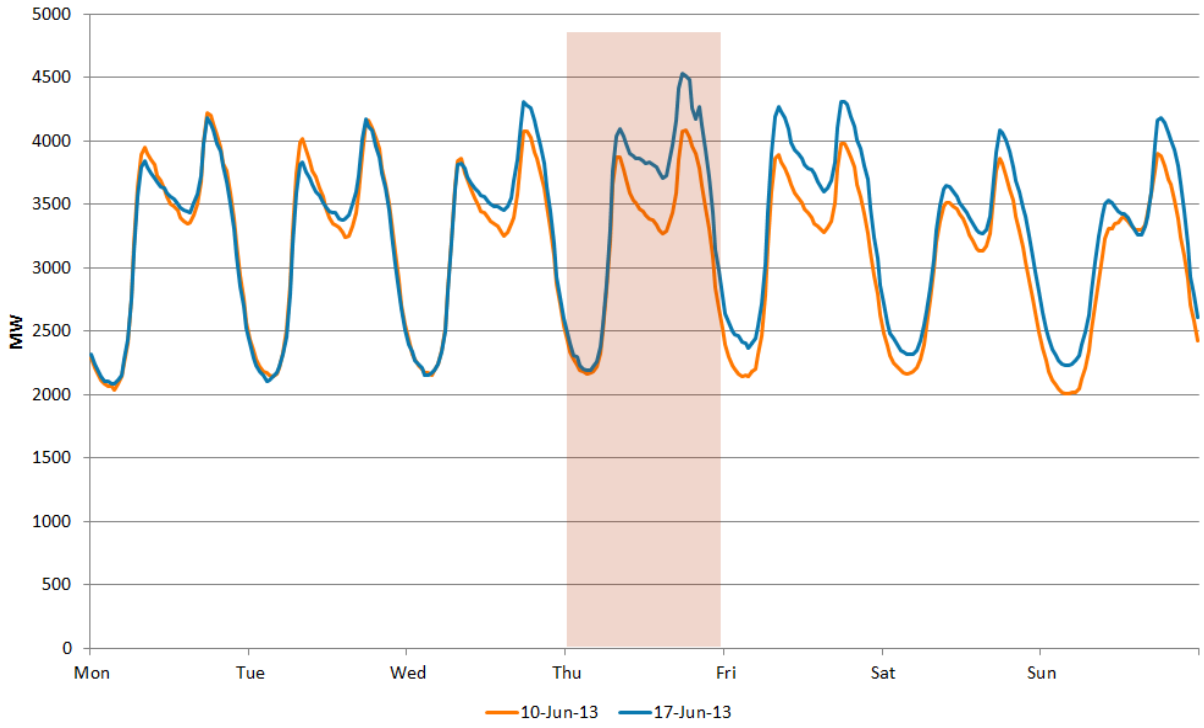
Source: System operator

3.4 The planned outage of the Kinleith-Lichfield-Tarukenga 2 circuit (KIN_TRK2.1 and KIN_TRK2.2) from 18 to 21 June 2013 was the second contributing factor. This outage reduced the number of in-service circuits on the 110kV parallel network into Kinleith and increased the flow on the remaining in-service Kinleith-Lichfield-Tarukenga 1 circuit (KIN_TRK1.1 and KIN_TRK1.2).[12]

3.5 The third contributing factor on 20 June 2013 was the increased North Island demand as a result of the cold weather across the country. Figure 3 shows the demand in the North Island for the weeks of 10 June 2013 and 17 June 2013 with the increased demand on 20 June 2013 highlighted. The increased demand increased the loading on the transmission network and increased the potential for binding transmission security constraints when catering for planned and unplanned outages.

[12] According to the Wholesale Information Trading System (WITS) the Kinleith-Lichfield-Tarukenga 2 circuit was received on 17 June 2013 in WITS and was confirmed on the Planned Outage Coordination Process system (POCP) on 22 April 2013. The grid owner has indicated to the Authority that no formal requests were received from any customers for the rescheduling of the above outage. However, the system operator did revise the generation availability requirements for the outage. These availability requirements are requests for generation being available for dispatch during peak load periods. There is no compensation for these generators nor is there any offer price requirement specified.

Figure 3 North Island demand comparison for weeks starting 10 June 2013 and 17 June 2013



Source: Electricity Authority

3.6 The tripping of the HVDC pole 2 and pole 3 in trading period 39 resulted in an under-frequency event in the North Island. The removal of the HVDC imports into the North Island increased the marginal supply cost in the North Island and for trading period 41 increased the generation from the central North Island which increased the flow on the Hamilton-Whakamaru circuit as load in the upper North Island was being restored.

3.7 At 19:12 (trading period 39), the Kinleith co-generator tripped.[13] At this time, the co-generator was offering 35MW into the market and was fully dispatched. The co-generator returned to service at 19:56 with a revised offer of 10MW provided for trading period 41.[14] The reduced output from the Kinleith co-generator in trading period 41 resulted in increased flow on the in-service Kinleith-Lichfield-Tarukenga 1 circuit which was the protected circuit in the binding transmission

[13] The Kinleith co-generator also tripped following the under-frequency event on 29 June 2013 when Hunlty T1 tripped. The Kinleith co-generator has been reclassified as a secondary risk since 01 July 2013.

[14] No offer revision was received for trading period 40 (20:00). Trustpower Limited, who offers the Kinleith co-generator on behalf of CHH, indicated that there was insufficient time to revise the offer for the 19:30 (trading period 40) with the first phone call from the CHH operator at 19:29.

security constraint during that time. This increased flow on the protected circuit resulted in an increase in the binding security constraint value.[15]

3.8 All of these factors resulted in the schedule, pricing and dispatch model (SPD) dispatching generators at significant cost to ensure the binding transmission security constraint (KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN) did not exceed its limit. This resulted in the high prices in the Tokoroa region. A deconstruction of the Lichfield (LFD1101) price is provided in Appendix E to explain how these high prices were determined by SPD.

3.9 The Authority simulated alternative price scenarios adjusting for each of the contributing factors to better understand their impact. The alternative scenarios and prices at representative nodes are listed in Table 1.

[15] The value of the constraint is the left-hand side. The transmission security constraints have the following generic form LHS <= RHS. Here the LHS represents the linear combination of protected and contingent branch flows and the RHS represents the limit of the protected branch.

Table 1 Impact of contributing factors

Scenario	Price ($/MWh)				
	LFD1101	KIN1101	HAY2201	OTA2201	Max. offer
Base	8336	6479	1004	1261	495
Arapuni bus split open	437	445	442	441	425
Kinleith-Lichfield-Tarukenga 2 closed	435	441	443	442	425
TP41 net demand conditions from same time on 19 June 2013	109	110	114	108	105
HVDC in-service for trading period 41[16]	621	491	93	122	95
Kinleith co-generator at full output	436	446	442	442	425

Source: Electricity Authority

3.10 The results from Table 1 illustrate that, under each of the alternative scenarios, nodal prices for trading period 41 in the Tokoroa region would have been at least 13 times lower than under the base case. This illustrates that all of the contributing factors were needed for prices in excess of $6,000/MWh to occur at Lichfield and Kinleith.

3.11 The high spring washer process is designed to ensure that, when nodal prices are significantly impacted by transmission security constraints, they are not sensitive to minor changes in the constraint limits. Therefore, under the current

[16] This result is after applying the high spring washer price relaxation factor to the binding transmission security constraints. This is because the maximum nodal price exceeds the highest unconstrained cleared offer price by a factor greater than 5.

high spring washer price resolution process the transmission security constraint with the highest shadow price can be increased by 1MW and cannot be adjusted more than once.

3.12 For trading period 41 of 20 June 2013, the system operator applied two iterations of the high spring washer price resolution process, with the limit of transmission security constraints with the highest shadow price adjusted in each iteration, as illustrated in Table 2. In the third iteration, an already adjusted transmission security constraint bound, still resulting in nodal prices more than five times greater than the highest cleared offer price. As per the clause 13.134(6) of the Code, the high spring washer resolution process was exited at this time with no further adjustments made to the already adjusted security constraint limit.

Table 2 Transmission security constraints adjusted during high spring washer resolution

Iteration	Constraint name	Limit (MW)	Adjusted limit (MW)
1	KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN	68.87	69.87
2	KIN_TRK1.1__HAM_WKM.1__$HAMWKM1__KIN__LN	66.49	67.49
3	KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN	69.87	*None*

Source: Electricity Authority

3.13 The Authority calculates that an 8MW (12%) and 7MW (11%) increase in the KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN and KIN_TRK1.1__HAM_WKM.1__$HAMWKM1__KIN__LN security constraint limits are needed to reduce the maximum nodal price below five times the highest offer price. This large increase in the security constraint limits illustrates that the current high spring washer price resolution process operated as designed, maintaining locational price signals that were not sensitive to minor adjustments in the constraint limits. Furthermore, analysis of real time constraint information indicates that these constraints bound during real time dispatch and pricing.[17]

3.14 The Authority does however consider that there is a potential issue where the limits used in the determination of spot prices can diverge from the actual asset

[17] This information was obtained from the Wholesale Information Trading System (WITS).

limits. This divergence can affect trade-offs being made in the market. This issue is discussed further in the next section.

4 Constraint limits affect efficient market trade-off

4.1 Transpower currently uses a summer, winter and shoulder thermal limit for the majority of its transmission circuits during the day hours (07:00 to 20:59). These limits differ due to changes in assumptions of ambient temperature which are 30°C for summer, 25°C for shoulder periods and 20°C for winter. During the night (21:00 to 06:59), the higher winter ratings are used throughout the year.[18] From 24 November 2011 Transpower has started a variable line rating trial on six circuits. On these circuits, the limits change six times a day reflecting the ambient conditions specific to each circuit. Further, the limits on these circuits also change monthly to reflect the changing ambient conditions for each month of the year.

4.2 On 20 June 2013 during trading period 41, the KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN transmission security constraint reached its limit, resulting in high spring washer prices in the Tokoroa region. This security constraint is designed to protect the KIN_TRK1.2 circuit in the event of the HAM_WKM.1 circuit tripping. More specifically, the constraint ensures the KIN_TRK1.2 circuit does not exceed the minimum ground clearance level in 15 minutes following the trip of the HAM_WKM.1 line. The 15 minute period is commonly referred to as the offload time and is used to allow the system operator time to re-dispatch generators, following the contingency, to reduce the loading on the protected circuit. For the above constraint, a 20°C ambient temperature was assumed in the calculation of the limits.[19]

4.3 To better understand the impact of the assumed ambient temperatures on the constraint limits and therefore spot prices, the Authority recalculated the transmission limits with more temperature information from the NIWA CliFlo[20] database, which indicates that the average temperature from 20:00 to 20:30 on 20 June 2013 at three weather stations around the Tokoroa region was 5°C. The weather station locations are shown in Appendix D.

4.4 Reducing the assumed 20°C ambient temperature to 5°C results in an increase in the limit of the KIN_TRK1.1 and KIN_TRK1.2 circuits from 62MW to 75.6MW, which also increases the limit of the transmission security constraints where the KIN_TRK1.1 and KIN_TRK1.2 circuits are the protected branch, as shown in Table 3. [21]

[18] Further details on the ratings applied during different periods are shown in Appendix C.

[19] These are the winter limit assumptions.

[20] See http://cliflo.niwa.co.nz/ for further information.

[21] These adjusted limits were determined using a calculator provided by Transpower to calculate the circuit offload coefficients.

Table 3 Revised constraint limits with updated ambient temperature

Branch security constraint	Original limit (20°C)	Revised limit (5°C)	% diff
KIN_TRK1.1__ATI_WKM.1__$ATIWKM1__KIN__LN	66.38	81.1	22%
KIN_TRK1.1__BPE_MTR1.1__BPE_MTR1__KIN__LN	66.65	81.6	22%
KIN_TRK1.1__HAM_OHW1.1__$HAMOHW1__KIN__LN	66.52	81.5	23%
KIN_TRK1.1__HAM_WKM.1__$HAMWKM1__KIN__LN	66.49	81	22%
KIN_TRK1.1__PAK_WKM1.2__PAK_WKM1__KIN__LN	66.68	81.8	23%
KIN_TRK1.1__PAK_WKM2.2__PAK_WKM2__KIN__LN	66.68	81.8	23%
KIN_TRK1.1__THI_WKM1.1__THIWKM1*__KIN__LN	66.68	81.7	23%
KIN_TRK1.1__THI_WRK1.1__THI_WRK1__KIN__LN	66.69	81.7	23%
KIN_TRK1.2__ATI_WKM.1__$ATIWKM1__TRK__LN	68.6	83.9	22%
KIN_TRK1.2__BPE_MTR1.1__BPE_MTR1__TRK__LN	68.84	84.3	22%
KIN_TRK1.2__HAM_OHW1.1__$HAMOHW1__TRK__LN	68.74	84.3	23%
KIN_TRK1.2__HAM_WKM.1__$HAMWKM1__TRK__LN	68.87	83.9	22%
KIN_TRK1.2__OHW_WKM1.1__$OHWWKM1__TRK__LN	68.86	84.5	23%
KIN_TRK1.2__PAK_WKM1.2__PAK_WKM1__TRK__LN	68.83	84.4	23%
KIN_TRK1.2__PAK_WKM2.2__PAK_WKM2__TRK__LN	68.83	84.4	23%
KIN_TRK1.2__THI_WKM1.1__THIWKM1*__TRK__LN	68.82	84.3	22%
KIN_TRK1.2__THI_WRK1.1__THI_WRK1__TRK__LN	68.82	84.3	22%

Source: Electricity Authority

4.5 The Authority recalculated the market prices with its vSPD model using the revised limits as shown in Table 3. The increased transmission limits removes the high spring washer price situation with prices in the Tokoroa region reducing below $500/MWh as shown in Table 4.

Table 4 Price comparison with revised branch limits

Branch limits	LFD1101[22]	KIN1101	HAY2201	OTA2201	Max offer
Base	8336	6479	1004	1261	495
Revised	441	452	442	442	425

Source: Electricity Authority

4.6 The above analysis highlights the sensitivity of the spot market prices to ambient conditions used in the calculation of the transmission circuit limits. Using the assumed static ambient temperatures for the calculation of the circuit limits results in binding transmission constraints and high spot prices in the Tokoroa region. These prices indicate a shortage of supply in the region and provide incentives on generator industry participants in the region to increase output and on offtake industry participants exposed to these prices to seek solutions to reduce their exposure to these prices. These solutions to offtake participants could be to reduce consumption, seek hedges, invest in local generation and pursue options for additional transmission capacity.

4.7 Using the lower ambient temperatures that were more reflective of actual conditions there are vastly different price signals in the Tokoroa region due to higher transmission circuit limits. Under these conditions, the spot prices indicate there is no shortage of transmission capacity into the Tokoroa region with localised prices reducing to reflect this condition.

4.8 One potential approach could be to consider using local ambient conditions that are more representative of actual conditions for the calculation of transmission system limits when resolving high spring washer price situations. Under this approach, if there was no high spring washer price situation, the status quo process of determining transmission limits would be used. If a high spring washer price situation did occur, there would typically be a greater impact on industry participants exposed to the spot prices. Under these conditions, more

[22] The prices shown for the base are the provisional prices (prior to the high spring washer resolution process).

representative ambient conditions could be considered to determine the limits on the binding transmission security constraints as part of the high spring washer price resolution process. This would result in spot prices, particularly when they are the most sensitive to constraint limits, being more reflective of actual conditions and therefore improving the economic trade-offs of supply and demand at the node given the local conditions.

4.9 An issue with the above approach is that it would increase the differences between the scheduling, dispatch and pricing processes which would increase the divergence between pricing signals used by participants before and during dispatch from those used for settlement. However, this increased uncertainty would only be restricted to high spring washer price situations which represent those instances when the nodal prices are most affected by constraint limits. Therefore it could be considered that greater effort should then be expended during these instances to ensure the constraint limits are more reflective of actual limits.

4.10 The benefits of ensuring the modelled transmission limits more closely reflect the actual transmission limits, particularly when their impact on market prices is the most acute, reduces the potential for inefficient investment in financial and physical price risk management if there is still some capacity in the system. However, there is increased uncertainty introduced with additional adjustments enabled in the final pricing solution. This uncertainty can result in operational decisions that seemed appropriate given the real-time price signals, only to be considered inefficient following the revision of modelled transmission limits closer to actual transmission limits during final pricing calculation. The benefits of ensuring more appropriate economic trade-offs based on modelled limits more closely aligned with actual conditions would need to be weighed up against the increased divergence between scheduling, dispatch and pricing.

4.11 Moving to a regime where transmission limits were monitored and updated closer to real-time would allow dispatch closer to actual circuit limits. However, there are some potential operational issues that would need to be considered. Firstly, some assumptions of upcoming ambient conditions would still be needed for the forecast and dispatch schedules. If a similar gate closure concept were introduced for circuit limits where the forecast limits from 2 hours ahead of real time were used, this could result in some divergence between actual limits and forecast (or expected limits), although these would be expected to be closer to the actual limits than those with more static assumptions. Secondly the changing constraint limits would introduce additional uncertainty into the market that participants would need to manage. This is particularly true if circuit limits can be adjusted closer to real time.

4.12 Transpower has indicated that it will be looking to extend its interim variable line rating project to additional circuits with some upgrades to its modelling and protection systems. Although this would result in limits more closely representing changes in ambient conditions across the day and year, these would still be based on historical data.

4.13 The Authority understands that Transpower will be undertaking a dynamic line rating trial this year on a single circuit. Transpower will collect and analyse the

real time circuit rating information, but will not feed it into the market system at that stage.

4.14 In 1996 Transpower initiated a dynamic line rating trial on some 220kV circuits. This trial involved the installation of tension monitoring equipment. Following this trial Transpower concluded that transmission line capacities could be substantially increased using dynamic line ratings which would reduce the likelihood of constraints and their associated pricing impacts.

4.15 The Authority is concerned at the rate of progress of the dynamic line rating initiative within Transpower, particularly given that Transpower's previous trial indicated positive benefits to the end user. Dynamic line rating is a relatively mature technology internationally, and we note that every transmission line in Tasmania has been dynamically rated for a number of years now. The Authority would be interested to learn from Transpower if there are unresolved issues that would prevent widespread deployment being feasible or economic.

4.16 While there are some developments to improve the rating of transmission circuits based on more representative ambient assumptions, the Authority also considered whether the current Code provisions posed any road blocks to participants entering into an agreement with Transpower to revise the rating of an interconnection circuit based on more dynamic assumptions. This does not appear to be the case provided some conditions are satisfied. The Authority considers that the current provisions outlined in clause 12.128 of the Code allows for such an agreement between Transpower and designated transmission customers on specified assets provided:

(a) there is approval from all other potentially affected designated transmission customers

(b) Transpower and the designated transmission customer certify to the Authority that they have consulted all potentially affected end use customers on the fact that Part 12 of the Code would not apply to the specified asset, and there are no material unresolved issues affecting the interests of those end use customers

(c) Transpower and the designated transmission customer notify the Authority as soon as practicable if Transpower and the customer enter into an agreement of this kind.

4.17 If these conditions were satisfied, then the grid owner would provide the transmission circuit limits and updates to the system operator.

Appendix A Grid Emergency Notice

TRANSPOWER SYSTEM OPERATOR

Grid Emergency Report

To:	GEN NZ Participants	**From:**	The System Operator
Sent:	09-jul-2013 16:58	**Telephone:**	0800 488 500
Ref:	1150969106	**Facsimile:**	07 843 7176

Revision of:
Grid Emergency Notice ref: 1149665075

Cause:	Insufficient Generation offers Arapuni
At:	Arapuni
Starting:	09-jul-2013 05:56
Ending:	09-jul-2013 16:11
Action Taken:	A generation outage at Arapuni required grid reconfiguration to close Arapuni CB 48 bus split to ensure protection requirements were met.

This notice is issued in accordance with Clause 13.97 (1), Part 13

Appendix B Customer Advice Notice and net benefit assessment summary

TRANSPOWER SYSTEM OPERATOR

Customer Advice Notice

To:	CAN NZ Participants	**From:**	The System Operator
Sent:	28-may-2013 16:29	**Telephone:**	0800 488 500
Ref:	1115087920	**Facsimile:**	07 843 7176

Revision of:

Closing of the ARI bus split
The Grid Owner has carried out a net benefit test for temporarily closing the Arapuni bus split for the duration of the unplanned outage of Arapuni T1. The results of the analysis have shown a positive net benefit for closing the Arapuni bus split. The Arapuni bus split will be closed from 16:30, 28th May 2013 until the end of the Arapuni T1 outage. A summary of the net benefit test will be uploaded onto Transpower's website tomorrow. ...

Arapuni Bus Split Advisory

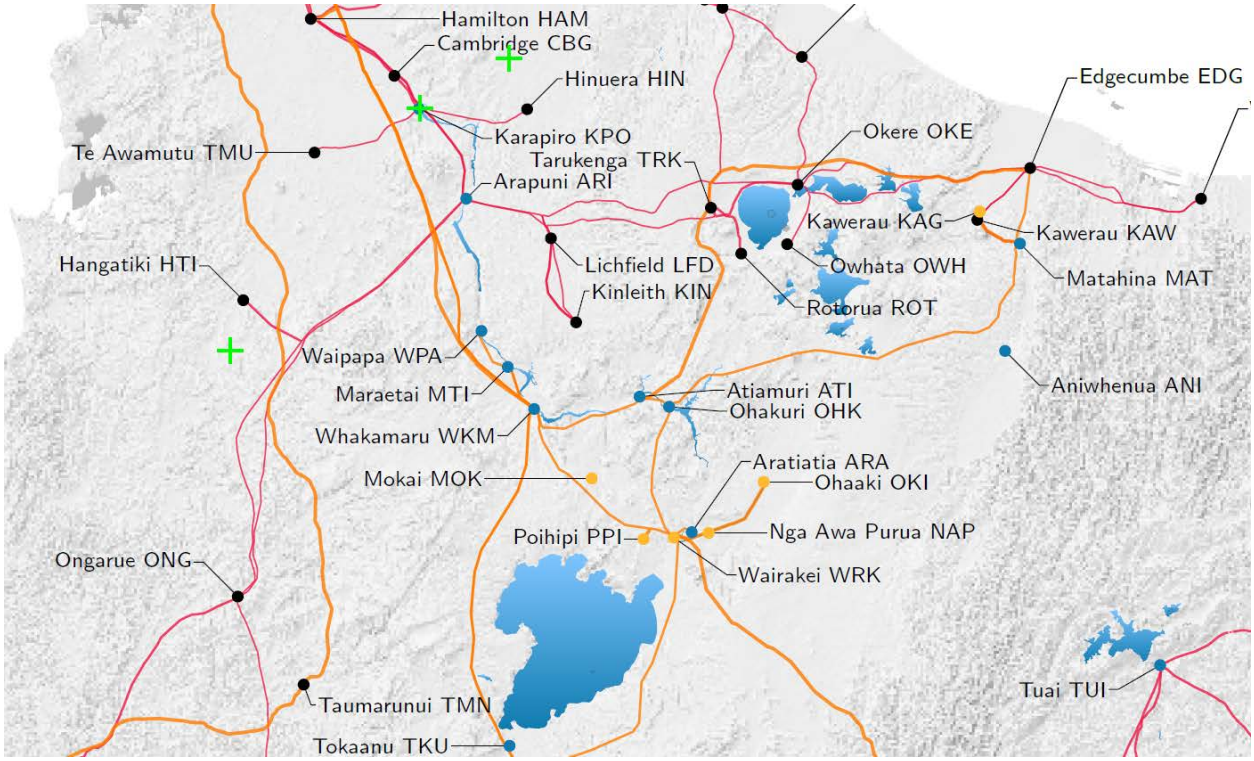
We have reviewed the Net Benefit Test for continuing the Arapuni grid reconfiguration following the outage of transformer T1 at Arapuni. There is no net benefit in splitting the Arapuni bus while T1 is out of service. We will close the Arapuni bus split from 28 May 2013 16:30 until further notice.

On 26 May 2013, transformer T1 at Arapuni power station was removed from service. Transformer T1 connects Arapuni generating units G1 to G4. The outage of the transformer makes these units unavailable. The majority of benefits from having a bus split on the 110 kV bus at Arapuni arise from relieving generation constraints at Arapuni. The unavailability of generating units G1 to G4 due to the outage of Arapuni transformer T1 means the benefits in relieving generation constraints no longer exist. There is now a net benefit in closing the split as the cost of energy not served (having reduced security to Kinleith substation) outweighs the benefits of reduced losses when the Arapuni 110 kV bus is split.

Appendix C Ratings applied during different periods

From date	To date	Day rating (07:00 to 20:59)	Night rating (21:00 to 06:59)
01 December	15 March	Summer	Winter
15 March	10 May	Shoulder	Winter
10 May	20 October	Winter	Winter
20 October	1 December	Shoulder	Winter

Appendix D Weather station locations around the Tokoroa region



Appendix E Description of the Lichfield price

E.1 The Lichfield (LFD1101) price after HSW resolution process was $8,318/MWh. The Authority deconstructed this price by considering the incremental cost of supplying a marginal increment of demand at the LFD1101 node. This was undertaken using the vSPD model.

E.2 The marginal (0.1 MW) increase in demand at LFD1101 requires:

(a) 1.68MW (16.8 times) increase in generation from Whirinaki at a price of $495/MWh = $831.6

(b) 1.58MW (15.8 times) reduction in generation from KAG at a price of $0/MWh = $0.

E.3 The incremental cost per unit of demand increase at LFD1101 = $831.8/0.1MWh = $8,318/MWh.

Glossary of abbreviations and terms

Authority	Electricity Authority
CHH	Carter Holt Harvey
Code	Electricity Industry Participation Code 2010
MRP	Mighty River Power Limited
MW	Megawatt
MWh	Megawatt hour
SO	System Operator
SPD	Scheduling, Pricing and Dispatch
TP	Trading period
TrustPower	TrustPower Limited
vSPD	Vectorised Scheduling, Pricing and Dispatch