System Security Forecast 2010

Part C Security Analysis

Waikato Region

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SYSTEM OPERATOR

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IMPORTANT

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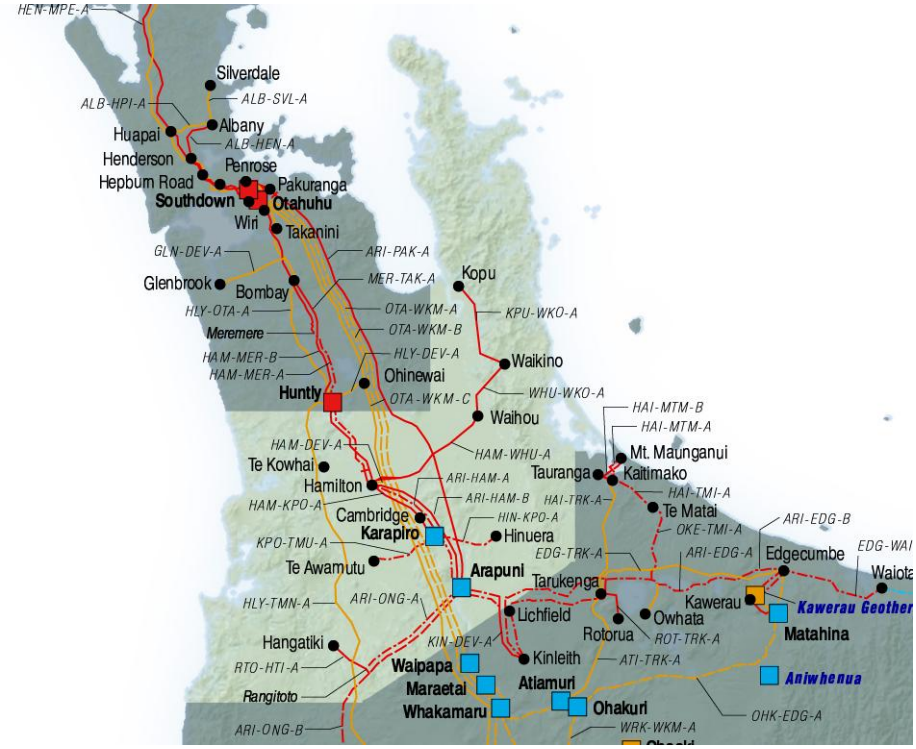
1. LIMIT GROUP ANALYSIS

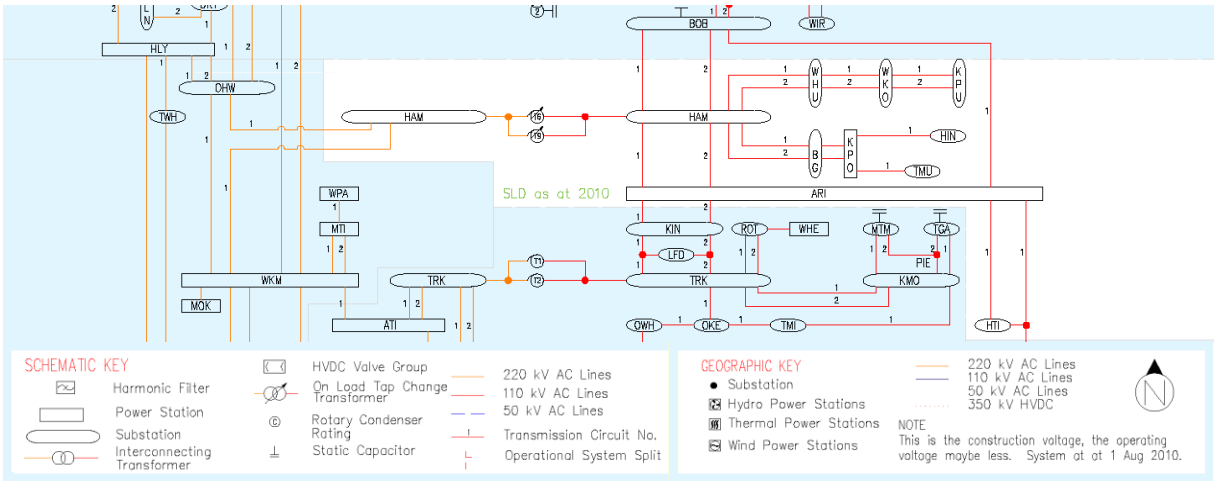
Power system issues within the Waikato region are described in this section.

1.1 NETWORK OVERVIEW

The Waikato region is the area bordered by and including Kopu in the north and Arapuni in the south. It is supplied by 220 kV and 110 kV transmission circuits and generation within the region, with interconnecting transformers located at Hamilton.

The Waikato Region is shown geographically and schematically below.





The capability of assets in the region is assumed to be that declared by asset owners as at 2nd July 2010.

The table below shows the committed and completed projects, as notified by the asset owners, which have affected or will affect the Waikato region within the study period. These projects have been considered in the analysis.

Asset	Upgrade	Region	Commissioning Date	Status
Arapuni-Pakuranga & Otahuhu-Pakuranga 110kV circuits	Dismantling the existing 110kV Arapuni to Pakuranga circuit and reconnecting the unused 110kV Otahuhu-Pakuranga circuit	Northland & Auckland	Oct 2009	Completed
Huntly-Ohinewai-2 220kV limiting components	Replace limiting components on the 220kV Huntly-Ohinewai-2 circuit	Waikato	Mar 2010	Completed
Drury Substation	New substation	Auckland	May 2010	Completed
Pakuranga (PAK) 220kV substation	Convert Pakuranga 110kV substation to 220kV substation [NIGUP]	Auckland	May 2011	Committed
Pakuranga – Brownhill -Whakamaru North 220kV circuit	New double circuit overhead line from Whakamaru North to Brownhill transition station and 8.17km underground cable from Brownhill to Pakuranga [NIGUP]	Auckland	June 2012	Committed
Pakuranga (PAK) 220kV substation upgrade	Upgrade Pakuranga 220kV substation to breaker and a half [NIGUP]	Auckland	May 2011	Committed
Otahuhu - Pakuranga 220kV	Convert existing Otahuhu - Pakuranga 110kV circuit to 220kV [NIGUP]	Auckland	May 2011	Committed
Decommission Pakuranga –Penrose circuit	Take Pakuranga – Penrose circuit out of service [NIGUP]	Auckland	June 2012	Committed
Pakuranga Supply Transformers	Decommission 2 x 110/33kV Pakuranga transformers and install 3x 220/33kV 120MVA transformers	Auckland	May 2011	Committed
Whakamaru B Substation	New Whakamaru North substation, extend 220kV structure at Whakamaru and build a tie line between sites	Auckland	June 2012	Committed

Committed upgrades in the region

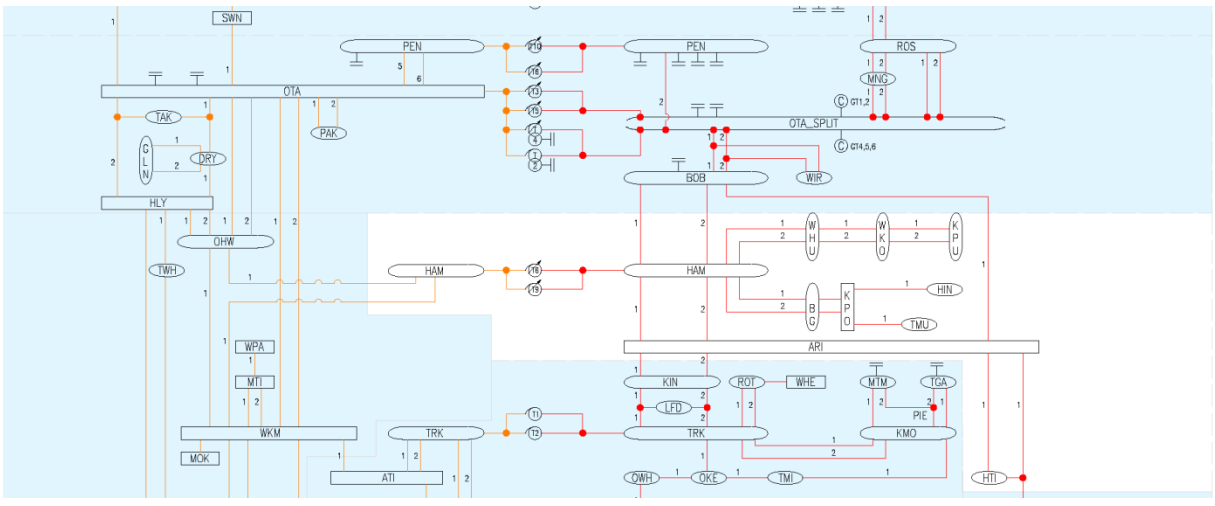


Figure 1 SLD as at 2011/12

Figure 1 shows the anticipated configuration of the power system once the PAK-OTA circuits have been re-strung for operating at 220 kV.

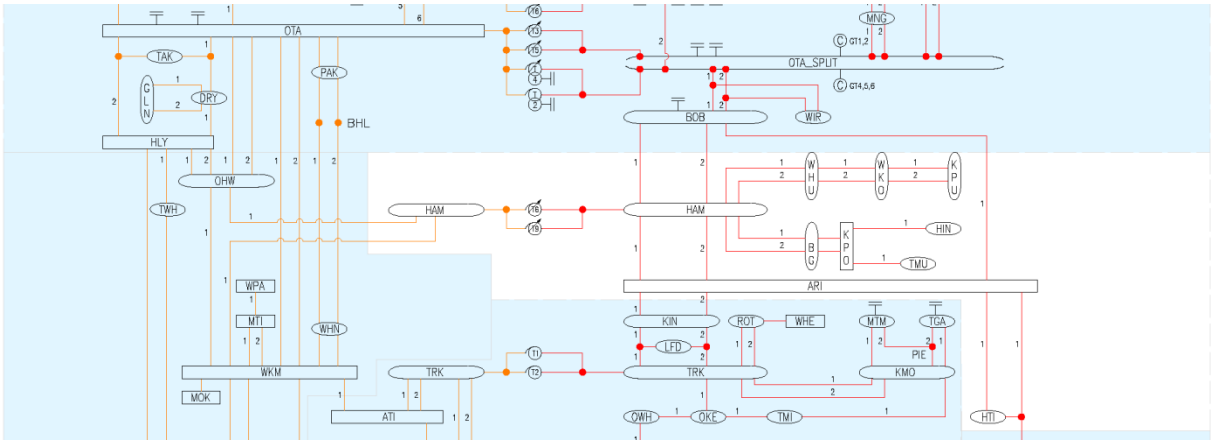


Figure 2 SLD for 2013

Figure 2 shows the anticipated configuration of the power system once Brown Hill and Whakamaru North are completed and connected to the grid.

1.2 DEMAND AND GENERATION WITHIN THE LIMIT GROUP

The Waikato region currently has 272 MW of generation capacity. EC Prudent load values indicate a 2011 winter peak load of 385 MW which is forecasted to grow/increase to 405 MW in 2013. Regional peak demand is considerably greater than regional connected generation capacity. Power factor scatter graphs for the region in summer and winter are shown in figures 3 and 4.

For the purpose of these studies the minimum power factor has been assumed. For both summer and winter peak studies the power factor is taken as 0.96.

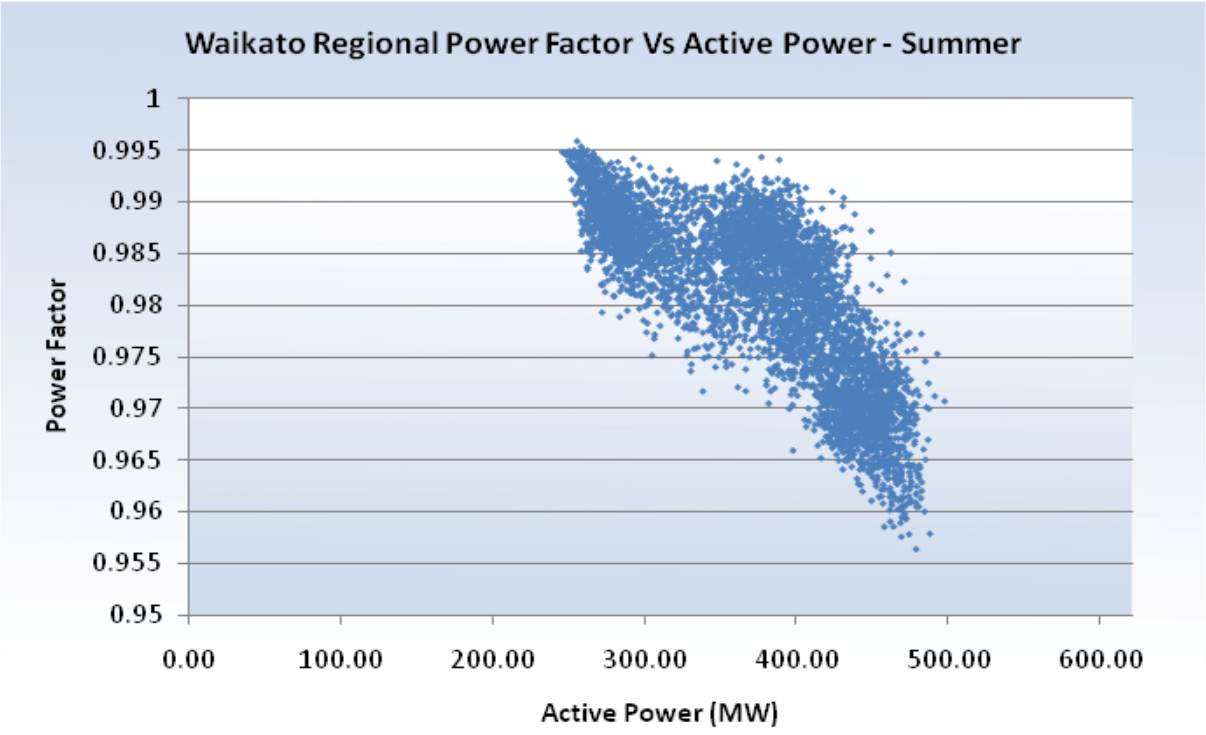


Figure 3

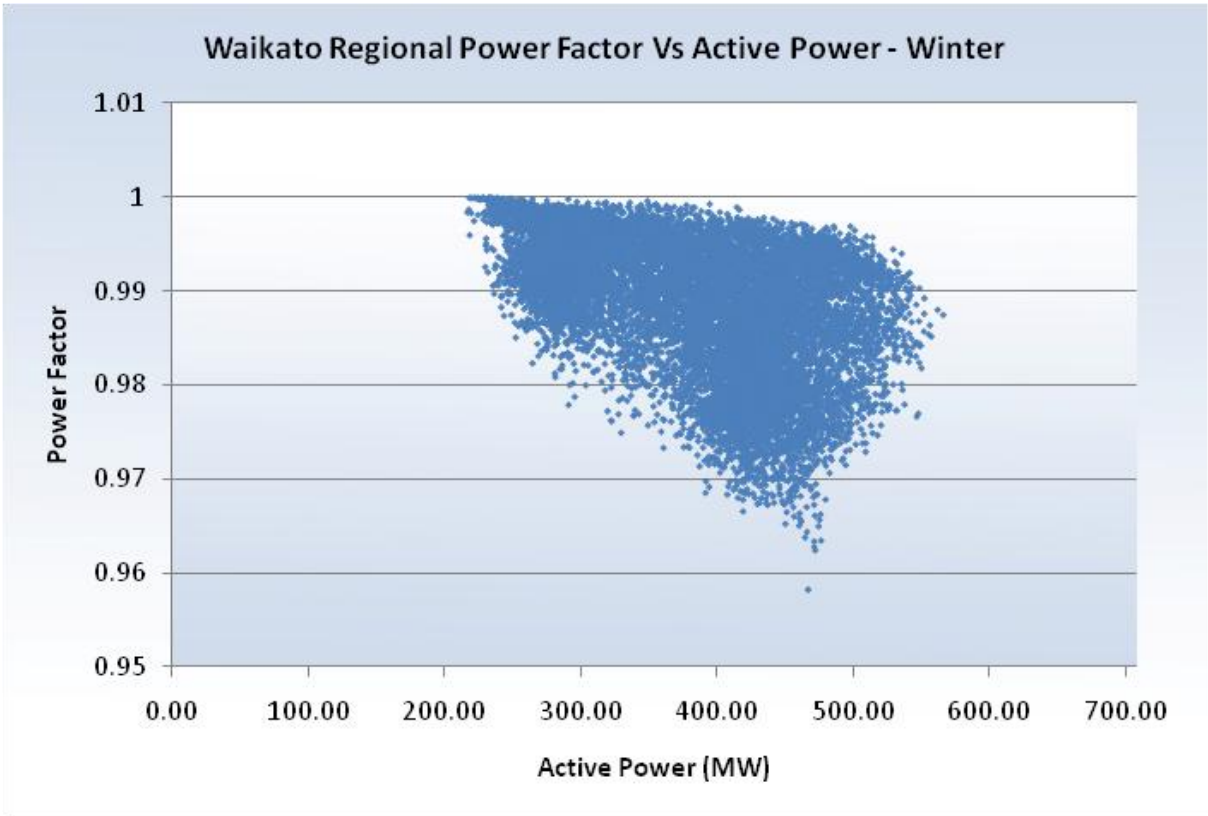


Figure 4

Note: The groupings used to determine indicative regional power factors are different to the EC groupings used in the System Security forecast.

1.3 GRID RECONFIGURATION

1.3.1 ARAPUNI 110 KV BUS SPLIT

Power system changes such as the decommissioning of Arapuni-Pakuranga 1 110 kV circuit and the commissioning of additional generation in the Bay of Plenty have caused the Arapuni-Hamilton and Kinleith-Tarukenga 110 kV circuits to reach stated capability for a loss of a parallel 220 or 110 kV circuit. While a runback scheme fitted on Arapuni-Hamilton 110 kV circuits helps to alleviate the need for constraints on ARI generation and/or the 220kV into the upper North Island, this has only partly resolved the issue. Effectively, station output capability at Arapuni has been reduced due to transmission constraints and constraints on the parallel 110kV (Arapuni-Hamilton and Kinleith-Tarukenga 110 kV circuits).

To alleviate this issue the 110 kV system has been split at Arapuni 110 kV bus. The North bus connects the Bombay, Hamilton 1 & 2, Hangatiki and Ongarue 110 kV circuits, G1 to G4, and a fifth generator as required. The South bus connects the two Kinleith 110 kV circuits, and the remaining three generators as required.

1.4 SPECIAL PROTECTION SCHEMES

1.4.1 ARAPUNI RUNBACK SCHEME

The Arapuni Runback Scheme provides automatic corrective action to reduce generation at Arapuni should an overload be detected on either of the Arapuni-Hamilton 110 kV circuits

For the purposes of the studies in this report, it had been assumed that Arapuni Runback Scheme has been offered by the grid owner and enabled, unless specifically mentioned otherwise. With the Arapuni 110 kV bus split, generators connected onto the bus with the Kinleith circuits are not subject to the Arapuni Runback Scheme.

1.4.2 BOMBAY SYSTEM SPLIT INTERTRIP SCHEME

The BOB 110 kV System Split Intertrip Scheme provides an N-G-1 (i.e. non-simultaneous loss of a generator and a transmission circuit) level of transmission security into Auckland.

When enabled, contingencies on parallel 220 kV circuits that result in loading in excess of the applicable ratings on Bombay-Hamilton 110kV circuits or the Arapuni-Bombay 110kV circuit will result in a system split at BOB being automatically applied thereby reducing the need for constraints to be applied pre-event.

For the purposes of the studies in this report, it had been assumed that the Bombay System Split Intertrip Scheme has not been offered by the grid owner, unless specifically mentioned otherwise.

1.5 KEY ASSETS

1.5.1 CRITICAL CONTINGENCIES

Contingency	Power System Issue	Management Measures	Analysis
Loss of the Hamilton – Whakamaru 220 kV circuit	Arapuni-Hamilton-1 and 2 110kV circuits exceed stated capability. Kinleith-Tarukenga-1 110 kV circuit may exceed its stated capability	Security constraints Short term ratings Arapuni Runback Scheme ARI 110 kV Bus Split Constrain generation	Sensitivities in 2.1.1
Loss of the Hamilton-Ohinewai 220 kV circuit.	Bombay-Hamilton-1 and 2 110 kV circuits exceed stated capability	Security constraints Short term ratings Grid Reconfiguration	Sensitivities in 2.1.2
Loss of the Huntly-Ohinewai-1 22 kV circuit	No issues (Previous issue: remaining Hamilton-Ohinewai 220 kV circuit may exceed its stated capability)		No longer a power system issue. Due to the limiting components on the 220kV Huntly-Ohinewai-2 circuit having been replaced.
Loss of a Bombay-Hamilton 110 kV circuit	Remaining Bombay-Hamilton circuit exceeds stated capability.	Security constraints Short term ratings Constrain generation Grid Reconfiguration	Transfer from Hamilton to Bombay of 73/90 MW (summer/winter)
Loss of a Hamilton-Karapiro 110 kV circuit	Remaining Hamilton-Karapiro circuit exceeds stated capability	Security constraints Short term ratings Constrain generation	Transfer from Karapiro to Hamilton of 57/70 MW (summer/winter)
Loss of a Hamilton-Waihou 110 kV circuit	Grid voltages fall below advised asset capability	Pre-contingent bus Voltages Load management	Load distribution, Voltage at Hamilton 110 kV bus, load power factors

1.5.2 CRITICAL OUTAGES

Outage	Contingency	Power System Issue	Management Measures	Analysis
Hamilton-Whakamaru 220 kV circuit *or* *Hamilton-Ohinewai 220 kV circuit*	Loss of the remaining 220 kV circuit into Hamilton-	Loss of supply to Waikato and Bombay loads except Hangatiki	Grid Reconfiguration Load management	220 kV feed into Hamilton limited to 404/493 MVA (summer/winter) Bombay load limited to 51/62 MVA (summer/winter)
One of the Arapuni-Hamilton 110 kV circuits	Loss of a parallel 220 kV or 110 kV circuit	Remaining Arapuni-Hamilton circuit exceeds stated capability	Short Term Ratings Security Constraints Arapuni Runback Scheme ARI 110 kV Bus Split	
Hamilton T6 220/110 kV interconnecting transformer	Loss of a Bombay-Otahuhu 110 kV circuit	Remaining Bombay-Otahuhu 110 kV circuit exceeds stated capability	Short term ratings Security Constraints Grid reconfiguration	Transfer from Otahuhu to Bombay limited to 104/108 MW (summer/winter)
Arapuni-Bombay 110 kV circuit	Loss of a parallel 220 kV or 110 kV circuit	Parallel 110 kV circuits exceed stated capability	Short Term ratings Arapuni Runback Scheme Grid Reconfiguration.	
One of the Bombay-Hamilton 110 kV circuits	Loss of a parallel 220 kV or 110 kV circuit	Remaining Bombay-Hamilton circuit exceeds stated capability	Short term ratings Security Constraints Grid reconfiguration	

1.6 POWER SYSTEM CAPABILITY LIMITS ON LIMIT GROUP

1.6.1 POWER SYSTEM LIMITS

Power system capability limits that apply to the region a grid exit or grid injection point (or a collection of such points) are shown in the following table. Detailed analysis for each issue can be found in Section 2. You can navigate to the relevant issue by clicking on the section number in the right hand column of the following table.

Contingency	Limit Group	summer/winter	Detailed Analysis Section
Loss of a Bombay-Hamilton 110 kV circuit	Transfer from Hamilton - Bombay	73/90 MW	2.1.3
Loss of a Hamilton-Karapiro 110 kV circuit	Transfer from Karapiro - Hamilton	57/70 MW	2.1.4

Outage	Contingency	Limit Group	summer/winter	Detailed Analysis Section
Hamilton-Whakamaru 220 kV circuit *or* *Hamilton-Ohinewai 220 kV circuit*	Loss of the remaining 220 kV circuit into Hamilton-	Waikato and Bombay load, excluding Hangatiki	404/493 MVA	2.2.1
		Bombay load	51/62 MVA	2.2.2
Hamilton T6 220/110 kV interconnecting transformer	Loss of a Bombay-Otahuhu 110 kV circuit	Transfer from Otahuhu - Bombay	104/108 MW	2.2.3

1.7 LOSS OF SUPPLY

The following Grid Exit Points will lose supply when the listed outages occur and the corresponding contingent event arises.

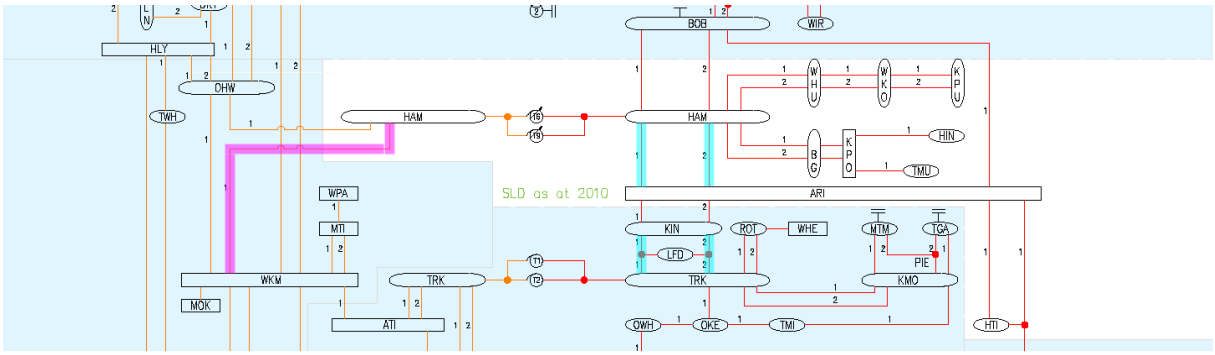
Grid Exit Point(s)	Outage	Contingent Event	Conditions
Waihou *Waikino* *Kopu*	Outage of a 110 kV circuit between Hamilton-Kopu	Loss of the other 110 kV circuit between Hamilton-Kopu	
Cambridge *Hinuera* *Te Awamutu*	Outage of a Hamilton-Karapiro 110 kV circuit	Loss of the other Hamilton-Karapiro 110kV circuit	Loss of supply occurs at Hinuera and Te Awamutu only, if Karapiro generation does not successfully island with the load.
Hinuera	-	Loss of the Hinuera-Karapiro 110 kV circuit	
Te Awamutu	-	Loss of the Karapiro-Te Awamutu 110 kV circuit	

2. POWER SYSTEM LIMIT ANALYSIS

2.1 ISSUES FOR NORMAL OPERATION

2.1.1 LOSS OF THE HAMILTON-WHAKAMARU-1 220 KV CIRCUIT

Grid Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures
Waikato region	Arapuni-Hamilton-1 and 2 110 kV circuits exceed stated capability	Loss of the Hamilton-Whakamaru-1 220 kV circuit	Transfer limit dependent on system conditions	Security constraints Short term ratings Arapuni Runback Scheme
Bay of Plenty	Kinleith-Tarukenga-1 and 2 110 kV circuit exceeds stated capability			110 kV bus split at Arapuni



The loss of the Hamilton-Whakamaru-1 220 kV circuit may cause the Arapuni-Hamilton-1 and 2 110kV circuits and/or the Kinleith-Tarukenga-1 and 2 110 kV circuits to exceed their stated capability depending on the levels of Upper North Island and Waikato generation.

If a 220 kV circuit north of Huntly or Whakamaru was on outage, the loss of Hamilton-Whakamaru would cause the same issues mentioned above, but at different levels of generation. The same operational measures discussed below would still apply.

2.1.1.1 Assumptions

For the purpose of the analysis, the following assumptions apply:

- Low Upper North Island generation
- Arapuni Runback is enabled
- Kinleith generation is fixed
- Pakuranga-Brownhill-Whakamaru circuits operational from Summer 2013

2.1.1.2 Sensitivities

The loading on one of the Arapuni-Hamilton 110 kV circuits and Kinleith-Tarukenga-1 110 kV circuit following the loss of the Hamilton-Whakamaru-1 110 kV circuit is affected by the generation at various stations and the Waikato and Upper North Island loads. These sensitivities are given in the following table. Note that these are indicative only and may vary based on system conditions.

Generation/Load	Arapuni-Hamilton 110 kV circuit		Kinleith-Tarukenga-1 110 kV circuit	
	2011/2012	2013	2011/2012	2013
Arapuni generation	0.239	0.237	-0.174	-0.168
Huntly generation	-0.039	-0.030	-0.028	-0.015
Karapiro generation	-0.120	-0.113	-0.086	-0.077
Otahuhu B generation	-0.038	-0.025	-0.031	-0.014
Upper North Island load	0.038	0.026	0.031	0.014
Waikato load	0.091	0.086	0.085	0.077

It can be seen that Arapuni generation has the greatest effect on the loading of both the Arapuni-Hamilton 110 kV circuits and the Kinleith-Tarukenga 110 kV circuit. The sensitivity studies show that a reduction in Arapuni generation decreases the loading on the Arapuni-Hamilton while increasing the loading on the Kinleith-Tarukenga-1 110 kV circuit. From 2013, with the Pakuranga-Brownhill-Whakamaru circuits, both circuits become less sensitive to Upper North Island load and generation.

Note that these sensitivities do not assume the 110 kV bus split at Arapuni.

2.1.1.3 Operational Measures

The following operational measures may apply:

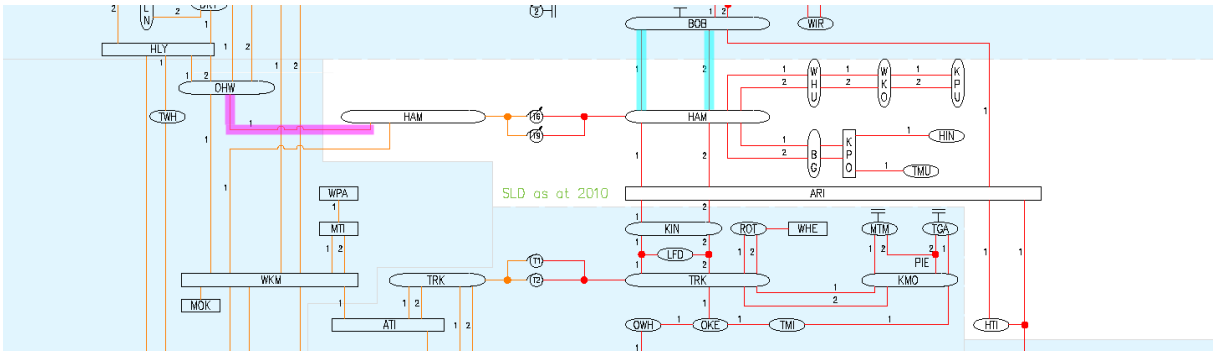
- Application of security constraints
- Use of short term ratings
- Arapuni Runback
- Constrain generation – increase Upper North Island generation
- Grid Reconfiguration including Arapuni 110 kV Bus Split

Arapuni Runback

The loss of Hamilton-Whakamaru 220 kV circuit may cause the Arapuni-Hamilton 110 kV circuits to exceed their stated capability, and under certain system conditions the operation of the Arapuni runback scheme may cause the Kinleith-Tarukenga-1 110 kV circuit to exceed its stated capability. By removing Arapuni-Kinleith 110 kV circuits or splitting the Kinleith 110 kV bus as pre-contingent operational measures may alleviate this issue. However, both grid reconfigurations have an impact on Kinleith's security. The Arapuni 110 kV bus split was implemented to alleviate these issues.

2.1.2 LOSS OF THE HAMILTON- OHINEWAI-1 220 KV CIRCUIT

Grid Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Upper North Island loads, Waikato generation	Bombay-Hamilton-1 and 2 110 kV circuits exceed stated capability	Loss of the Hamilton-Ohinewai-1 220 kV circuit	Varies based on system conditions	Security constraints Short term ratings	1.6.1



The loss of the Hamilton-Ohinewai-1 220 kV circuit may cause the Bombay-Hamilton-1 and 2 110 kV circuits to exceed their stated capability under the conditions of low generation in the Upper North Island region and high Waikato generation.

2.1.2.1 Assumptions

For the purpose of the analysis, the following assumptions apply:

- Low Upper North Island generation
- Pakuranga-Brownhill-Whakamaru circuits operational from Summer 2013

2.1.2.2 Power System Analysis due to Asset Capability

Power system capability limits on the transfer from Hamilton to Bombay are required to avoid Bombay-Hamilton-1 and 2 110 kV circuits exceeding their stated capability following the loss of the Hamilton-Ohinewai-1 220 kV circuit. The transfer prior to the loss will vary based on system conditions.

2.1.2.3 Sensitivities

The loading on one of the Bombay-Hamilton circuits following the loss of the Hamilton-Ohinewai-1 220 kV circuit is affected by the generation at various stations, and to some extent, the Upper North Island load. Sensitivities are given in the table below. Note that these are indicative only and may vary based on system conditions

Generation/Load	Sensitivity Factor	
	2011/2012	2013
Arapuni generation	0.056	0.053
Huntly generation	-0.032	-0.020
Karapiro generation	0.143	0.135

Generation/Load	Sensitivity Factor	
Otahuhu B generation	-0.042	-0.025
Upper North Island load	0.042	0.026

It can be seen that the local Waikato generation mainly Karapiro has the greatest effect on the loading on the Bombay-Hamilton-1 and 2 110 kV circuits. The lowering of the dispatch level at Karapiro will increase the allowable level of Upper North Island load.

From 2013, with the Pakuranga-Brownhill-Whakamaru circuits operational, Bombay-Hamilton-1 and 2 110 kV circuits becomes less sensitive to Upper North Island load and generation.

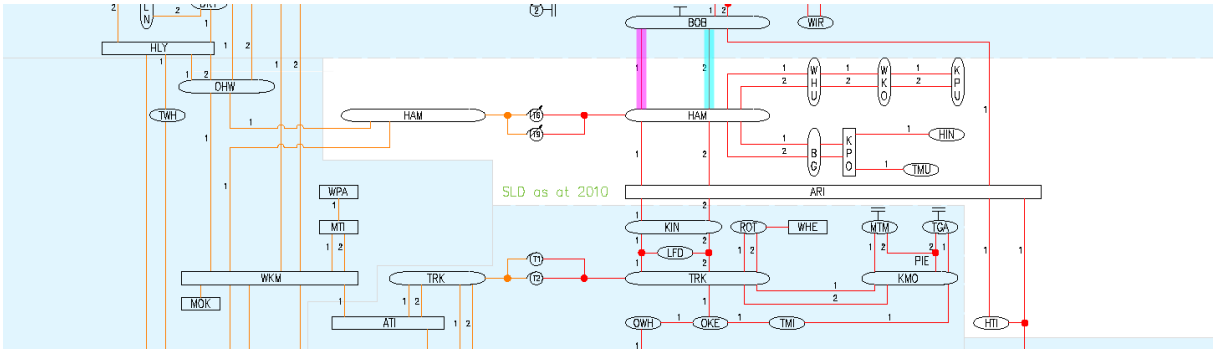
2.1.2.4 Operational Measures

The following operational measures may apply:

- Application of security constraints
- Use of short term ratings
- Grid reconfiguration – Bombay system split

2.1.3 LOSS OF ONE OF THE BOMBAY-HAMILTON 110 KV CIRCUITS

Grid Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Waikato Region	Remaining Bombay-Hamilton 110 kV circuit exceeds stated capability	Loss of one of the Bombay-Hamilton 110 kV circuits	Transfer limit on the Bombay-Hamilton 110 kV circuits 73/94 MW (summer/winter)	Short term ratings Security constraints Grid Reconfiguration	1.6.1



The loss a Bombay-Hamilton 110 kV circuit may cause the remaining circuit to exceed its stated capability under the conditions of low Upper North Island generation.

From 2013 the new Pakuranga-Brownhill-Whakamaru circuits as part of the North Island grid upgrade project alleviates loading on the Waikato regions 110 kV network. As a result following a loss of a Bombay-Hamilton 110 kV circuit, the remaining circuit no longer exceeds its stated capability under the conditions of low Upper North Island generation.

2.1.3.1 Assumptions

For the purpose of the analysis, the following assumptions apply:

- Low Upper North Island generation
- Pakuranga-Brownhill-Whakamaru circuits operational from Summer 2013

2.1.3.2 Power System Analysis due to Asset Capability

Power system capability limit on the transfer between Hamilton and Bombay is required to avoid the remaining circuit exceeding its stated capability following the loss of the other Bombay-Hamilton 110 kV circuit. The indicative power system capability limits on transfer are 73/90 MW (summer/winter). From summer 2013 the transfer limits are unchanged but, due to the reduced loading on the Waikato 110 kV network, are no longer reached for the system conditions of low Upper North Island generation.

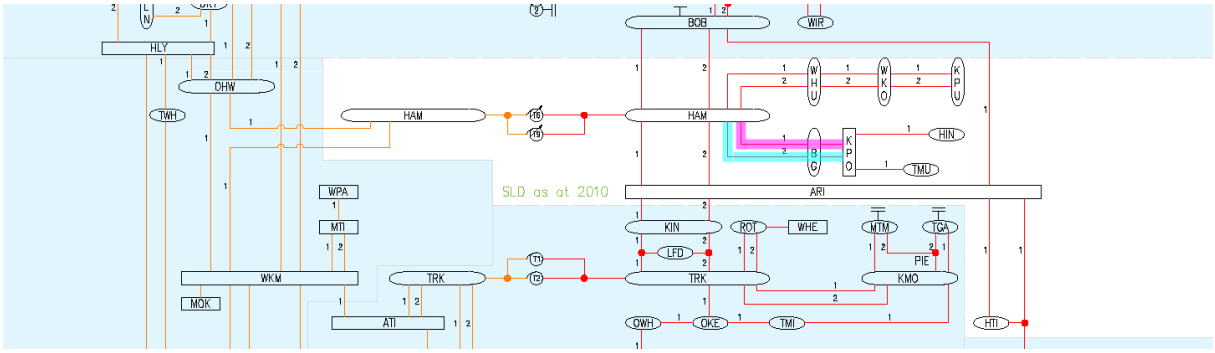
2.1.3.3 Operational Measures

The following operational issues may apply:

- Use of short term ratings.
- Application of security constraints
- Constraining generation – Increase Upper North Island generation
- Grid reconfiguration – Bombay system split

2.1.4 LOSS OF ONE OF THE HAMILTON-KARAPIRO 110 KV CIRCUITS

Grid Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Karapiro	Remaining Hamilton-Karapiro 110 kV circuit exceeds stated capability	Loss of the one of the Hamilton-Karapiro 110 kV circuits	Transfer limit of 57/70 MW	Security constraints Constrain generation	1.6.1



The loss of one of the Hamilton-Karapiro 110 kV circuits may cause the remaining circuit to exceed its stated capability under the system conditions of high Karapiro generation and low Hinuera and Te Awamutu load.

2.1.4.1 Assumptions

For the purpose of the analysis, the following assumptions apply:

- High Karapiro generation
- Low Hinuera and Te Awamutu load

2.1.4.2 Power System Analysis due Asset Capability

The combined power transfer on the two Hamilton-Karapiro 110 kV circuits is limited by the capacity of one circuit, following the loss of the other circuit. The power system capability limit is on transfer from Karapiro to Hamilton is approximately 57/70 MW (summer/winter). Karapiro generation is limited to the capability of the remaining Hamilton-Karapiro circuit plus the Hinuera and Te Awamutu loads.

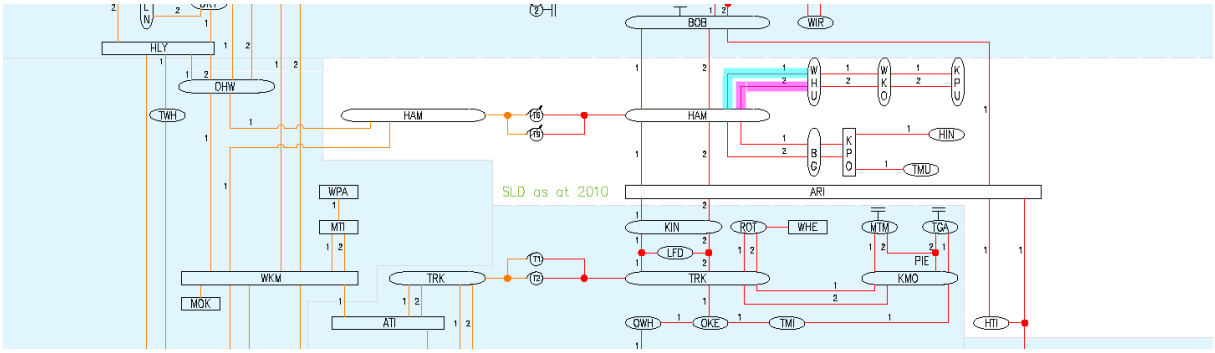
2.1.4.3 Operational Measures

The following operational measures may apply:

- Application of security constraints
- Constrain generation – Reduce Karapiro Generation

2.1.5 LOSS OF ONE OF THE HAMILTON-WAIHOU 110 KV CIRCUITS

Grid Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures
Waihou Waikino Kopu	Avoid grid voltage falling below advised capability	Loss of one the Hamilton-Waihou 110 kV circuits	High loads at Waihou and Waikino	Pre contingent bus voltages



The Hamilton-Waihou-1 and 2 110 kV circuits are a section of what is known as the "Valley Spur", which is a double circuit 110 kV radial line from Hamilton supplying demand at Waihou, Waikino and Kopu substations. The loss of one of the Hamilton-Waihou 110 kV circuits may cause grid voltages to fall below minimum allowed voltage limits.

2.1.5.1 Assumptions

- Supply transformer taps at Waihou and Waikino are fixed.

2.1.5.2 Power System Analysis Due to low grid voltages

The low voltages that occur are related to the load at Waihou and Waikino 33 kV grid exit points.

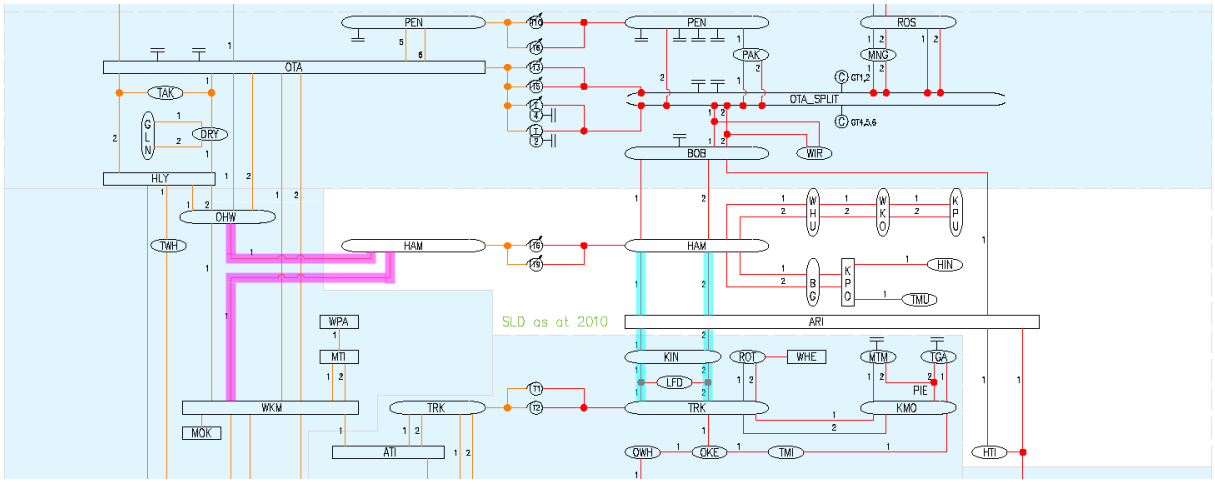
2.1.5.3 Operational Measures

Raising the voltage set points on the 110 kV busses in the Waikato region pre-contingent attempts to restrict grid voltages on the Valley spur from falling below allowed voltage limits following the loss of a Hamilton-Waihou 110 kV circuit. However, low voltage issues may still arise depending on the load and power factor at Waihou and Waikino, post-contingent measures will further mitigate these issues.

2.2 ISSUES DURING OUTAGES

2.2.1 OUTAGE OF EITHER HAMILTON-WHAKAMARU-1 OR HAMILTON-OHINEWAI-1 220 KV CIRCUITS AND THE LOSS OF THE OTHER CIRCUIT

Grid Exit Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Waikato Region (excluding Hangatiki) Bombay	Parallel 110 kV network exceeds stated capability Loss of supply	Outage on either the Hamilton-Whakamaru-1 or Hamilton-Ohinewai-1 220 kV circuits and loss of the other circuit		Grid reconfiguration Security constraints	1.6.1



An outage of the Hamilton-Ohinewai-1 or Hamilton-Whakamaru-1 220 kV circuits removes a significant in-feed to the Waikato region.

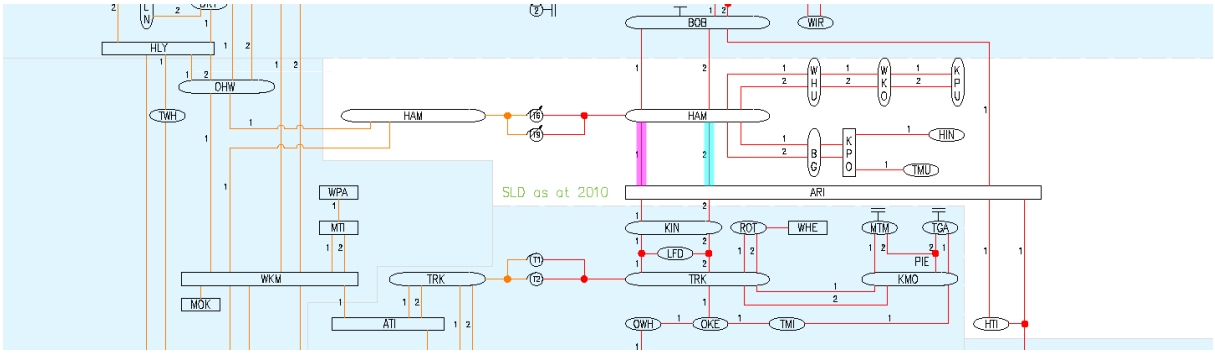
For the outage of either 220 kV circuit into Hamilton the grid will be reconfigured by system splits north of Bombay and Arapuni, placing the Waikato and Bombay load on N security for the loss of the remaining 220 kV circuit. This requires the combined Waikato (excluding Hangatiki) and Bombay loads to be limited to the rating of remaining 220 kV circuit into Hamilton in both cases 404/493 MVA (summer/winter). The loss of the remaining 220 kV circuit will cause a loss of supply to Waikato and Bombay loads.

Further to this Bombay load is limited by the asset capability of a single Bombay-Hamilton 110 kV circuit 51/62 MVA (summer/winter) to ensure for a loss of a Bombay-Hamilton 110 kV circuit that the remaining circuit does not exceed its stated asset capability.

Operational measures to manage these issues are that load management may be required at Bombay and Waikato regional loads.

2.2.2 OUTAGE OF ONE OF THE ARAPUNI-HAMILTON 110 KV CIRCUITS AND LOSS OF ANOTHER CIRCUIT

Grid Exit Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Waikato	Arapuni-Hamilton 110 kV circuits exceeds stated capability	Outage of one of the Arapuni-Hamilton 110 kV circuits and loss of another circuit	N/A	Short term ratings Security constraints Special protection Scheme	1.6.1



An outage of one of the Arapuni-Hamilton 110 kV circuits removes an in-feed into the Waikato region. The loss of a parallel 220 kV or the Arapuni-Bombay 110 kV circuit may cause the remaining Arapuni-Hamilton 110 kV circuit to exceed stated capability.

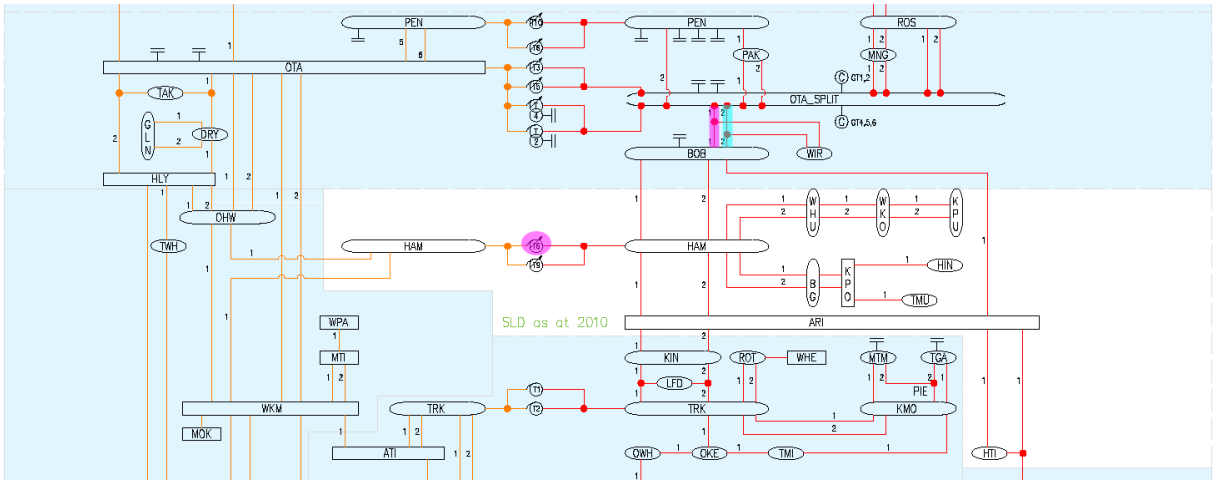
The Arapuni 110 kV Bus Split has been implemented to reduce possible pre-contingency constraints of generation at Arapuni.

The Arapuni runback scheme is an operational measure to manage the power system issue. With the scheme enabled the loss of any circuit resulting in the remaining Arapuni-Hamilton 110 kV circuit exceeding its stated capability, Arapuni generation will be runback to alleviate the overloading.

Note that with the Arapuni 110 kV bus split generators connected to the South Bus, where the Arapuni-Kinleith circuits are connected, will not be subjected to the Arapuni Runback Scheme (generation reduction and sequential tripping).

2.2.3 OUTAGE OF THE HAMILTON T6 TRANSFORMER AND THE LOSS OF BOMBAY-OTAHUHU-1 110KV CIRCUIT

Grid Exit Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Waikato 110 kV load	Bombay-Otahuhu 110 kV circuits exceed stated capability	Outage of the Hamilton T6 220/110 kV transformer and the loss of a Bombay-Hamilton circuit	104/108 MW (summer/winter)	Short term ratings, Security constraints Grid reconfiguration Constrain generation	1.6.1



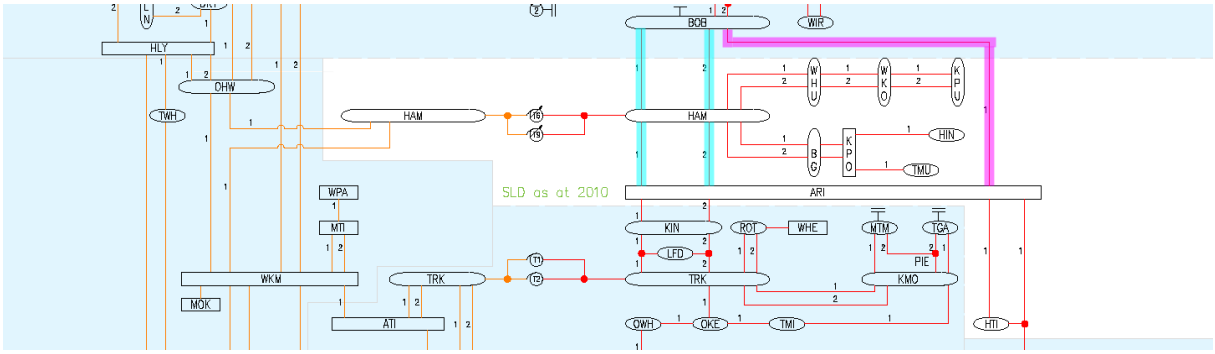
An outage of the Hamilton T6 220/110 kV transformer and the loss of one of the Bombay-Otahuhu 110 kV circuits may cause the remaining Bombay-Otahuhu circuit to exceed its stated capability. These issues are prevalent when Waikato generation low.

A power system capability limit on the transfer between Otahuhu and Bombay is required to avoid the remaining Bombay-Otahuhu 110 kV circuit exceeding its stated capability following the loss of the other circuit. This limit is affected by both Waikato generation and the load at Bombay and Wiri. Indicative power system capability limits on transfer between Otahuhu and Bombay are 104/108 MW (summer/winter).

Operational measures to manage the power system issue are the use of short term ratings, security constraints, grid reconfiguration – Bombay system split or to constrain Waikato generation above a minimum level depending on system conditions.

2.2.4 OUTAGE OF THE ARAPUNI-BOMBAY 110 KV CIRCUITS AND LOSS OF ANOTHER CIRCUIT

Grid Exit Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures	Back to Limit Group
Local generation	Parallel 110 kV circuits exceed stated capability	Outage of the Arapuni-Bombay 110 kV circuit and loss of another circuit	N/A	Short term ratings Security constraints Arapuni Runback scheme	1.6.1

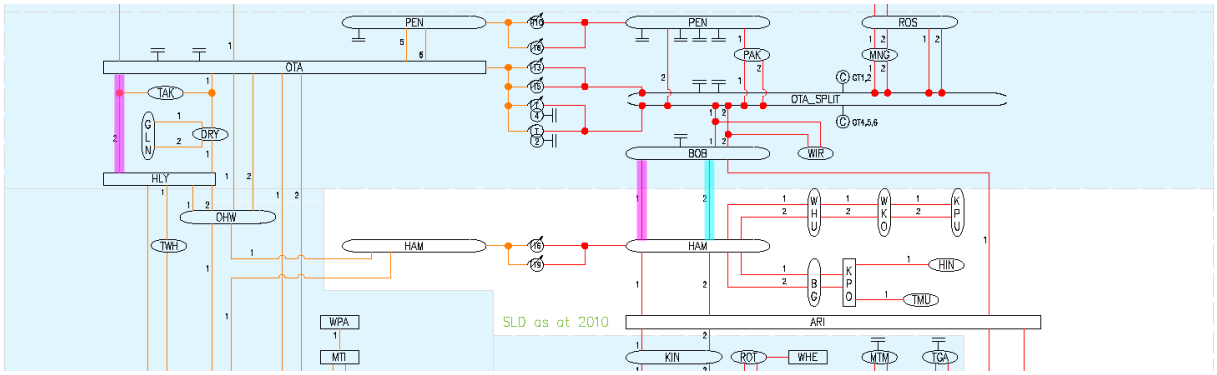


An outage of the Arapuni-Bombay 110 kV circuits and the loss of a parallel 220 kV or 110 kV circuit under the conditions of low Upper North Island generation may cause any one of the 110 kV circuits between Arapuni-Hamilton and Hamilton-Bombay to exceed stated capability.

Operational measures to manage the power system issues are the use of short term ratings, security constraints, grid reconfiguration – Bombay split, Arapuni Runback or to constrain Upper North Island generation above a minimum level depending on system conditions.

2.2.5 OUTAGE OF ONE OF THE BOMBAY-HAMILTON 110 KV CIRCUITS AND LOSS OF HUNTLY-OTAHUHU OR HAMILTON-OHINEWAI 220KV CIRCUIT

Grid Exit Point	Power System Issue	Causing Factor	Indicative Limit	Operational Measures
Bombay	Bombay-Hamilton 110 kV circuits exceed stated capability	Outage of one of the Bombay-Hamilton 110 kV circuits and loss of another circuit	N/A	Short term ratings Security constraints



An outage of one of the Bombay-Hamilton 110 kV circuit and the loss of a either Huntly-Otahuhu or Hamilton-Ohinewai 220 kV circuits under the conditions of low Upper North Island generation, may cause the remaining Bombay-Hamilton 110 kV circuit to exceed its stated capability.

From 2013 the new Pakuranga-Brownhill-Whakamaru circuits as part of the North Island grid upgrade project alleviates loading on the Waikato regions 110 kV network. This results in only a loss of the Hamilton-Ohinewai 220 kV circuit having an effect on the remaining Bombay-Hamilton 110 kV circuit under the conditions of very low upper north island generation.

The loading on one of the Bombay-Hamilton circuits following the loss of the Huntly-Otahuhu 220 kV circuit is affected by the generation at various stations and the local load a Bombay. Sensitivities are given in the table below. Note that these are indicative only and may vary based on system conditions.

Generation/Load	Sensitivity factor	
	2011/2012	2013
Bombay Load	0.168	0.164
Karapiro generation	0.097	0.099
Upper North Island load	0.035	0.025
Arapuni generation	0.030	0.033
Huntly generation	-0.010	-0.004
Otahuhu B generation	-0.040	-0.025

Operational measures to manage the power system issues are the use of short term ratings, security constraints, grid reconfiguration – Bombay split, or to constrain Upper North Island generation above a minimum level depending on system conditions.