TRANSPOWER

System Security Forecast 2022

Part D

Power System Security Analysis

Grid Zone 8 Wellington

Issued December 2022

IMPORTANT

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1. GRID ZONE 8 NETWORK OVERVIEW

Grid Zone 8 comprises the Wellington region, which is bordered by and includes Mangamaire and Paraparaumu in the north. It is supplied over 220 kV and 110 kV transmission circuits with interconnecting transformers at Haywards and Wilton. The HVDC link, static capacitors, a STATCOM and synchronous condensers are installed at the Haywards substation. There is wind generation at West Wind and Mill Creek.

The Wellington region is shown geographically and schematically in Figure 1-1 and Figure 1-2.

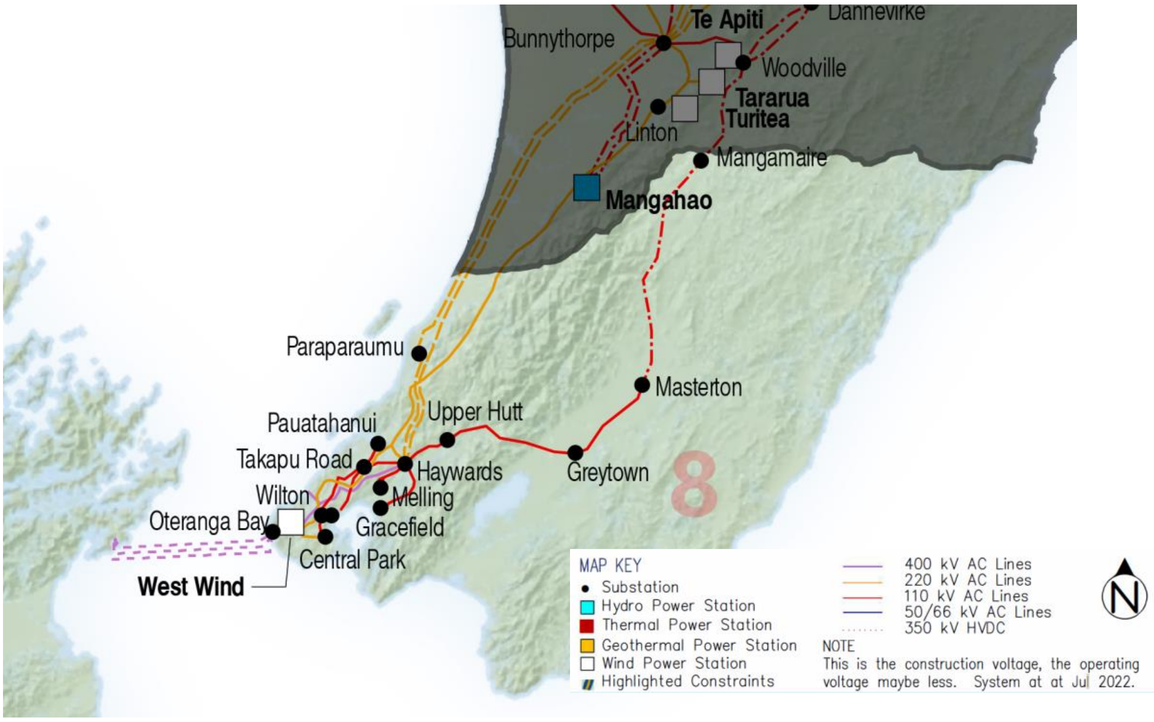

Figure 1-1 Geographic representation of Grid Zone 8

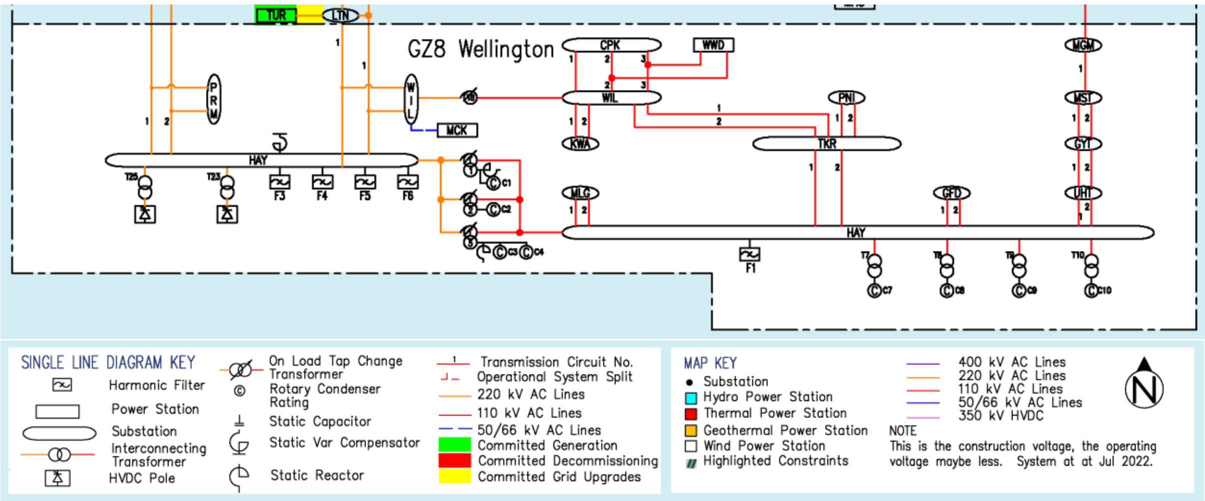

Figure 1-2 Schematic representation of Grid Zone 8

2. COMMITTED UPGRADES

There are no committed upgrades in the zone over the period of this study.

3. DEMAND AND GENERATION

The northern end of the HVDC link terminates at Haywards. Grid-connected generation capacity in Grid Zone 8 is approximately 202.4 MW, as shown in Table 3-1.

Table 3-1: Location, type, and capacity of generators in Grid Zone 8

Station	Type	MW
Mill Creek	Wind	59.8
West Wind	Wind	143

Generation outside Grid Zone 8 impacts power transfer into or out of this zone as this generation is connected to the transmission lines supplying Grid Zone 8. The generation capacity outside but influencing Grid Zone 8 is approximately 427.6 MW, increasing to 530 MW in quarter 4 of 2023, as outlined in Table 3-2.

Table 3-2: Location, Type, and capacity of generators influencing transfer into Grid Zone 8

Station	Type	MW
Tararua Central	Wind	93.0
Tararua North	Wind	34.3
Tararua South	Wind	33.7
Te Rere Hau	Wind	48.5
Turitea North	Wind	119
Turitea South	Wind	102[1]
Te Apati	Wind	99.3

The winter regional peak demand in Grid Zone 8 is expected to grow from 702 MW in 2022 to 775 MW in 2025. Peak and trough demand in Grid Zone 8 for the forecast period is shown in Table 3-3.

Table 3-3: Demand forecast in Grid Zone 8

Demand (MW)	2022	2023	2024	2025
Summer peak	463	478	499	510
Winter peak	702	728	757	775
Summer trough	172	174	180	181
Winter trough	219	225	233	237

The load duration curve for the regional loads between June 2021 and June 2022 is shown in Figure 3-1. The figure also includes the load duration curve for Grid Zone 8 net of the West Wind generation. This illustrates the effect of West Wind generation has upon the load being fed by the Haywards and Wilton

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[1] Turitea South Wind Farm will be commissioned in stages from Dec 2022 – April 2023.

220/110 kV interconnecting transformers. The load that is supplied by these transformers is used by the HVDC control system to estimate the GZ8 load for the purpose of calculating the HVDC power limit. Consequently, generation at West Wind offsets the control systems GZ8 load calculation. Mill Creek wind generation, which is connected to the 220 kV network and not fed by the Wilton interconnecting transformer, will not change the HVDC control system load calculation. This is discussed further in relation to the HVDC power limits in section 4.2.

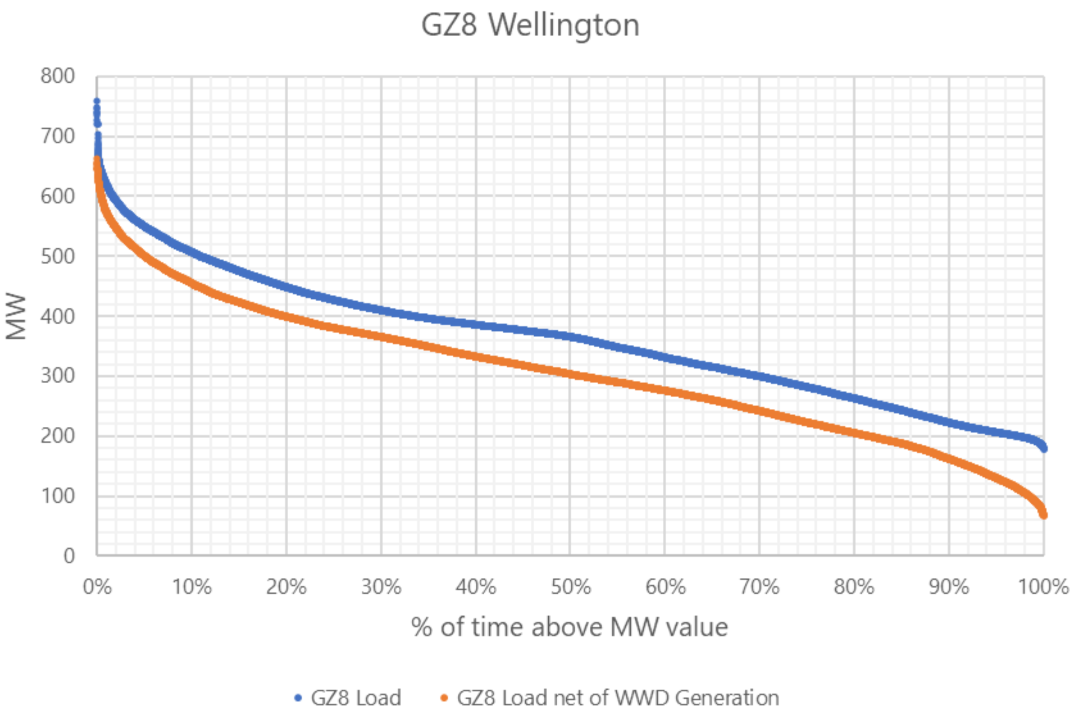

Figure 3-1 Load duration curve Grid Zone 8

3.1 WIND GENERATION CONTRIBUTION

The minimum-wind to maximum-wind generation range for all the wind generators identified in section 3 is from 0 MW to 732.6 MW. Based on historical data there is no correlation between wind output and system load and there is no significant correlation between wind output and time of year, therefore, the full range of wind output could occur at any time. There is, however, a significant correlation between the wind outputs of the lower North Island windfarms, so studies assume all the windfarms are at the same percent output across the region.

4. ASSUMPTIONS AND BACKGROUND

The following assumptions and background information were considered for Grid Zone 8 studies unless specified otherwise in the detailed analysis.

4.1 HVDC CAPABILITY

The maximum HVDC transfer capability is shown in Table 4-1 at a power factor of 0.9. All reactive power plant at Haywards must be available to facilitate these transfer capabilities.

Table 4-1:Maximum HVDC transfer capability

HVDC Transfer	MW (sent)	MW (received)
North transfer	1200	1132
South transfer	850	816

The installed capacity of generation in the North Island is now approximately 6,500 MW which includes 1,000 MW of wind generation and the forecast North Island winter peak load in 2023 is approximately 5,200 MW excluding system losses.

4.2 HVDC POWER LIMITS AND RUNBACKS AT HAYWARDS

The HVDC control system automatically applies a lower maximum transfer capability limit (known as a power limit) during network outages and certain other network conditions. The calculation of the power limits is quite complex. It is summarised briefly below for Haywards, with a description of the potential effect on the north and south transfer constraints related to the HVDC link.

The automatic limiting action is applied across all load conditions but for different conditions. For example, under low load conditions, during outages, the maximum transfer is limited in both directions. This limitation is to avoid excessive over-voltages if the bipole power transfer is interrupted when all the AC harmonic filters are in service. In addition to a bipole trip, a bipole power interruption can occur for an AC network fault at the other end of the HVDC link. Another example is under high load conditions, with or without outages, in which case the maximum transfer is limited in south flow to ensure that there is sufficient reactive power margin at Haywards to maintain voltage control.

The control system uses a range of real-time data inputs to determine a limit. For Haywards this includes the DC power direction, an estimate of the GZ8 load, the status of all the 220 kV transmission circuits from north of Bunnythorpe to Haywards, and the status and reactive power output of all the reactive power plant at Haywards (i.e. the AC harmonic filters, condensers, and the STATCOM).

The load is measured as this is a significant factor for how much the maximum HVDC transfer needs to be limited. The HVDC control system does not measure the Grid Zone 8 load directly, instead it uses the measurement of power flowing in the Haywards and Wilton 220/110 kV interconnecting transformers plus a measure of the load at Paraparaumu 33 kV substation to approximate this. Of the lower North Island wind generation, only West Wind is within this measurement boundary. Mill Creek connects to the 220 kV at Wilton Substation via the 33 kV so is outside this measurement boundary.

4.2.1 HVDC north flow limits with an intact network

The Grid Zone 8 load net of West Wind output is a good approximation to the value that the HVDC control system will be using during north flow conditions on the HVDC link as shown in Table 4-2.

Table 4-2: HVDC transfer and Grid Zone 8 load – North flow scenario

Year	HVDC north flow (MW)	GZ8 demand (MW)	HVDC load measurement(1): minimum wind (MW)	HVDC load measurement: max wind (MW)
2022 Summer Peak	1200	463	448	310
2023 Winter Peak	1200	728	677	538

(1) HVDC load measurement is the combined MW value measured at Haywards and Wilton 220/110 kV interconnecting transformers plus the load measured at Paraparaumu 33 kV substation.

4.2.2 HVDC north flow limits for AC circuit outages

During north flow, the maximum reduction to the HVDC north flow limit, due to a 220 kV circuit outage, is applied for load measured below 250 MW. The reduction to HVDC north flow limit decreases linearly to zero for loads between 250 and 500 MW. For each 220 kV circuit outage between Bunnythorpe and Haywards the maximum reduction is 150 MW[2], and for the Haywards to Wilton 220 kV circuit the maximum reduction is 100 MW. An example is shown below in Table 4-3.

Table 4-3: HVDC transfer limits example – North flow outage scenario

Outage Scenario	HVDC load measurement (MW)	HVDC north transfer power limit (MW)
220 kV circuit out of service between Bunnythorpe and Haywards (except Haywards to Wilton 220 kV circuit), all other circuits in service and reactive power equipment available	<= 250	1050
	375	1125
	>= 500	1200

The HVDC north transfer power limit may remove the need for constraint equations to be applied during N-1 and N-1-1 outage conditions, especially for low load and high wind output conditions.

4.2.3 HVDC south flow limits with an intact network

For south flow, the HVDC control system applies a power limit of 850 MW for load measurements up to 400 MW. This then reduces with a slope of 1.383 MW/MW for loads above 400 MW. When power is flowing south into the Wellington area from Mangamaire on the Mangamaire-Masterton 1 110 kV circuit, the HVDC load measurement will be lower than the actual Grid Zone 8 load. This is due to a combination of West Wind and south power transfer on the Mangamaire-Masterton 1 110 kV circuit; reducing the net load seen by the Grid Zone 8 interconnecting transformers. The indicative maximum HVDC south flow for the peak demand conditions in these studies is shown below in Table 4-4.

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[2] Circuits that are in series are not double counted.

Table 4-4: HVDC transfer and Grid Zone 8 load – South flow scenario

Year	GZ8 demand (MW)	HVDC load measurement (MW)	HVDC south flow power limit (MW)
2022 Summer Peak (minimum wind)	463	362	850
2022 Summer Peak (max wind)	463	208	850
2023 Winter Peak (minimum wind)	728	604	567
2023 Winter Peak (max wind)	728	448	783

4.2.4 HVDC south flow limits for AC circuit outages

Outages reduce the HVDC south flow limit further. For south transfer at times of low system load there is an HVDC control system calculated limitation to limit over-voltages, similar to the north flow case. However, for south transfer at high system load, there is a second limit calculated for outages to ensure the reactive power margin is retained. This second limit applies a maximum reduction at loads above 500 MW, reducing linearly to zero for loads below 250 MW. For south flow at high load, the maximum reduction is 100 MW for the first 220 kV circuit outage, and 150 MW for each subsequent 220 kV circuit outage. The final south flow limit is the lowest of the calculated limits. As outages have their maximum effect on the power limit at both low and high system demand, the best possible south transfer during outages is often for medium system demand periods.

The HVDC south transfer power limit assumes favourable operating conditions and high windfarm output from all the lower north island windfarms to avoid the introduction of constraints. The power limits are therefore unlikely to be achieved on the network under normal operation, and it is likely that constraint equations will be applied, resulting in lower transfer limits than those permissible by the HVDC control system.

4.2.5 HVDC runbacks

The HVDC control system can also apply an automatic reduction to its MW transfer level (known as a runback) under certain conditions, even if the transfer level is below the maximum power limit. This runback is a single reduction of 100 MW in the dispatched power level which is applied as a slow ramp (100 MW/minute). For Haywards, two conditions that could trigger a runback are if the 220 kV bus voltage is below 209 kV for 5 seconds, or if there is less than 80 Mvar of reactive power margin for 30 seconds. These runbacks are intended to ensure that even with unusual operating circumstances the HVDC power transfer does not create a voltage stability issue. These runbacks do not over-ride the frequency keeping control (FKC), and because this is the normal operation of the HVDC link, both the voltage and reactive power conditions noted above are avoided using manual constraints.

For the cases presented here, the voltage stability limit for south flow into Grid Zone 8 ensures that there is a minimum 80 Mvar reactive power margin post fault. This usually requires a pre-contingent reactive power margin of approximately 200 Mvar. The Mvar margin requirement produces very similar results to the more conventional method of determining the voltage stability limit by applying a 5% load margin and then reducing the maximum achievable transfer by 5%.

4.3 BUNNYTHORPE-WOODVILLE 1 AND 2 OVERLOAD PROTECTION SCHEME

The Bunnythorpe-Woodville 1 and 2 110 kV scheme is usually enabled. This scheme manages overloading on the two circuits via three stages:

Stage 1 – when one Bunnythorpe-Woodville circuit overloads and either circuit breaker is open on the other Bunnythorpe-Woodville circuit, the Mangamaire-Woodville 1 110 kV circuit is opened. This addresses overloading during both HVDC north and south transfer.
Stage 2 – when either circuit overloads, a runback of Te Apiti generation starts after a time delay and continues until the overload is removed. This addresses any remaining overloading due to high Te Apiti generation.
Stage 3 - if the runback signal in Stage 2 is still active after a set time, Te Apiti generation is tripped (unless it has already run back to zero and only the local service supply remains).

Stage 1 is disabled for a system split, circuit outage between Woodville-Mangamaire-Masterton 110 kV, or an outage of the Woodville 110 kV bus (unless both Bunnythorpe-Woodville 1 and 2 110 kV circuits are still in-service).

This scheme does not provide overload protection of the Bunnythorpe-Woodville circuits when both are in service. Overloads can occur on these circuits for contingencies on the 220 kV network during HVDC south flow, with a 220 kV circuit outage south of Bunnythorpe, and low generation at Te Apiti. Under such conditions, a thermal constraint is required to prevent the overloading, and such a constraint reduces the maximum HVDC south transfer that could be achieved. The HVDC south transfer may also be constrained if the Woodville-Mangamaire 1 or Mangamaire-Masterton 1 110 kV circuit were opened to mitigate the overloading of the Bunnythorpe-Woodville circuits.

4.4 BUNNYTHORPE–MATAROA REACTOR AND OVERLOAD PROTECTION SCHEME

To allow maximum HVDC north transfer during periods of high wind generation, some action is required to address the potential overload of the Bunnythorpe-Mataroa 1 and Mataroa-Ohakune 1 110 kV circuits. A series reactor has been installed at Mataroa on the Bunnythorpe-Mataroa circuit to allow higher pre-contingency generation and is normally in service. Alongside this series reactor, the BPE-MTR circuit overload protection scheme has been developed and will normally be enabled.

If an overload is detected on the Mataroa end of the Bunnythorpe-Mataroa line, Stage 1 of the SPS confirms that the Mataroa reactor is in service, or if it is not, it opens the Mataroa reactor bypass circuit breaker thereby putting the Mataroa reactor in service. If the overload is still present, Stage 2 of the SPS will trip the Mataroa end of the Mataroa-Ohakune line.

4.5 MANGAMAIRE OVERLOAD TRIP AND AUTO-CHANGE OVER SCHEME

This scheme is installed at Mangamaire and is usually disabled. With the reconductoring of the Mangamaire-Woodville 1 and Mangamaire-Masterton 1 110 kV circuit, the overload function is no longer used, with only the auto-changeover function still functional.

This scheme is enabled when the 110 kV is split at Mangamaire on the Mangamaire-Masterton 1 110 kV circuit. With the voltage present on the Mangamaire-Masterton 1 circuit and the Mangamaire-Masterton 1 circuit breaker open, if no voltage is present on the Mangamaire-Woodville 1 110 kV circuit then Mangamaire switches over and is supplied from the Mangamaire-Masterton 1 110 kV circuit after a 1-second delay. Note that the auto-changeover does not work in the reverse direction, i.e. it will not switch Mangamaire supply from Masterton to Woodville.

The auto-changeover function improves security to Mangamaire.

4.6 CENTRAL PARK TRANSFORMER OVERLOAD PROTECTION SCHEME

The Central Park Transformer Overload Protection Scheme is usually disabled. It is enabled during a planned outage of a Central Park 110/33 kV transformer with or without the associated circuit outage.

It monitors the loading on the in-service Central Park 110/33 kV transformers. On detection of an overload, which can happen on the loss of the second transformer, it commences tripping of Central Park feeders until loading is restored within the applicable rating.

This scheme removes the need to split the Central Park 33 kV bus pre-event which can present supply risks and ripple control issues for Wellington Electricity.

4.7 TARANAKI COMBINED CYCLE (SPL) SENSITIVITY

Studies were performed on the possibility of Taranaki Combined Cycle (SPL) closing at the end of 2024. The 2025 winter and summer studies were performed with both “SPL In” and “SPL out” scenarios to demonstrate the effect of its closure. When in service, the following generation assumptions were made regarding SPL:

- During summer north transfer, SPL was assumed to not be running during both the “minimum wind” and “maximum wind” scenarios.
- During summer south transfer, SPL was assumed to be running at maximum output during both the “minimum wind” and “maximum wind” scenarios.
- During all winter transfer scenarios, SPL was assumed to be running at maximum output.

5. STEADY STATE VIOLATIONS

Table 5-1 shows the network violations within Grid Zone 8, that occur during steady state network conditions with all circuits in-service. Table 5-1 also outlines the operational measures likely to be taken during these violations, as well as the constraint equation or the indicative transfer limit. The constraint equations and transfer limits are only indicative as actual limits and constraint equations depend on real-time system conditions.

Table 5-1: Summary of steady state violations

Effect on System	Scenario	Operational Measure	Constraint Equation	Detailed Analysis Section
Overload of BPE-MTR-1 110 kV circuit in steady state conditions.	Peak demand, all years, north HVDC flow, maximum wind output. Winter with SPL in service and summer (SPL out).	Limit power transfer northwards using branch constraints or apply system split on the BPE-MTR 1 110 kV circuit	1 * BPE_MTR1.1 < 57/70 MW (summer/winter)	9.1.1
Overload of RPO-TNG-1 220 kV circuit in steady state conditions	Peak demand, south HVDC flow, minimum wind output. All years and seasons. SPL in and out of service.	Limit power transfer southwards using branch constraints.	1 * RPO_TNG1.1 < 239/291 MW (summer/winter)	-

6. CONTINGENCIES UNDER INTACT NETWORK CONDITIONS (N-1)

Table 6-1 shows the circuits that caused network violations within Grid Zone 8 if they trip under an intact network scenario, with all other circuits in service. The circuit that tripped is referred to as a contingency. It also outlines the operational measures likely to be taken during these contingencies, including the constraint equation or the indicative transfer limit. The transfer limit and constraint equations are only indicative, as actual limits and constraint equations will depend on real-time system conditions.

Table 6-1: Contingencies during intact network conditions

Contingency	Effect of Contingency	Scenario	Operational Measure/ Constraint Equation	HVDC Transfer Limit (MW)[3]		Detailed Analysis Section
				Summer	Winter	
HAY-WIL-LTN-1 or 2 220 kV circuit	Voltage stability limit reached in the Wellington region	All years, all seasons, HVDC south flow, peak demand, maximum wind output. SPL in and out of service.	Limit HVDC south transfer to ensure: 1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 + -1 * HAY_WIL_LTN1.1 + -1 * HAY_WIL_LTN1.2 + -1 * MGM_WDV1.1 < 1046 (summer) and < 1102 (winter)	SPL in 760 SPL out 743	SPL in 637 SPL out 518	9.2.1
HAY-WIL-LTN-1 or 2 220 kV circuit	Overload on BPE-WDV 1 and 2 110 kV circuit	All years, all seasons, HVDC south flow, peak demand, minimum wind output. SPL in service.	Limit HVDC south using thermal constraints Winter: 1.08 * BPE_WDV1.1 + -0.07 * HAY_WIL_LTN1.1 <= 73.4 MW Summer: 1.08 * BPE_WDV1.1 + -0.05 * HAY_WIL_LTN1.1 <= 61.3 MW	360 south	215 south	9.2.1

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[3] HVDC Transfer is specified as the value at Haywards. So north flow is the MW figure received at Haywards, and south flow is the MW figure sent from Haywards.

7. CONTINGENCIES DURING PLANNED OUTAGES (N-1-1)

A trip of an asset while another asset is on outage is known as a planned outage with a contingency combination or an N-1-1 contingency. Some N-1-1 combinations can cause network violations within Grid Zone 8. For each asset outage, the worst N-1-1 combination was examined in detail, and operational measures taken to clear identified network violations are outlined. These operational measures were applied and the system studies were undertaken again to ensure all network violations were cleared for the particular N-1-1 contingency study being examined.

The contingencies under planned outages that caused the worst network violations in Grid Zone 8 are detailed in the following tables:

- Table 7-1 shows the winter contingencies during north flow on the HVDC link
- Table 7-2 shows the summer contingencies during north flow on the HVDC link
- Table 7-3 shows the winter contingencies during south flow on the HVDC link
- Table 7-4 shows the summer contingencies during south flow on the HVDC link

The transfer limit and constraint equations are only indicative, as actual limits and constraint equations depend on real-time system conditions.

The light load conditions did not result in any post contingency voltage outside the ±10 percent of 220 kV and 110 kV voltages.

Table 7-1: Contingencies during planned outages – Winter HVDC north flow

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW)	Detailed Analysis Section
					Winter 2025	
HAY-WIL-LTN-1 or 2 220 kV circuit	HAY-UHT-1 or 2 110 kV circuit	Overload of the remaining HAY-UHT 110 kV circuit	Winter peak loads from 2025, minimum wind output.	Limit HVDC north transfer using security constraints: 1.00 * HAY_UHT2.1 + 0.95 * HAY_UHT1.1 <= 111 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	1120	9.3.1
HAY-WIL-LTN-1 or 2 220 kV circuit	HAY-UHT-1 or 2 110 kV circuit	Overload of the remaining HAY-UHT 110 kV circuit	Winter peak loads from 2025, maximum wind output, SPL out of service.	Limit HVDC north transfer using security constraints: 1.00 * HAY_UHT_2.1 + 0.95 * HAY_UHT_1.1 <= 113 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	1050	9.3.1
BPE-PRM-HAY-1 or 2 220 kV circuit					1050	
BPE-LTN-2 220 kV circuit					1005	
BPE-TWC-LTN-1 220 kV circuit					925	
HAY-WIL-LTN-1 or 2 220 kV circuit	Any other 220 kV circuit from HAY	No network effect	Summer and winter, all years.	HVDC is limited for over voltage control, particularly for low demand conditions.	HVDC Power Limit	9.3.2

Table 7-2: Contingencies during planned outages – Summer HVDC north flow

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW)	Detailed Analysis Section
					Summer 2025	
BPE-PRM-HAY-1 or 2 220 kV circuit	MST-GYT-UHT-1 or 2 110 kV circuit	Overload remaining MST-GYT-UHT circuit	Summer peak loads, all years, minimum wind output	Limit HVDC north transfer using thermal constraints -1.09 * MST_UHT2.2 + 0.84 * MST_UHT1.1 <= 73 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	1000	-
HAY-WIL-LTN-1 or 2 220 kV circuit					980	-
BPE-LTN-2 220 kV circuit					980	-
BPE-TWC-LTN-1 220 kV circuit					1000	-
MST-GYT-UHT-1 or 2 110 kV circuit	BPE-LTN-2 220 kV circuit			Limit HVDC north transfer using thermal constraints -1.14 * MST_UHT2.2 + -0.06 * BPE_LTN2.1 <= 75 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	950	-
MST-GYT-UHT-1 or 2 110 kV circuit	BPE-TWC-LTN-1 220 kV circuit	Overload of remaining GYT-UHT 1 or 2 section	Summer peak loads, all years, maximum wind output	Limit HVDC north transfer using thermal constraints -1.13 * MST_UHT2.2 + -0.03 * BPE_TWC_LTN1.1 <= 74.5 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	765	-
BPE-TWC-LTN-1 220 kV circuit	MST-GYT-UHT-1 or 2 110 kV circuit			Limit HVDC north transfer using thermal constraints -1.09 * MST_UHT2.2 + -0.71 * MST_UHT1.2 <= 73 MW Or, a system split on MGM-MST-1 110 kV circuit will alleviate this issue.	785	-

Table 7-3: Contingencies during planned outages – Winter HVDC south flow

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW) South Flow Winter 2025		Detailed Analysis Section
					SPL In	SPL Out	
BPE-PRM-HAY-1 or 2 220 kV circuit	BPE-LTN-2 220 kV circuit	Overload of remaining BPE-PRM-HAY circuit (BPE-PRT section)	Winter peak loads, all years, minimum wind output. SPL in and out of service.	With MGM-MST-1 110 kV circuit opened, limit HVDC south using thermal constraints (SPL out) 1.29 * BPE_PRM_HAY2.1 + 0.42 * BPE_LTN_2.1 <= 465 MW	110	75	9.3.3
HAY-WIL-LTN-1 or 2 220 kV circuit	Remaining HAY-WIL-LTN 220 kV circuit	Overload of BPE-PRM-HAY-1 and 2 220 kV circuits (BPE-PRT section)		With MGM-MST-1 110 kV circuit opened, limit HVDC south using thermal constraints 1.27 * BPE_PRM_HAY2.1 + -2.72 * HAY_WIL_LTN2.2 <= 487 MW	0	0	
BPE-LTN-2 220 kV circuit or BPE-TWC-LTN-1 220 kV circuit	BPE-TWC-LTN-1 220 kV circuit or BPE-LTN-2 220 kV circuit			With MGM-MST-1 110 kV circuit opened, limit HVDC south using thermal constraints 1.24 * BPE_PRM_HAY2.1 + 0.56 * BPE_TWC_LTN1.1 <= 476 MW	0	0	
				With MGM-MST-1 110 kV circuit opened, limit HVDC south using thermal constraints 1.24 * BPE_PRM_HAY2.1 + 0.56 * BPE_LTN_2.1 <= 476 MW	0	0	
BPE-PRM-HAY-1 or 2 220 kV circuit	HAY-WIL-LTN-1 220 kV circuit	Voltage stability limit reached in the Wellington region	Winter peak loads, all years, maximum wind output. SPL in and out of service.	Limit HVDC south using security constraints (SPL out). 1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 + -1 * HAY_WIL_LTN1.1 + -1 * HAY_WIL_LTN1.2 + -1 * MGM_WDV1.1 <= 1018 MW	440	435	-
BPE-LTN-2 220 kV circuit		Overload of BPE-PRM-HAY-1 and 2 220 kV circuits (BPE-PRT section)		Limit HVDC south using thermal constraints. 1.27 * BPE_PRM_HAY1.1 + -0.69 * HAY_WIL_LTN1.2 <= 496 MW	335	335	-

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW) South Flow Winter 2025		Detailed Analysis Section
					SPL In	SPL Out	
HAY-WIL-LTN 1 or 2 220 kV circuit	Remaining HAY-WIL-LTN 220 kV circuit circuit	Overload of BPE-PRM-HAY-1 and 2 220 kV circuits (BPE-PRT section)	Winter peak loads, all years, maximum wind output. SPL in and out of service.	Limit HVDC south using thermal constraints: 1.28 * BPE_PRM_HAY1.1 + -0.80 * HAY_WIL_LTN2.2 <= 500 MW	330	330	-
BPE-TWC-LTN 1 220 kV circuit	HAY-WIL-LTN 1 220 kV circuit	Voltage stability limit reached in the Wellington region		Limit HVDC south using security constraints (SPL out). 1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 + -1 * HAY_WIL_LTN1.1 + -1 * HAY_WIL_LTN1.2 + -1 * MGM_WDV1.1 <= 1027 MW	470	445	-
MGM-WDV 1 110 kV circuit, MGM-MST 1 110 kV circuit, any one of HAY T1, HAY T2 or HAY T5 220/110 interconnecting transformers.				Limit HVDC south using thermal constraints.	-	-	9.3.4

Table 7-4: Contingencies during planned outages – Summer HVDC south flow

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW) South Flow Summer 2025		Detailed Analysis Section
					SPL In	SPL Out	
BPE-PRM-HAY-1 or 2 220 kV circuit	BPE-LTN-2 220 kV circuit	With SPL in service, overload of remaining BPE-PRM-HAY 220 kV circuit (BPE-PRT section) With SPL out of service, overload of RPO-TNG-1 220 kV circuit	Summer peak loads, all years, minimum wind output	With MGM-MST-1 110 kV circuit **opened**, limit HVDC south transfer using thermal constraints. 1.29 * BPE_PRM_HAY2.1 + 0.42 * BPE_LTN2.1<= 448 MW Limit HVDC south using thermal constraints 1.47 * RPO_TNG1.1 + 0.01 * BPE_LTN2.1<= 346 MW	320	210	-
		Overload of BPE-WDV-1 and 2 110 kV circuits		With MGM-MST-1 110 kV circuit **closed**, limit HVDC south transfer using thermal constraints 1.08 * BPE_WDV1.1 + 0.04 * BPE_LTN2.1 <= 61.6 MW	140	140	-
HAY-WIL-LTN-1 or 2 220 kV circuit	Remaining HAY-WIL-LTN 220 kV circuit	Overload of both BPE-PRM-HAY 1 and 2 220 kV circuits (BPE-PRT section)		With MGM-MST-1 110 kV circuit **opened**, limit HVDC south transfer using thermal constraints. 1.27 * BPE_PRM_HAY2.1 + -1.27 * HAY_WIL_LTN2.2 <= 449 MW	220	210	-
		Overload of BPE-WDV 1 and 2 110 kV circuits		With MGM-MST-1 110 kV circuit **closed**, limit HVDC south transfer using thermal constraints 1.08 * BPE_WDV_2.1 + -0.40 * HAY_WIL_LTN2.2 <= 61 MW	0	0	-
BPE-LTN-2 220 kV circuit or BPE-TWC-LTN 1 220 kV circuit	BPE-TWC-LTN-1 220 kV circuit or BPE-LTN 2 220 kV circuit	Overload of both BPE-PRM-HAY 1 and 2 220 kV circuits (BPE-PRT section)		With MGM-MST-1 110 kV circuit **opened**, limit HVDC south transfer using thermal constraints. 1.25 * BPE_PRM_HAY1.1 + 0.54 * BPE_TWC_LTN1.1 <= 446 MW	165	165	-

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW) South Flow Summer 2025		Detailed Analysis Section
					SPL In	SPL Out	
		Overload of BPE-WDV 1 and 2 110 kV circuits		With MGM-MST-1 110 kV circuit **closed**, limit HVDC south transfer using thermal constraints 1.08 * BPE_WDV_2.1 + 0.05 * BPE_TWC_LTN1.1 <= 61.8 MW	0	0	-
BPE-PRM-HAY 1 or 2 220 kV circuit	HAY-WIL-LTN 1 220 kV circuit	Overload of BPE-PRM-HAY 2 and 2 220 kV circuits (BPE PRT section)	Summer peak loads, all years, maximum wind output	Limit HVDC south transfer using thermal constraints 1.29 * BPE_PRM_HAY2.1 + -0.46 * HAY_WIL_LTN1.2 <= 455 MW	645	645	-
BPE-LTN-2 220 kV circuit				Limit HVDC south transfer using thermal constraints 1.27 * BPE_PRM_HAY1.1 + -0.59 * HAY_WIL_LTN1.2 <= 455 MW	525	525	-
HAY-WIL-LTN 2 220 kV circuit				Limit HVDC south transfer using thermal constraints 1.27 * BPE_PRM_HAY1.1 + -0.58 * HAY_WIL_LTN1.2 <= 454 MW	525	525	-
HAY-WIL-LTN 1 220 kV circuit	BPE-LTN 2 220 kV circuit			Limit HVDC south transfer using thermal constraints 1.28 * BPE_PRM_HAY1.1 + 0.50 * BPE_LTN2.1 <= 459 MW	525	525	-

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Transfer Limit (MW) South Flow Summer 2025		Detailed Analysis Section
					SPL In	SPL Out	
BPE-TWC-LTN 1 220 kV circuit	HAY-WIL-LTN 1 220 kV circuit	Voltage stability limit reached in the Wellington region for SPL in service. Overload of RPO-TNG 1 220 kV circuit for SPL out of service.		Limit HVDC south using security constraints. 1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 + -1 * HAY_WIL_LTN1.1 + -1 * HAY_WIL_LTN1.2 + -1 * MGM_WDV1.1 <= 650 MW Limit HVDC south transfer using thermal constraints 1.40 * RPO_TNG1.1 + -0.24 * HAY_WIL_LTN1.2 <= 343 MW	710	550	-

Table 7-5: Contingencies during planned outages – Others (not dependent on transfer direction)

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	Detailed Analysis Section
HAY T1, T2, or T5 220/110 kV interconnecting transformer	Another HAY 220/110 kV interconnecting transformer	Overloads the remaining HAY 220/110 kV interconnecting transformers	Winter peak demand. Minimum wind output and maximum wind output for north transfer. Minimum wind output for south transfer.	Outage window selection Split HAY 110 kV bus into two bus sections during planned ICT outage. HVDC north transfer limits may be required.	9.3.5
HAY T1, T2, or T5 220/110 kV interconnecting transformer	WIL T8 220/110 kV interconnecting transformer	Overloads the remaining Haywards 220/110 kV transformers			9.3.5
WIL T8 220/110 kV interconnecting transformer	HAY T1, T2, or T5 220/110 kV interconnecting transformer	Overloads the remaining Haywards 220/110 kV transformers			9.3.5
HAY-UHT 1 or 2 110 kV circuit	Remaining HAY-UHT 110 kV circuit	Causes either very low voltages, or voltage collapse at Masterton 110 kV bus	All years, all seasons	System split on MGM-MST 1 110 kV circuit may be required. Loss of remaining circuit causes loss of supply to UHT, GYT, and MST.	-
HAY-TKR 1 or 2 110 kV circuit	Remaining HAY-TKR 110 kV circuit	Overloads WIL T8 220/110 kV interconnecting transformer	Winter, peak demand, minimum wind	Outage window selection Load management at TKR, CPK, KWA and PNI	-
MST-GYT-UHT-1 or 2 110 kV circuit	MGM-WDV-1 110 kV circuit	Overload of remaining GYT-UHT-1 or 2 110 kV section	Winter peak loads from 2025, minimum wind and maximum wind output.	Load management at MGM, MST, GYT and UHT.	-
MGM-WDV-1 110 kV circuit	MST-GYT-UHT-1 or 2 110 kV circuit				-
MGM-WDV-1 110 kV circuit	HAY-UHT-1 or 2 110 kV circuit	Overload of remaining HAY-UHT circuit	Winter peak loads from 2024, minimum wind and maximum wind output.	With split on MGM-MST-1 applied, MGM Overload Trip and Autochangeover Scheme will activate to restore MGM supply. Load management at MGM, MST, GYT, UHT.	-
HAY-UHT-1 or 2 110 kV circuit	MGM-WDV-1 110 kV circuit				-

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	Detailed Analysis Section
CPK-MHT-2 or CPK-MHT-3 110 kV circuit	CPK-WIL-1 110 kV circuit	Remaining circuit and transformer into CPK will overload.	All years, all seasons	Central Park Transformer Overload Protection Scheme will operate and trip feeders at CPK.	-
CPK-WIL-1 110 kV circuit	CPK-MHT-2 or CPK-MHT-3				-

8. LOSS OF SUPPLY OR GENERATION CONNECTION

Some contingencies or contingencies under planned outages result in the loss of supply of load or generation within Grid Zone 8. Table 8-1 outlines these scenarios and the network issue identified.

Table 8-1: Loss of supply caused by outages or contingencies

Outage	Contingency	Loss of supply
MGM-MST 1 110 kV circuit	MGM-WDV 1 110 kV circuit	MGM load
GFD-HAY 1 110 kV circuit	GFD-HAY 2 110 kV circuit	GFD load
KWA-WIL 1 110 kV circuit	KWA-WIL 2 110 kV circuit	KWA load
HAY-MLG 1 110 kV circuit	HAY-MLG 2 110 kV circuit	MLG load
MST-GYT-UHT 1 or 2 110 kV circuit	The remaining MST-GYT-UHT 110 kV circuit	GYT load
PNI-TKR 1 110 kV circuit	PNI-TKR 2 110 kV circuit	PNI load
none	CPK-WWD-WIL 2 or 3 110 kV circuit	Portion of WWD generation[4]
CPK-WWD-WIL 2 or 3 110 kV circuit	CPK-WWD-WIL 3 or 2 110 kV circuit	WWD generation and CPK load
BPE-PRM-HAY 1 or 2 220 kV circuit	The remaining BPE-PRM-HAY 220 kV circuit	PRM load
BPE-TWC-LTN-1	HAY-WIL-LTN 1 220 kV circuit	Turitea generation, Te Rere Hau generation, portion of Tararua generation.

9. DETAILED ANALYSIS

9.1 STEADY STATE VIOLATIONS

9.1.1 Loss of a Bunnythorpe-Mataroa 1 110 kV Circuit

Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation
None	Overload of BPE-MTR 1 110 kV circuit in steady state conditions	Peak demand, all years, north HVDC flow, maximum wind output. Winter with SPL in service and summer (SPL out).	Limit power transfer northwards using branch constraints: 1 * BPE_MTR1.1 < 57/70 MW (summer/winter) Or apply pre-contingent system split on the BPE-MTR 1 110 kV circuit

During periods of high HVDC north transfer and very high wind output in the lower North Island, the Bunnythorpe-Mataroa 110 kV circuit may overload in steady state conditions. This overload can be managed by either applying a branch constraint to limit north transfer through the 110 kV network or

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[4] West Wind has a bus tie breaker which can be closed during circuit outages. This will allow a portion, but not all, of WWD generation to transfer across to the remaining circuit.

by applying a system split on the Bunnythorpe-Mataroa 110 kV circuit. Under intact network conditions, this split would need to be offered for use by the Grid Owner.

For this scenario, the Bunnythorpe-Mataroa reactor is assumed to be in service, however, stage 2 of the Bunnythorpe-Mataroa overload protection scheme is assumed to be deactivated such that all circuits are in service as a starting point for the N-1 studies. It may, however, be possible to achieve higher north transfer limits with a system split in place.

9.2 CONTINGENCIES UNDER INTACT NETWORK CONDITIONS (N-1)

9.2.1 Loss of a Haywards-Wilton-Linton 220 kV circuit

Contingency	Effect of Contingency	Scenario	Operational Measure/ Constraint Equation
HAY-WIL-LTN 1 or 2 220 kV circuit	Voltage stability limit reached in the Wellington region	All years, all seasons, HVDC south flow, peak demand, maximum wind output. SPL in and out of service.	Limit HVDC south transfer to ensure: 1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 + -1 * HAY_WIL_LTN1.1 + -1 * HAY_WIL_LTN1.2 + -1 * MGM_WDV1.1 < 1046 (summer) and < 1102 (winter)
	Overload on BPE-WDV 1 and 2 110 kV circuit	All years, all seasons, HVDC south flow, peak demand, minimum wind output. SPL in service.	Limit HVDC south using thermal constraints Winter: 1.08 * BPE_WDV1.1 + -0.07 * HAY_WIL_LTN1.1 <= 73.4 MW Summer: 1.08 * BPE_WDV1.1 + -0.05 * HAY_WIL_LTN1.1 <= 61.3 MW

During high HVDC south flow, the loss of one of the Haywards-Wilton–Linton 1 or 2 220 kV circuits may result in voltage collapse in the lower North Island if this is not managed.

The maximum HVDC south flow that can be accommodated depends on Grid Zone 8 load, Grid Zone 8 wind farm output and reactive plant availability at Haywards. The following permanent voltage stability constraint is published to the market to indicate the voltage stability limit in the lower North Island:

1 * BPE_PRM_HAY1.1 + 1 * BPE_PRM_HAY2.1 - 1 * HAY_WIL_LTN1.1 + 1 * HAY_WIL_LTN2.1- 1 * MGM_WDV1.1 <= Right Hand Side (RHS)

Studies with all transmission and reactive plant in-service and maximum Grid Zone 8 wind farm output indicate an expected RHS of 1046 MW (summer) and 1102 MW (winter). In real-time operations, the RHS is determined more accurately using online voltage stability analysis tools.

The Grid Zone 8 wind generation output increases the available HVDC south flow in a simple pro-rata 1 MW/MW. Wind generation output further north in Grid Zone 7 has much less effect on increasing the HVDC south transfers at peak as the power still needs to be transferred to Haywards on the limited 220 kV circuits.

The RHS of the lower North Island voltage stability permanent constraint is reduced by any reactive plant being removed from service in the lower North Island and reduction of output from wind farms connected to circuits going into Grid Zone 8. Indicative reductions are shown in the table below. Note that the effect of removing reactive plant or wind farm generation does vary for different network conditions:

Removed From Service	HVDC Transfer Reduction (MW)
Reactive Power Plant	
Haywards Statcom 60 Mvar	40
Haywards 60 Mvar filter	40
Haywards 46 Mvar filter	30
Haywards synchronous condenser 1 or 2	30
Haywards synchronous condenser 3 or 4	20
Haywards synchronous condenser 7, 8, 9, or 10	40
Wind Farm Generation	
Tararua south (at Linton 33 kV)	10
Tararua central	20

9.2.1.1 Te Apiti Wind Farm

Te Apiti wind farm output has a significant impact on flows through the Bunnythorpe–Woodville 1 and 2 110 kV circuits. During HVDC south flow, the flow on these circuits is mostly from Bunnythorpe to Woodville. Te Apiti wind farm output off-sets the flow through these circuits. If Te Apiti generation is too low, then a thermal constraint for the 110 kV circuits may bind before the voltage stability constraint.

9.2.1.2 Maximum Wind – All Seasons

For the present demand forecasts, voltage stability in the lower North Island will set the transfer limits maximum wind, peak demand conditions. Studies indicate that the loss of one of the Haywards-Wilton-Linton 1 or 2 220 kV circuits produces the worst case voltage stability constraint depending on the conditions.

The following voltage stability constraint can be applied to ensure system security:

1 * BPE_HAY1.1 + 1 * BPE_HAY2.1 - 1 * HAY_WIL_LTN1.1 + 1 * HAY_WIL_LTN2.1- 1 * MGM_WDV1.1[5]
<= RHS.

Studies with all transmission and reactive plant in-service, and maximum Grid Zone 8 wind farm output, indicate an expected RHS of 1102 MW in winter and 1046 MW in summer.

As shown above, the RHS of the voltage stability permanent constraint is reduced by reactive plant being removed from service at Haywards and reduction of output from wind farms connected to circuits going into Grid Zone 8.

9.2.1.3 Minimum Wind – All Seasons

Studies indicate that with low wind generation output and peak demand conditions, the loss of one of the Haywards-Wilton-Linton 1 or 2 220 kV circuits can cause the Bunnythorpe–Woodville 1 and 2 110

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[5] This voltage stability constraint calculation includes the flow on Mangamaire-Masterton 1 110 kV circuit by considering the flow on the Mangamaire-Woodville circuit, unless a system split is in place or the circuit is removed from service.

kV circuits to overload. To avoid overloading the circuits, HVDC south transfer will be limited. The overload protection scheme associated with these circuits is not designed to operate when both are in service, consequently, a 110 kV system split will not be introduced automatically.

9.3 CONTINGENCIES DURING PLANNED OUTAGES (N-1-1)

9.3.1 HVDC North Transfer Limitations for Winter Peak Loads

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Limit (MW)
HAY-WIL-LTN-1 or 2 220 kV circuit	HAY-UHT-1 or 2 110 kV circuit	Overload of the remaining HAY-UHT 110 kV circuit	Winter peak loads from 2025, minimum wind output.	System split on MGM-MST 1 110 kV circuit or limit HVDC north transfer using security constraints. 1.00 * HAY_UHT2 + 0.95 * HAY_UHT1 <= 111 MW	1120
HAY-WIL-LTN-1 or 2 220 kV circuit	HAY-UHT-1 or 2 110 kV circuit	Overload of the remaining HAY-UHT 110 kV circuit	Winter peak loads from 2025, maximum wind output, SPL out of service.	System split on MGM-MST 1 110 kV circuit or limit HVDC north transfer using security constraints. 1.00 * HAY-UHT-2 + 0.95 * HAY-UHT-1 <= 112 MW	1050
BPE-PRM-HAY-1 or 2 220 kV circuit					1050
BPE-LTN-2 220 kV circuit					1005
BPE-TWC-LTN-1 220 kV circuit					925

During winter peak loads from 2025 at high HVDC north transfer and minimum wind output, an outage of one Haywards-Wilton-Linton circuit with the loss of one Haywards-Upper Hutt circuit can cause the remaining Haywards-Upper Hutt circuit to overload.

During the maximum wind scenario, this overload occurs for a planned outage of any of the 220 kV circuits into Haywards. This issue is only seen when SPL is out of service. When SPL is in service, HVDC north flow is limited due to the steady state overload Bunnythorpe-Mataroa 1.

This overload can be mitigated by applying a system split on the Mangamaire-Masterton 1 110 kV circuit or by limiting HVDC north transfer by applying constraints.

9.3.2 Planned Outage of one Haywards-Wilton-Linton 220 KV circuit with the loss of the remaining Haywards-Wilton-Linton 220 kV circuit with minimum wind.

Planned Outage	Season	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Limit (MW)
HAY-WIL-LTN 1 or 2 220 kV circuit / remaining HAY-WIL-LTN 220 kV circuit	Summer and winter	No network effect	Demand below 500 MW	HVDC will be limited for over voltage control, particularly for low demand conditions.	HVDC limit north
	Winter	Overload of BPE-PRM-HAY 1 and 2 220 kV circuits (BPE-PRT section)	Peak demand, minimum wind output	With MGM-MST 1 110 kV circuit opened, limit HVDC south using thermal constraints 1.27 * BPE_PRM_HAY2.1 + -2.72 * HAY_WIL_LTN2.2 <= 487 MW	0 south

Planned Outage	Season	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Limit (MW)
	Summer	Overload of BPE-PRM-HAY 1 and 2 220 kV circuits (BPE-PRT section)	Peak demand, minimum wind output	With MGM-MST-1 110 kV circuit opened, limit HVDC south transfer using thermal constraints. 1.27 * BPE_PRM_HAY2.1 + -1.27 * HAY_WIL_LTN2.2 <= 449 MW	220 south
		Overload of BPE-WDV 1 and 2 110 kV circuit		With MGM-MST-1 110 kV circuit closed, limit HVDC south transfer using thermal constraints 1.08 * BPE_WDV_2.1 + -0.40 * HAY_WIL_LTN2.2 <= 61 MW	0 south

During HVDC north transfer, the outage of either Haywards-Wilton-Linton 220 kV circuits results in a reduction of up to 100 MW in the maximum power transfer allowed by the HVDC controls. The subsequent outage of the remaining Haywards-Wilton-Linton 220 kV circuit can result in a further reduction of up to 150 MW in the maximum HVDC north power transfer. As discussed in section 4.2, the actual reduction in the power limit depends on the HVDC load measurement at the time, and if the measured load was high enough no power limit is needed; the HVDC power limit after the 2nd outage is 950 MW for a HVDC load measurement of up 250 MW, and increases linearly to 1200 MW (i.e. no reduction due to the outages) at a HVDC load measurement of 500 MW and above.

For HVDC south flow and low wind in the region, the loss of the remaining Haywards-Wilton-Linton 220 kV circuit during a planned outage of either Haywards-Wilton-Linton 1 or 2 220 kV circuit can overload both Bunnythorpe-Woodville 110 kV circuits.

This overload can also be mitigated by applying a system split on the Mangamaire-Masterton 1 110 kV circuit. When this system split is in place with higher levels of HVDC south transfer, both Bunnythorpe-Paraparaumu-Haywards 220 kV circuits may overload during the summer ratings period.

9.3.3 Planned Outage of one 220 kV circuit into Haywards, with the loss of another 220 kV circuit into Haywards with minimum wind

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation	HVDC Limit (MW)
BPE-PRM-HAY 1 or 2 220 kV circuit	BPE-LTN 2 220 kV circuit	Overload of remaining BPE-PRM-HAY circuit (BPE-PRT section)	Winter peak loads, minimum wind output. SPL in and out of service.	With MGM-MST 1 110 kV circuit opened, limit HVDC south using thermal constraints 1.29 * BPE_PRM_HAY2.1 + 0.42 * BPE_LTN_2.1 <= 465 MW	110 SPL in 75 SPL out
HAY-WIL-LTN 1 or 2 220 kV circuit	Remaining HAY-WIL-LTN 220 kV circuit	Overload of BPE-PRM-HAY 1 and 2 220 kV circuits (BPE-PRT section)		With MGM-MST 1 110 kV circuit opened, limit HVDC south using thermal constraints 1.27 * BPE_PRM_HAY2.1 + -2.72 * HAY_WIL_LTN2.2 <= 487 MW	0
BPE-LTN 2 220 kV circuit or BPE-TWC-LTN 1 220 kV circuit	BPE-TWC-LTN 1 220 kV circuit or BPE-LTN 2 220 kV circuit			With MGM-MST 1 110 kV circuit opened, limit HVDC south using thermal constraints 1.24 * BPE_PRM_HAY2.1 + 0.56 * BPE_TWC_LTN1.1 <= 476 MW	0

During winter peak loads at high HVDC south transfer and minimum wind output, a planned outage of one of the 220 kV circuits into Haywards with the loss of another 220 kV circuit into Haywards can cause the Bunnythorpe-Paraparaumu-T sections of the Bunnythorpe-Paraparaumu-Haywards 220 kV circuits to overload.

This assumes that a split has already been applied at Mangamarie-Masterton 110 kV circuit to eliminate overloads on the Bunnythorpe-Woodville circuits. HVDC south transfer must also be limited using constraints. However, even with south transfer at 0 MW, overloads may still be seen on these T circuits.

9.3.4 HVDC south transfer limitations for winter peak loads with maximum wind

Planned Outage	Contingency	Effect of Contingency	Scenario	Operational Measure/Constraint Equation
MGM-WDV 1 110 kV circuit, MGM-MST 1 110 kV circuit, any one of HAY T1, HAY T2 or HAY T5 220/110 interconnecting transformers.	HAY-WIL-LTN 1 220 kV circuit	Voltage stability limit reached in the Wellington region	Winter peak loads, maximum wind output. SPL in and out of service.	Limit HVDC south using security constraints.

A planned outage of any one of Mangamarie-Woodville 1 110 kV circuit, Mangamarie-Masterton 1 110 kV circuit, or any one of the Haywards 220/110 kV interconnecting transformers with the loss of Haywards-Wilton-Linton 1 220 kV circuit can cause the voltage stability limit to be reached in winter. This is mainly due to the N-1 issue of the loss of Haywards-Wilton-Linton 1, however, any of these other circuits/transformers can push the voltage slightly over the stability limit.

9.3.5 Planned Outage of a Haywards or Wilton Interconnecting Transformer with the loss of a second Interconnecting Transformer

Planned Outage	Contingency	Effect of Contingency	Operational Measure/Constraint Equation
HAY T1, T2 or T5 220/110 kV interconnecting transformer	HAY T1, T2 or T5 220/110 kV interconnecting transformer	Overloads the remaining HAY interconnector	Outage window selection, split HAY 110 kV bus into two bus sections during planned ICT outage
HAY T1, T2 or T5 220/110 kV interconnecting transformer	WIL T8 220/110 kV interconnecting transformer		
WIL T8 220/110 kV interconnecting transformer	HAY T1, T2 or T5 220/110 kV interconnecting transformer		

During winter peak loads and low wind farm output, the loss of a second 220/110 kV interconnecting transformer during a planned outage of a Haywards or Wilton 220/110 kV interconnecting transformer can overload the remaining Haywards interconnecting transformers.

The Haywards and Wilton interconnecting transformers are classified as Extended Contingent Events. Extended Contingent Events are events where the impact, probability, costs and benefits are not considered to justify the controls required to totally avoid demand shedding or maintain the same quality limits defined for Contingent Events.

Therefore, for an outage of a Haywards interconnecting transformer, the Haywards 110 kV bus could be split into two bus sections during the planned outage, with the following configuration[6]:

- One Haywards interconnecting transformer supplying Haywards-Upper Hutt 1 and 2, Haywards-Melling 1 and 2, system split at Mangamaire-Masterton
- The other Haywards Interconnecting transformer supplying Haywards-Takapu Road 1 and 2, Haywards-Gracefield 1 and 2, system split at both Takapu Road-Wilton 1 and 2

Effectively Grid Zone 8 110 kV loads have been divided into three areas, each supplied from the 220 kV grid via an Interconnecting transformer (two Haywards interconnecting transformers and Wilton T8). This means that Grid Zone 8 110 kV loads are on N security. A contingency of any one of these interconnecting transformers results in the loss of an area of load.

For an outage of Wilton T8 interconnecting transformer, the Haywards 110 kV bus could be split into three bus sections (A1, A2 and B), with the following configuration[7]:

- Bus A2 will have Haywards T5, Haywards-Upper Hutt 1 and 2, Haywards-Melling 1 and 2, Haywards-Gracefield 1 and 2, system split at Mangamaire-Masterton
- Bus A1 will have Haywards T1, Haywards-Takapu Road 1, system split at Takapu Road in order to supply Takapu Road and Pauatahanui
- Bus B will have Haywards T2, Haywards-Takapu Road 2, system split at Takapu Road in order to supply Central Park, West Wind and Kaiwharawhara

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[6] Mitigation proposed in Section 1.18.2 of Appendix 1 - North Island ICTs, located here: *Event categorisation | Transpower*

[7] Mitigation proposed in Section 1.17.2 of Appendix 1 - North Island ICTs, located here: *Event categorisation | Transpower*