TRANSPOWER

System Security Forecast 2022

Part F

Dry Year Operational Issues

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IMPORTANT

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1. DRY YEAR TRANSFER LIMITS

Hydro generation in New Zealand has limited storage. Extended periods of low inflows into hydro storage catchments can result in storage levels reaching a point[1] where action by the industry is required to avert the need to ration electricity to consumers. Industry actions include the use of an Official Conservation Campaign to minimise demand, North Island thermal units running at higher capacity factors and grid re-configurations to maximise the capacity of the grid to transfer electricity from thermal stations to demand centres.

In 2008 and 2012, hydro storage levels in the South Island reached thresholds where action by the industry was deemed appropriate. In early June 2017, South Island storage levels reached the 2% hydro risk curve[2]. In such dry year situations, the HVDC south transfer is used to preserve South Island hydro storage during night and afternoon trough load conditions so that South Island (SI) hydro generation can be used for north transfer during peak loads. Conversely, for situations of dry year in the North Island, high north transfer is used throughout the day to support high loads that thermal units would otherwise only partially supply.

The maximum capability of the HVDC link for south transfer is 815 MW received at Benmore, and the capability of the HVDC link for north transfer is 1134 MW received at Haywards. In evaluating the transmission constraints for a dry island, we have assumed there is sufficient generation to meet the opposite island’s load as well as supporting high HVDC flows towards the dry island. Although this is not necessarily a realistic scenario, the purpose is to find constraints in the dry island. It is likely that for a South Island dry year during peak periods HVDC transfer will be North and South Island generation will be higher, with high HVDC south transfer in off-peak periods to conserve water.

Key changes in the power system are foreseen to affect system security within the study timeframe. These events are the potential displacement North Island thermal generation and the potential closure of the Tiwai Point Aluminium Smelter in 2025. Tiwai Point remaining has been studied as a sensitivity to highlight how we can continue to manage the operation and security during dry year scenarios. Displacement of thermal generation has not been studied in detail because there is no significant committed decommissioning however some general commentary on the anticipated effect of thermal generation decommissioning is provided.

This section of the SSF describes the potential dry year scenarios, system constraints, and mitigation measures employed to maximise the capability of the power system. The scenarios analysed in this section are more onerous in terms of the generation assumptions in the South Island than those used in Part D: Power System Security Analysis.

[1] *Emergency Management Policy | Transpower*

[2] *Hydro Risk Curves Explanation | Transpower*

2. OVERVIEW OF BACKBONE CONSTRAINTS

Figure 2-1 shows the major constraints on the power system under high transfer conditions.

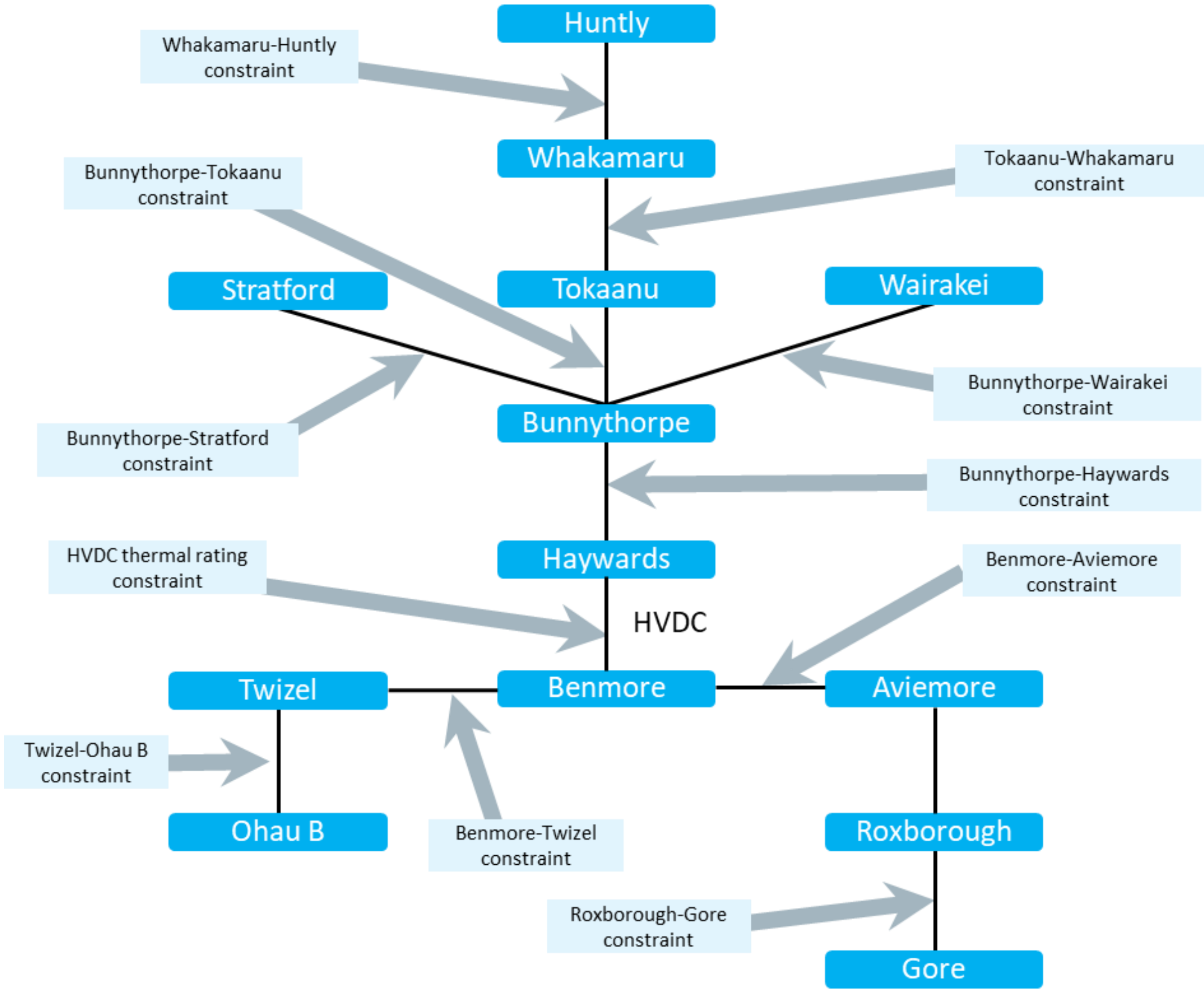

Figure 2-1: System Constraints during high HVDC transfer

There are two major power system constraints in the North Island under high north transfer situations. These constraints are transfers from:

- Stratford to Huntly
- Bunnythorpe to Haywards

In the North Island under north transfer conditions, power is supplied from the South Island and is limited by HVDC operating limits and constraints on North Island backbone circuits, or available reserves in the North Island. The HVDC itself has north flow operating limits dependent on Transient Over-Voltage (TOV) from low Wellington load, and any concurrent outages of filters or circuits linking north of Wellington. In addition to the HVDC limits, several North Island circuits have thermal constraints that may limit transfer under high transfer conditions between the regions of Bunnythorpe to Haywards and Stratford to Huntly. Several voltage stability constraints also limit transfer, for supplying high Wellington load, and for backbone transfer into Upper North Island above Whakamaru and Huntly.

In the South Island, the amount of power that can be transferred between the Waitaki Valley (where the southern terminal of the HVDC link is located) and the Southland and Otago region is limited by two major constraints on the power system. These constraints are:

- Benmore to Aviemore circuit thermal capacity
- GZ14 Voltage Stability

Weather the voltage stability constraint binds is dependent on power system conditions, especially the amount of generation at Clyde, Roxburgh, and Manapouri.

The South Island has voltage stability constraints on the backbone for importing into the Upper South Island, however practically the transfer is typically limited under N-1-1 conditions only. These voltage stability constraints are explored further in Part D: South Island Backbone, 5.2 Voltage Stability Limits.

3. Scenario: Dry North Island Only

In the scenario of low North Island hydro storage, it is expected that North Island hydro generation will run at minimal output, relying on thermal generation as well as South Island generation via the HVDC to supply load.

3.1 Assumptions

- No planned outages
- Hydro generation operating at 10th percentile of peak output (from the last 3 years), adjusted based on operating considerations.

Table 3-1: North Island hydro generation summer and winter output at 10th percentile peak.

Hydro Station	Summer Output (10th Percentile Peak)	Winter Output (10th Percentile Peak)
Aratiatia	20	20
Arapuni	20	76
Atiamuri	15	33
Kaitawa	-	4
Karapiro	40	39
Mangahao	27	11
Matahina	-	-
Maraetai	20	91
Ohakuri	15	46
Piripaua	5	10
Rangipo	-	43
Tokaanu	-	75
Tuai	7	10
Waipapa	15	24
Whakamaru	20	51

- All thermal generation available (i.e. no concurrent thermal supply shortages). Due to reduced demand during summer, the preference is to disable the Rankine units and Whirinaki generating units where possible. Different thermal generation levels at Huntly were studied against the HVDC to find the network limits.
- Wind contribution at 20% of installed capacity.
- HVDC has high north flow, and a limit of 1134 MW received at Haywards.
- Committed transmission and generation changes are incorporated as per Part B: Grid Configuration and Operation.

3.2 Operational Considerations

During the summer ratings period, low North Island hydro during peak load can cause 220 kV backbone circuits to overload. Bunnythorpe-Mataroa 1 110 kV circuit may overload pre-contingency as early as

2022, requiring the Bunnythorpe-Mataroa 110 kV Circuit Overload Protection Scheme (BPE-MTR COPS) to be enabled. See section on Part D Grid Zone 7 Bunnythorpe for further information on this circuit overload protection scheme as well as the Tokaanu Circuit Overload Protection Scheme. After this mitigation, other 220 kV backbone circuits risk overloading post-contingently as listed in Table 3-2. This requires generation in Grid Zones 1, 2 or 3 to be constrained on.

During the winter rating period, low North Island hydro generation requires all thermal units to be in service to meet the expected peak load, particularly during winter 2025. With thermal units available and offered in the market system, maximum HVDC north flow, and additional line capacity from winter ratings, peak load can be supplied without constraining on downstream generation or reducing upstream generation.

Note that not all constraints have been reported in this section, only those which would require more North Island hydro than is available or mainly appear during a dry North Island scenario. For a more detailed list of constraints, please consult the regional reports.

Table 3-2: Dry North Island, summer, contingency studies.

Contingency	Effect of Contingency	Scenario	Operational Measure	Constraint Equation
None	BPE-MTR 1 overloads	Summer, high north flow, Huntly output 550 MW.	SPD will adjust the generation dispatch	1 * BPE_MTR1.1 ≤ 57/70 MW (summer/winter)
TKU-WKM 1 or 2	Remaining TKU-WKM circuits overload. After TKU-COPS, BPE-MTR 1 overloads	Summer, high north flow, Huntly output 600 MW.	TKU Circuit Overload Protection Scheme operates then BPE-MTR Reactor and Circuit Overload Protection Scheme operates	
	BPE-TNG 1	Summer, high north flow, Huntly output 600 MW. Applies after BPE-MTR COPS and TKU-COPS.	Increase generation in the north, e.g. Huntly	1.35 * BPE_TNG1.1 + 0.38 TKU_WKM1.1 ≤ 327 MW
BPE-TKU 1 or 2	BPE-TNG-1 and remaining BPE-TKU circuits overload	Summer, high north flow, Huntly output 570 MW. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	1.26 * BPE_TKU1.1 + 0.51 * BPE_TKU2.1 ≤ 395 MW
SFD-TMN-1	HLY-SFD 1 overloads	Summer, high north flow, Huntly output 600 MW. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	-1.00 * HLY_SFD.1 + 0.39 * SFD_TMN1.1 ≤ 354 MW
TMN-TWH-1	HLY-SFD 1 overloads	Summer, high north flow, Huntly output 600 MW. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	-1.00 * HLY_SFD.1 + 0.40 * TMN_TWH1.1 ≤ 354 MW
HLY-SFD 1	BPE-TNG 1 overloads	Summer, high north flow, Huntly output 600 MW. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	1.37 * BPE_TNG1.1 + -0.27 * HLY_SFD.1 ≤ 330 MW
SFD-TMN 1	BPE-TNG 1 overloads	Summer, high north flow. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	1.37 * BPE_TNG1.1 + 0.27 * SFD_TMN1.1 ≤ 329 MW
TMN-TWH-1	BPE-TNG 1 overloads	Summer, high north flow. Applies after BPE-MTR COPS.	Increase generation in the north, e.g. Huntly	1.37 * BPE_TNG1.1 + 0.28 * TMN_TWH1.1 ≤ 329 MW

If existing baseload thermal generation were to be decommissioned, there is a shortfall in supplying peak winter load that cannot be met by existing North Island non-hydro units nor by the HVDC's existing north flow capacity. However, off-peak load can be supplied with low HVDC north flow, suggesting that during dry conditions hydro stations may be able to reduce their off-peak output in order to preserve water for peak loads. Any new non-intermittent generation plant installed in the North Island would reduce the risk of a generation shortfall or load management during peak load following thermal generation displacement.

For operational considerations in the South Island, see Part D: South Island Backbone, System Condition 2: "High Lower South Island Generation" which outlines the N-1 constraints for north flow for the HVDC. In summary, for N-1 network conditions, Southland export is bound by constraints along Aviemore-Benmore 1 and 2, and the HVDC north flow capacity.

4. Scenario: Dry South Island Only

For the low South Island hydro storage scenario, it is expected that during off peak periods, South Island hydro will run at minimal output to conserve water, with HVDC south transfer supplying the remaining load, as there is no other non-intermittent generation available in the South Island. It is expected that during peak times, South Island hydro will increase output and HVDC transfer will be north to meet demand in the North Island.

4.1 Assumptions

- No planned outages.
- Hydro generation operating at 10th percentile of peak output from the last 3 years.

Table 4-1: South Island hydro generation summer and winter output at 10th percentile peak.

Hydro Station	Summer Output (10th Percentile Peak)	Winter Output (10th Percentile Peak)
Argyle	-	6
Aviemore	85	98
Benmore	258	245
Cobb	3	19
Coleridge	19	17
Clyde	208	290
Manapouri	346	467
Ohau A	110	112
Ohau B	96	96
Ohau C	95	95
Roxburgh	137	184
Tekapo A	-	-
Tekapo B	71	74
Waipori	-	3
Waitaki	39	43

- Wind contribution at 20% of installed capacity.
- HVDC has high south flow, and a limit of 815 MW received at Benmore.
- Tiwai is assumed to exit in 2025. Tiwai remaining is studied as a sensitivity.

- A replacement load of 191MW is commissioned. For illustration purposes the new "replacement" loads from new industry with Tiwai closure is connected to the North Makarewa 220 kV bus; in reality the replacement load could be connected to a number of existing or new grid exit points. This load not being commissioned is studied as a sensitivity.
- Committed transmission and generation changes are incorporated as per Part B: Grid Configuration and Operation.
- Studies were run at peak load and 90% of peak load.

4.2 OPERATIONAL CONSIDERATIONS

For the South Island, the same constraints exist as mentioned in Part D: South Island Backbone. These post-contingent constraints are emphasised with high south flow on the HVDC, and low hydro generation. The constraints are listed in Table 4-2. Note that only backbone constraints are listed here, for regional issues refer to the regional reports.

For dry South Island conditions, high HVDC south flow is required to supply South Island load during off peak times so that water can be conserved to allow north flow during peak times.

During winter, the additional capacity from thermal ratings alleviates the backbone constraints, however the HVDC is still at risk of overloading.

Additionally, by winter 2024, loading on the HVDC is expected to exceed the south flow limit with 10th percentile hydro generation in the South Island. In practice, the south flow limit may be reduced for reserve sharing or if backbone constraints in either island limit transfer. Therefore, it is expected that additional South Island generation or load management may be required to meet peak demand. If Tiwai exits in 2025 the generation issue will be resolved, however if Tiwai remains this issue will continue to bind.

Table 4-2: Operational considerations.

Contingency	Effect of Contingency	Scenario	Operational Measure	Load Limit and Constraint Equation	Additional Comments
AVI-BEN 1 or 2 220 kV circuit	Overloads remaining AVI-BEN 220 kV circuit	All years, summer only. Any south flow with low Aviemore / Southland generation.	Security constraints on Aviemore-Benmore circuits System Splits	-1.23 * AVI_BEN1.1 + -0.89 * AVI_BEN2.1 ≤ 259 MW	See Section 4.2.1
OHB-TWZ 3 or OHC-TWZ 4 220 kV circuit	Overloads BEN-TWZ 1	All years, summer only.	Manageable within short-term ratings If there is a system split at AVI, a security	1.26 * BEN_TWZ.1 + 0.51 * OHB_TWZ.1 ≤ 522 MW	See Section 4.2.1

			constraint is required		
None	HVDC transfer may be limited	All seasons, all years. High south flow.	Additional generation required to meet peak demand		See Section 4.2.2

4.2.1 AVI-BEN overload and Possible System Splits

Studies completed for the dry year 2021 investigation identified three possible system splits to resolve AVI-BEN overloads. One of these splits might be necessary if the security constraint cannot be meet due to generation limits. These have been reviewed and are discussed below:

1. Removing AVI-BEN-1 and 2 from service. In the studied scenario, this split causes an overload of BEN-TWZ-1 for a contingency of OHB-TWZ-3 or OHC-TWZ-4, however this overload is highly dependent on the mix of generation in the WTK block and may not bind in a real scenario. In implementing this system split it is also necessary to consider that the split puts AVI and WTK on N security which could introduce a binding CE risk if Manapouri generation is low. If this split were implemented it would be necessary to study, using the system conditions at the time, to ensure that AVI and WTK could run islanded to supply the GZ13 110 kV if the LIV-WTK-1 circuit were lost.

2. Remove AVI-WTK-1 from service. When this was identified in 2021 the STU split was closed during summer, which provided N-1 security to WTK when AVI-WTK-1 was out of service. The STU split is now open all year and cannot be closed in summer without overloading BPD-WTK-1 pre-contingently. With the STU split open the AVI-WTK-1 would only be an option if there was enough generation at WTK to successfully island the GZ13 110kV for a contingency of LIV-WTK-1. This would need to be monitored in real time.

3. Remove NSY-ROX from service. In the summer 2024 at peak load, this split causes an overload of BEN-TWZ-1 for a contingency of OHB-TWZ-3 or OHC-TWZ-4, however this overload is highly dependent on the mix of generation in the WTK block and may not bind in a real scenario. It is also likely that during peak periods there will be more generation than in the studied scenario, so this split could still be advantageous. Note that BEN-TWZ-1 does not overload with this split in place at peak load in 2023 or at 90% of peak load in 2024. This split will reduce voltage stability limits.

In a real dry year scenario, these system splits would need to be studied at the time, using the actual generation mix, to see which split was most advantageous. It is likely that the NSY-ROX split would be implemented based on the studied scenario, however this is subject to change based on system conditions. Any split will reduce the voltage stability limit, and this would need to be monitored in real time to check if the voltage stability limit were binding, however it is likely that the HVDC transfer limit will bind first in a dry year scenario, even with a split in place.

Note that the Aviemore-Benmore Circuit Overload Protection scheme does not apply in this scenario. The scheme only operates when power is flowing from AVI to BEN, however in a dry year power flow is from BEN to AVI so the scheme does not apply.

4.2.2 HVDC Transfer and Generation Balance

The absolute maximum HVDC south transfer limit is 815MW received at Benmore. The practical transfer limit is usually lower and varies based on North Island backbone constraints, reserve sharing, and Wellington voltage stability; see Part D: Grid Zone 8 and the HVDC Bipole Operating Policy for more details. Table 4-3 summarizes the scenarios where the maximum transfer limit is exceeded, assuming 10th percentile hydro generation and peak load.

Table 4-3: Scenarios where HVDC Transfer Limit is exceeded

Scenario	HVDC Transfer (MW)	HVDC Overload (MW)
Winter 2024	858	43
Summer 2024	868	53
Winter 2025, TWI remains	943	128
Summer 2025, TWI remains	1072	257

In practice, it is likely that South Island generation will be higher than the 10th percentile for peak periods. However, it is also likely that the HVDC south transfer limit will normally be lower. A common limit is the Wellington voltage stability limit of 510MW/215MW (summer/winter). Transfer exceeds this limit in all seasons and all years at peak load, and at 90% of peak load from winter 2023 and summer 2024. If Tiwai exits and replacement load is not commissioned, the south transfer does not exceed this limit in 2025. In practice, if South Island hydro could not be increased it is likely that an official conservation campaign and possibly rolling outages would be required to ensure supply meets demand. If Tiwai exits this issue will be resolved. If North Island thermal generation is displaced the generation balance issue during dry years will be worse unless replacement non-intermittent generation is commissioned.