

HVDC Capacity

Background Information on HVDC Transfer Restrictions

Transpower New Zealand Limited

November 2016

Keeping the energy flowing



TRANSPOWER



IMPORTANT

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- 1 HVDC Capacity 4
 - 1.1 HVDC North Transfer 2016 4
 - 1.2 HVDC North Transfer 2016 since 1 June 2016 4
 - 1.3 Current Hydro Summary 5
 - 1.4 Energy Transfer (GWh) 5
 - 1.5 Limitations on HVDC North Transfer 6
 - 1.6 Factors affecting HVDC capacity 7
 - 1.6.1 HVDC outages 7
 - 1.6.2 North Island AC network power limits 7
 - 1.6.3 Transient overvoltage power transfer limits at Haywards 8
 - 1.6.4 Filter outages 9
 - 1.6.5 Reduced voltage operation 10
 - 1.6.6 Reserve shortfalls 10
 - 1.6.7 Economic cost of extra SI energy 10
 - 1.6.8 Economic cost of extra reserves 10

1 HVDC CAPACITY

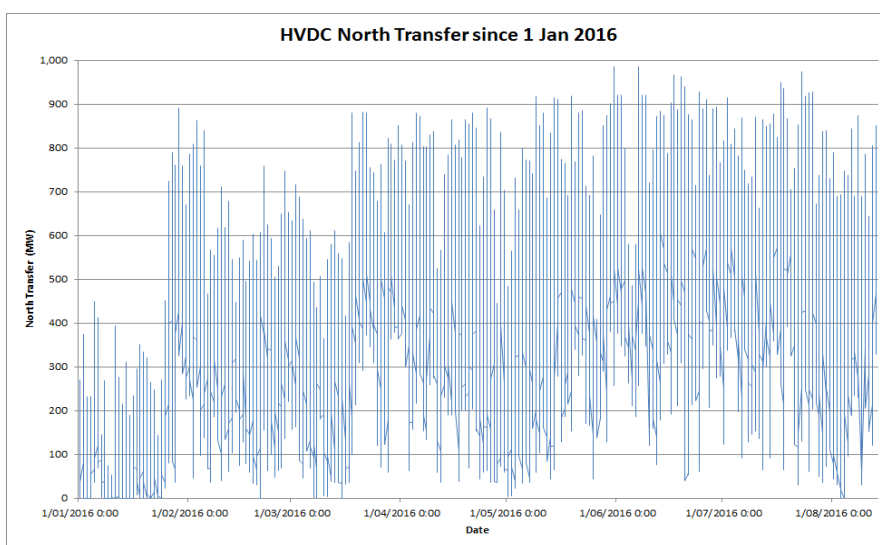
In late 2013 Transpower completed commissioning of the upgraded HVDC link which included the new Pole 3 and controls plus upgraded Pole 2 controls. This increased the transfer capability to 1200MW north and 850MW south.

However a question arose as to why the HVDC was only transferring in the order of 700-800MW north throughout winter despite south island lake levels being well above average (around 130% of average for that time of the year).

4

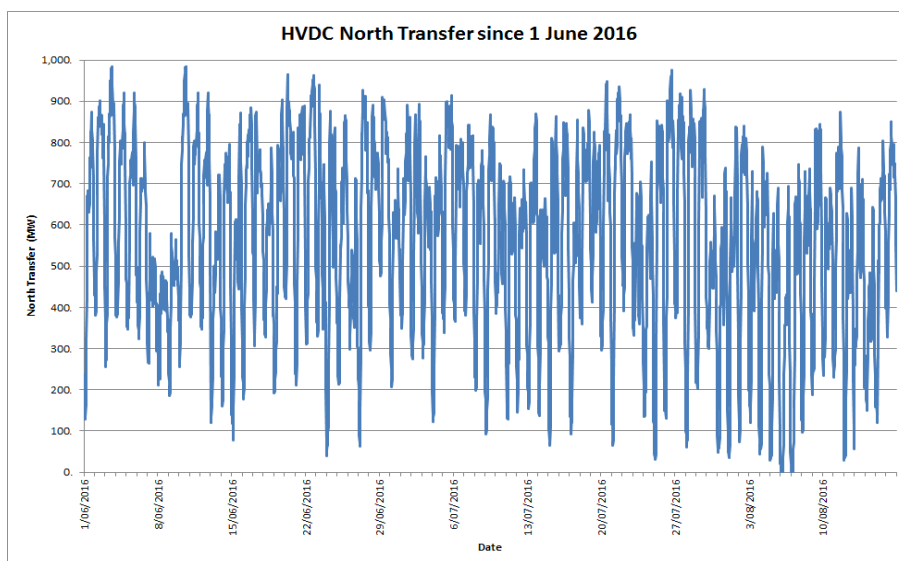
1.1 HVDC NORTH TRANSFER 2016

The graph below shows HVDC north transfer (in MW) for each trading period since 1 January 2016. It can be seen that at times the HVDC has approached 1000MW north and transfer has been consistently northwards since February.



1.2 HVDC NORTH TRANSFER 2016 SINCE 1 JUNE 2016

The graph below focusses on the period since 1 June 2016. Again the pattern of consistent high north transfer can be seen.

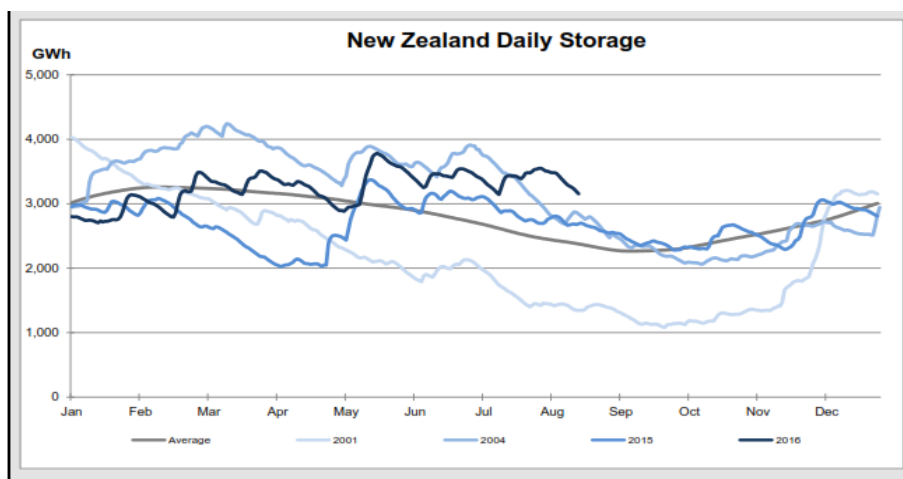


1.3 CURRENT HYDRO SUMMARY

Hydro storage (as at 17 Aug) from the NZX daily summary is shown below. This shows lake levels were generally well above average.

NZX		Hydrological Summary		17 Aug 16	
SECTION 1 - STORAGE					
Stored Energy (GWh)	17 Aug 16 Stored Energy	Stored Energy As % of Maximum	Stored Energy As % of Average	7 Day Change In Stored Energy	28 Day Change In Stored Energy
Taupo	479	84%	148%	-1%	28%
Waikaremoana	107	74%	108%	10%	75%
Waitaki	2068	79%	140%	-6%	-9%
-Tekapo	475	57%	108%	-	-
-Pukaki	1590	91%	154%	-	-
-Ohau	3	14%	83%	-	-
Clutha	117	22%	52%	-23%	-42%
-Hawea	60	21%	35%	-	-
-Wanaka (uncontrolled)	32	25%	113%	-	-
-Wakatipu (uncontrolled)	25	20%	103%	-	-
Waiau	305	72%	119%	-16%	-31%
-Te Anau	189	71%	112%	-	-
-Manapouri	116	74%	132%	-	-
North Island ²	640	79%	135%	1%	33%
South Island (controlled) ³	2433	74%	128%	-	-
South Island ⁴	2514	68%	126%	-8%	-15%
New Zealand (controlled) ³	2912	75%	130%	-	-
New Zealand ⁵	3154	70%	128%	-6%	-8%

5

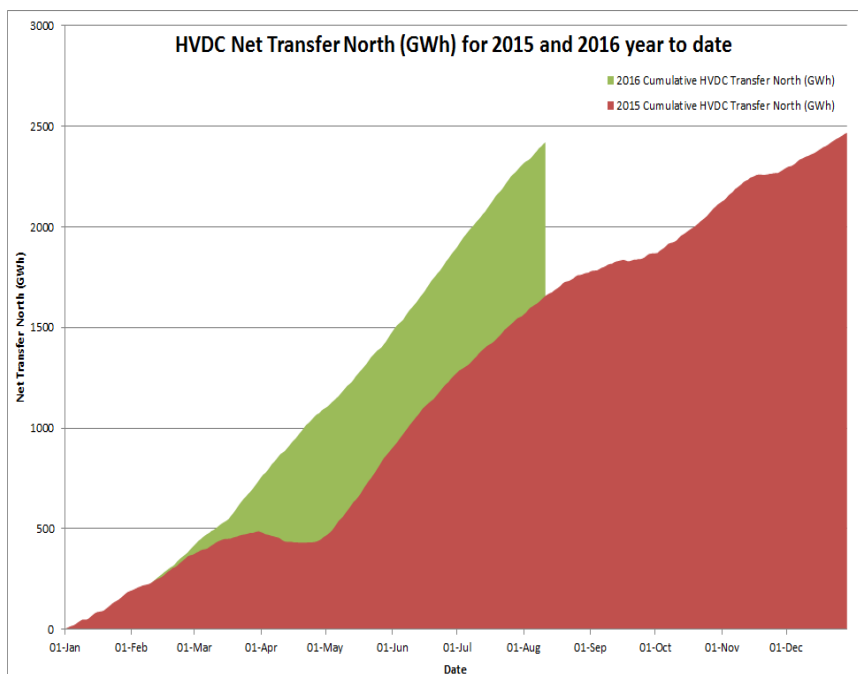
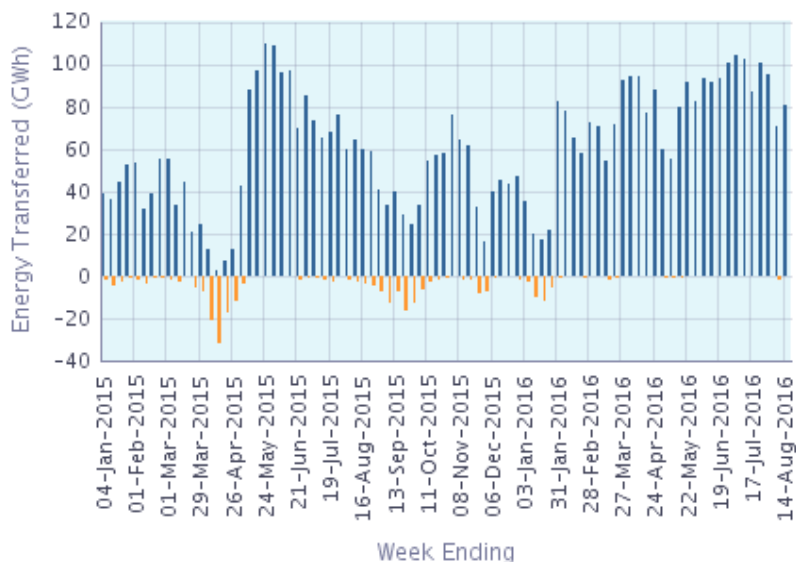


1.4 ENERGY TRANSFER (GWH¹)

Above average inflows to the Southern Lake catchments for the 2016 calendar year to mid-August resulted in the net transfer north on the HVDC being approximately equal to all of 2015.

	HVDC Transfer Net (GWh)
2016 To week ended 14 August 2016	2,420.40
2015 Calendar year	2,467.75

¹ 1GWh is roughly equivalent to the annual consumption of 125 households (based on an 8000kWh annual consumption)



1.5 LIMITATIONS ON HVDC NORTH TRANSFER

HVDC north transfer can be limited to below tested capability by

- Reductions to HVDC capacity due to
 - HVDC outages
 - North Island AC network power limits
 - Transient overvoltage power limits at Haywards
 - Filters in service/ on outage
 - Normal/Reduced Voltage
- SI energy availability and cost
- NI reserve availability and cost
- HVDC Reserve Requirement/ Risk Offset
 - Risk Subtractor – n-1 HVDC capacity/runback for contingent events, e.g. tripping

- a pole, which depends on voltage level
 - an AC line
 - a statcom
 - a filter.
- NI load, a percentage of which determines free reserves, for an extended contingent event of a bipole trip, due to Automatic Under-Frequency Load Shedding (AUFLS).
 - Secondary risks, e.g. wind farms with no fault ride through, of which there are more for a bipole trip than a contingent event runback.

Frequency Keeping Control Modulation Risk - currently 30 MW of additional risk for Frequency Keeping Control modulations of the HVDC

1.6 FACTORS AFFECTING HVDC CAPACITY

7

There are a number of factors which may affect HVDC transfer capacity. The main ones are explained below before looking at the current situation. For a full list of HVDC transfer limitations please refer to the HVDC: Bipole Operating Policy which can be found after logging into the Transpower web site.

1.6.1 HVDC outages

An outage of the HVDC bipole will obviously reduce the capacity of the HVDC to zero. An outage of Pole 2 will reduce the capability to only Pole 3 of 700MW and an outage of Pole 3 will reduce the capability to only Pole 2 of 500MW. However, the main effect of running in monopole mode with the other pole out of service is that there is no HVDC risk offset and high transfer levels can only be supported with high levels of cleared reserves. A common reason for reduced HVDC transfer when running in monopolar mode is that there are often insufficient cheap offered reserves in the receiving island.

1.6.2 North Island AC network power limits

Power limits on the HVDC transfer are required to maintain the stability of the power system following an AC tripping close to the converter station at Haywards. The power limits are dependent on the Wellington region demand and AC outages. Wellington demand is defined as the total power flowing through the interconnecting transformers T1, T2 and T5 at Haywards and T8 at Wilton plus an approximation of the load at the Paraparaumu 220/33kV substation.

The demand is defined as Low demand < 250MW, High demand > 500MW

Power limits for stability are as below (from the HVDC bi-pole operating policy):

L1.1 Stability power limits for low demand in Wellington area

Description of event	Direction	Power Limit
		With Statcom
Disconnection of one 220 kV circuit at HAY	North Flow	1150 MW
	South Flow	None
HAY 220 kV Bus section A,B, or C cleared by backup protection	North Flow	1000 MW
	South Flow	None
BPE 220 kV bus section A1 or B cleared by backup protection	North Flow	900 MW
	South Flow	None

L1.2 Stability power limits for high demand in Wellington area

Description of event	Direction	Power Limit
		With Statcom
Disconnection of one 220 kV circuit at HAY	North Flow	None
	South Flow	None
HAY 220 kV Bus section A,B, or C cleared by backup protection	North Flow	None
	South Flow	None
BPE 220 kV bus section A1 or B cleared by backup protection	North Flow	None
	South Flow	300 MW

1.6.3 Transient overvoltage power transfer limits at Haywards

The Transient Overvoltage power transfer limits are to prevent voltage rise for a loss of the Bi-pole, from rising above 1.45pu at Haywards. The TOV power transfer limit is determined by the configuration of the AC system. There are only TOV power transfer limits for outages at low Wellington demand and none for outages at high Wellington demand. Between low and high Wellington demand the power limit is proportioned.

From the bi-pole operating policy:

The HVDC power transfer limits to prevent the TOV limits from being exceeded are calculated using the following equation:

$$P_{\text{limit}} = P_{\text{max}} - [P_{\text{line}} + P_{\text{condenser}} + P_{\text{transformer}} + P_{\text{Statcom}} + P_{\text{voltage}} + P_{\text{special}}] * \text{Wellington TOV demand factor}$$

P_{limit} is calculated by using the Bipole capacity (P_{max}) and subtracting from that different power values depending on what equipment is out.

For $0 > \text{Wellington load} > 250$: Wellington TOV demand factor = 1

For $250 > \text{Wellington load} > 500$: Wellington TOV demand factor = $1 - (\text{Wellington load} - 250) / 250$

For Wellington load > 500 : Wellington TOV demand factor = 0. These values are defined as:

P_{line} is the power limit value due to the circuit outages. The circuits are defined as the following:

Equipment Type	Included Equipment
Single circuit towers	BPE-PRM-HAY 1 BPE-PRM-HAY 2
Double circuit towers	BPE-TWC-LTN 1 HAY-LTN 1 ¹⁶ BPE-LTN-WIL 1
HAY-WIL 1 circuit	HAY-WIL 1 ¹⁷

$P_{condenser}$ is the power limit due to condenser outages. The Haywards condensers are split into two categories:

Equipment Type	Included Equipment
Condenser (small)	HAY SC3, SC4 ¹⁰
Condenser (large)	HAY SC1, SC2, SC7, SC8, SC9, SC10

$P_{transformers}$ is the power limit due to outages of the Haywards interconnecting transformers HAY T1, T2, T5.

$P_{statcom}$ is the power limit due to the outages of the Haywards Statcom.

$P_{voltage}$ is the power limit that considers the AC bus bar voltage at Haywards 220 kV

$P_{special}$ are power limits due to other outages that are not covered by the above criteria. The special considerations are:

- 4th HAY route All four 220 kV circuits out of HAY out of service¹⁹
- All transformers out All of the HAY interconnecting Transformer out of service
- 220 kV bus split Due to the split of the 220 kV bus at HAY

The power limits are defined as reductions in MW transfer capability and are defined as follows:

Equipment Type	North Flow		South Flow	
P_{max}	1200 MW		850 MW**	
	1 st outage	Each further outage	1 st outage	Each further outage
Single circuit towers	150	150	100	150
Double circuit Towers	150	150	100	150
HAY-WIL 1	100	n/a	100	n/a
4 th HAY route	250	n/a	250	n/a
Circuits North of BPE	150	150	100	150
Transformer	100	100	100	100
All transformers	300	n/a	300	n/a
220 kV split bus	150	n/a	200	n/a
Condenser (Small)	100	n/a	50	n/a
Condenser large	100	50	50	50
Statcom	200	200	100	150
$P_{voltage}$	50 if $V_{ac} < 220$ kV		50 if $V_{ac} < 220$ kV	

****Note:** This power limit is based on the designed south power limit of 850 MW. Refer to Table C6 for the offered south capability.

The power limit resulting from a tripping of a piece of equipment from the table above can also affect the risk offset (risk subtractor), if that equipment is classified as a contingent event, e.g. a line or a statcom. This can result in restrictions on the HVDC capacity through insufficient low-priced reserves to support higher HVDC transfers.

1.6.4 Filter outages

If there are not enough filters available then the HVDC transfer will be restricted. In addition outages of filters may result in a reduction to the HVDC risk offset (HVDC risk subtractor). This can result in restrictions on the HVDC capacity through insufficient low-priced reserves to support higher HVDC transfers. These restrictions are listed in the HVDC bi-pole operating policy Appendix G1 and G2.

1.6.5 Reduced voltage operation

Reduced voltage operation restricts Pole 2 to 300MW and Pole 3 to 500MW (or 300MW if redundant cooling is not fully available) and removes the overload capability of both poles. This means not only is the capacity restricted but so is the HVDC risk offset (HVDC risk subtractor). This can result in restrictions on the HVDC capacity through insufficient low-priced reserves to support higher HVDC transfers.

1.6.6 Reserve shortfalls

(not enough North Island Reserves to support extra transfer over the HVDC)

At times there may be insufficient North Island reserves (FIR and/or SIR) offered at any price to support higher levels of HVDC transfer.

10

1.6.7 Economic cost of extra SI energy

This is where the cost of extra North Island energy is cheaper than an extra MW of South Island energy.

1.6.8 Economic cost of extra reserves

This is where the cost of extra North Island energy is cheaper than an extra MW of South Island energy plus an extra MW of North Island reserves.