

# Security Policy Review: Credible Event Management

## Appendix 6 – Busbar Event Costs

December 2009



SYSTEM OPERATOR

*Keeping the energy flowing*

TRANSPower



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## Appendix 6 – Busbar Event Costs

### North Island

Busbar	Stability Event (\$m)	Contingent Event (\$m)	Extended Contingent Event (\$m)			Link
	\$20k	\$10k	\$10k	\$5k	\$2k	
<b>Northland</b>						
ALB 220_1	0.05	82.344	0.0015	0.0008	0.0003	<a href="#">ALB 220_1</a>
ALB 110_1	0.23	1955.23	0.0356	0.0178	0.0071	<a href="#">ALB 110_1</a>
ALB 110_2	0.016	39.42	0.0007	0.0004	0.0001	<a href="#">ALB 110_2</a>
HEN 220_1	0.101	173.448	0.0032	0.0016	0.0006	<a href="#">HEN 220_1</a>
MPE 110_1	0.035	141.912	0.0026	0.0013	0.0005	<a href="#">MPE 110_1</a>
MPE 110_2	0.035	141.912	0.0026	0.0013	0.0005	<a href="#">MPE 110_2</a>
<b>Auckland</b>						
OTA 220_C	0.0108	11.388	0.00021	0.00010	0.00004	<a href="#">OTA 220_C</a>
OTA 220_D	0.0156	9.636	0.00018	0.00009	0.00004	<a href="#">OTA 220_D</a>
OTA 110_A1	0.0835	168.192	0.00306	0.00153	0.00061	<a href="#">OTA 110_A1</a>
OTA 110_A2	0.0092	10.512	0.00019	0.00010	0.00004	<a href="#">OTA 110_A2</a>
PEN 220_1	0.0233	40.296	0.00073	0.00037	0.00015	<a href="#">PEN 220_1</a>
PEN 220_2	0.0117	5.256	0.00010	0.00005	0.00002	<a href="#">PEN 220_2</a>
PEN 220_3	0.0233	40.296	0.00073	0.00037	0.00015	<a href="#">PEN 220_3</a>
<b>Hamilton</b>						
HAM 220_1	0.0043	2.628	0.00005	0.00002	0.00001	<a href="#">HAM 220_1</a>
HAM 220_2	0.0043	2.628	0.00005	0.00002	0.00001	<a href="#">HAM 220_2</a>
<b>Bay of Plenty</b>						
ATI 220_2	0.2404	446.76	0.008	0.0041	0.0016	<a href="#">ATI 220_2</a>
OHK 220	0.0155	22.78	0.0004	0.0002	0.0001	<a href="#">OHK 220</a>

<i>Busbar</i>	<i>Stability Event (\$m)</i>	<i>Contingent Event (\$m)</i>	<i>Extended Contingent Event (\$m)</i>			<i>Link</i>
TRK 220_2	0.0084	14.016	0.0003	0.0001	0.00005	<a href="#">TRK 220_2</a>
TRK 110_1	0.0085	12.264	0.00022	0.0001	0.00004	<a href="#">TRK 110_1</a>
TRK 110_2	0.1814	685.908	0.01249	0.0062	0.0025	<a href="#">TRK 110_2</a>
<b>Hawkes Bay</b>						
RDF 220_A	0.0868	280.32	0.00511	0.00255	0.00102	<a href="#">RDF 220_A</a>
RDF 220_B	0.0868	280.32	0.00511	0.00255	0.00102	<a href="#">RDF 220_B</a>
<b>Taranaki</b>						
SFD 110_1	0.0008	0.438	0.00001	0.000004	0.000002	<a href="#">SFD 110_1</a>
SFD 110_2	0.0170	8.760	0.00016	0.00008	0.00003	<a href="#">SFD 110_2</a>
<b>Bunnythorpe</b>						
BPE 220_A1 HVDC North	0.0172	3.504	0.00006	0.00003	0.00001	<a href="#">BPE 220_A1 HVDC North</a>
BPE 220_A1 HVDC South (pre-2012)	1.6582		0.0012	0.0012	0.0012	<a href="#">BPE 220_A1 HVDC South</a>
BPE 220_A1 HVDC South (post-2012)	1.6582		0.00055	0.00055	0.00055	
BPE 220_A2 HVDC North	0.0169	9.636	0.00018	0.00009	0.00004	<a href="#">BPE 220_A2 HVDC North</a>
BPE 220_A2 HVDC South (pre-2012)	1.6582		0.0012	0.0012	0.0012	<a href="#">BPE 220_A2 HVDC South</a>
BPE 220_A2 HVDC South (post-2012)	1.6582		0.00009	0.00009	0.00009	
BPE 220_B HVDC North	0.0171	6.132	0.00011	0.00006	0.00002	<a href="#">BPE 220_B HVDC North</a>

<b>Busbar</b>	<b>Stability Event (\$m)</b>	<b>Contingent Event (\$m)</b>	<b>Extended Contingent Event (\$m)</b>			<b>Link</b>
BPE 220_B HVDC South (pre-2012)	1.6582		0.0012	0.0012	0.0012	<a href="#">BPE 220_B HVDC South</a>
BPE 220_B HVDC South (post-2012)	1.6582		0.00009	0.00009	0.00009	
BPE 110_A HVDC North	0.0166	18.396	0.00034	0.00017	0.00007	<a href="#">BPE 110_A HVDC North</a>
BPE 110_A HVDC South (pre-2012)	0.444		0.00167	0.00122	0.00120	<a href="#">BPE 110_A HVDC South</a>
BPE 110_A HVDC South (post-2012)	0.444		0.00073	0.0005	0.00036	
BPE 110_B North Transfer	0.0170	7.008	0.00013	0.00006	0.00003	<a href="#">BPE 110_B HVDC North</a>
BPE 110_B HVDC South (pre-2012)	0.444		0.0012	0.0012	0.0012	<a href="#">BPE 110_B HVDC South</a>
BPE 110_B HVDC South (post-2012)	0.444		0.00004	0.00004	0.00004	
MHO 110_1	0.0195	70.08	0.00128	0.00064	0.00026	<a href="#">MHO 110_1</a>
MHO 110_2	0.0195	70.08	0.00128	0.00064	0.00026	<a href="#">MHO 110_2</a>
TKU 220_1 HVDC South (pre-2012)	1.6582		0.0012	0.0012	0.0012	<a href="#">TKU 220_1 HVDC South</a>
TKU 220_1 HVDC South (post-2012)	1.6582		0.00004	0.00004	0.00004	

<i>Busbar</i>	<i>Stability Event (\$m)</i>	<i>Contingent Event (\$m)</i>	<i>Extended Contingent Event (\$m)</i>			<i>Link</i>
TKU 220_2 HVDC South (pre-2012)	1.6582		0.0012	0.0012	0.0012	<a href="#"><i>TKU 220_2 HVDC South</i></a>
TKU 220_2 HVDC South (post-2012)	1.6582		0.00004	0.00004	0.00004	
<b>Wellington</b>						
HAY 220_A HVDC North	0.215	740.2	0.013	0.007	0.003	<a href="#"><i>HAY 220_A HVDC North</i></a>
HAY 220_A HVDC South (pre-2012)	0.09	183.9	0.004	0.0017	0.0007	<a href="#"><i>HAY 220_A HVDC South</i></a>
HAY 220_A HVDC South (post-2012)	0.09	183.9	0.003	0.0017	0.0007	
HAY 220_B HVDC North	0.215	740.2	0.013	0.007	0.003	<a href="#"><i>HAY 220_B HVDC North</i></a>
HAY 220_B HVDC South (pre-2012)	0.124	380.2	0.008	0.004	0.001	<a href="#"><i>HAY 220_B HVDC South</i></a>
HAY 220_B HVDC South (post-2012)	0.124	380.2	0.008	0.004	0.001	
HAY 220_C HVDC North	0.089	214.6	0.004	0.002	0.0008	<a href="#"><i>HAY 220_C HVDC North</i></a>
HAY 220_C HVDC South (pre2012)	0.09	183.9	0.003	0.002	0.0007	<a href="#"><i>HAY 220_C HVDC South</i></a>
HAY 220_C HVDC South (post-2012)	0.09	183.9	0.003	0.002	0.0007	

<i>Busbar</i>	<i>Stability Event (\$m)</i>	<i>Contingent Event (\$m)</i>	<i>Extended Contingent Event (\$m)</i>			<i>Link</i>
HAY 110_A HVDC North	1.005	10798.44	0.194	0.0097	0.039	<a href="#">HAY 110_A HVDC North</a>
HAY 110_A HVDC South (pre-2012)	0.91		0.14	0.009	0.003	<a href="#">HAY 110_A HVDC South</a>
HAY 110_A HVDC South (post-2012)	0.91		0.14	0.009	0.003	
HAY 110_B HVDC North	0.170	670.14	0.012	0.006	0.002	<a href="#">HAY 110_B HVDC North</a>
HAY 110_B HVDC South (pre-2012)	0.171		0.010	0.005	0.002	<a href="#">HAY 110_B HVDC South</a>
HAY 110_B HVDC South (post-2012)	0.171		0.010	0.005	0.002	
TKR 110_1 HVDC North	0.053	131.4	0.002	0.001	0.0004	<a href="#">TKR 110 1 HVDC North</a>
TKR 110_1 HVDC South	0.180	756.6	0.014	0.007	0.003	<a href="#">TKR 110 1 HVDC South</a>
TKR 110_2 HVDC North	0.053	131.4	0.002	0.001	0.0004	<a href="#">TKR 110 2 HVDC North</a>
TKR 110_2 HVDC South	0.180	756.6	0.014	0.007	0.003	<a href="#">TKR 110 2 HVDC South</a>
WIL 220_A HVDC South (pre-2012)	0.0012		0.012			<i>HVDC only</i> <a href="#">WIL 220_A HVDC South</a>
WIL 220_A HVDC South (post-2012)	0.0012		0.00001			

<i>Busbar</i>	<i>Stability Event (\$m)</i>	<i>Contingent Event (\$m)</i>	<i>Extended Contingent Event (\$m)</i>			<i>Link</i>
	\$20k	\$10k	\$10k	\$5k	\$2k	
WIL 220_B HVDC South (pre-2012)	0.0012		0.012			<i>HVDC only</i>
WIL 220_B HVDC South (post-2012)	0.0012		0.00001			<i>WIL 220_B HVDC South</i>

## South Island

Busbar	Stability Event (\$m)	Contingent Event (\$m)	Extended Contingent Event (\$m)			Link
	\$20k	\$10k	\$10k	\$5k	\$2k	
<b>Nelson</b>						
ATU 110	0.266	57.82	0.0010	0.00052	0.00021	<a href="#">ATU 110</a>
IGH 110	0.687	364.42	0.0066	0.003	0.0013	<a href="#">IGH 110</a>
KIK 220_A	0.5504	87.6	0.0016	0.001	0.0003	<a href="#">KIK 220_A</a>
KIK 110	1.207	848.84	0.0153	0.008	0.0031	<a href="#">KIK 110</a>
STK 220_A	0.550	91.98	0.0017	0.001	0.0003	<a href="#">STK 220_A</a>
STK 220_B	0.2383	2182.99	0.0392	0.020	0.0078	<a href="#">STK 220_B</a>
STK 110	0.113	683.28	0.0123	0.006	0.0025	<a href="#">STK 110</a>
<b>Christchurch</b>						
ADD 66_1	0.014	30.66	0.0007	0.0036	0.00015	<a href="#">ADD 66_1</a>
ISL 220_A	2.087	490.56	0.0088	0.004	0.002	<a href="#">ISL 220_A</a>
ISL 220_B	1.820	409.97	0.0074	0.004	0.001	<a href="#">ISL 220_B</a>
ISL 220_C	0.638	70.08	0.0013	0.00063	0.00025	<a href="#">ISL 220_C</a>
ISL 66_C	0.748	59.57	0.0014	0.00071	0.00028	<a href="#">ISL 66_C</a>
<b>Canterbury</b>						
ASB 220_A	0.148	491.44	0.0088	0.00442	0.00177	<a href="#">ASB 220_A</a>
ASB 220_C	3.245	1102.01	0.0198	0.00991	0.00396	<a href="#">ASB 220_C</a>
BRY 220_A	0.0413	98.11	0.0018	0.00088	0.00035	<a href="#">BRY 220_A</a>
BRY 220_B	0.0413	98.11	0.0018	0.00088	0.00035	<a href="#">BRY 220_B</a>
TIM 110	0.069	-	-	-	-	<a href="#">TIM 110_B</a>
<b>Otago</b>						

<i>Busbar</i>	<i>Stability Event (\$m)</i>	<i>Contingent Event (\$m)</i>	<i>Extended Contingent Event (\$m)</i>			<i>Link</i>
	<i>\$20k</i>	<i>\$10k</i>	<i>\$10k</i>	<i>\$5k</i>	<i>\$2k</i>	
TKB 220	1.639	210.24	0.0038	0.00189	0.00076	<a href="#">TKB 220</a>
<b>Southland</b>						
BWK 110	0.031	161.18	0.002	0.001	0.0006	<a href="#">BWK 110</a>
INV 110	0.005	14.89	0.0003	0.0001	0.00005	<a href="#">INV 110</a>
INV 220_1	0.005	14.89	0.0003	0.0001	0.00005	<a href="#">INV 220_1</a>
HWB 220_A	0.249 1676.66	6.66	0.03	0.015 0.006		<a href="#">HWB 220_A</a>

**Event:** Loss of Otahuhu 110kV busbar A1

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Post event:** Loss of Otahuhu transformers 4 and 5 and capacitors 11 and 12. Loss of 110kV Otahuhu-Mangere-1 and 2 and Otahuhu-Bombay-1 and 2.

**Consequence:** 110kV Otahuhu-Mount Roskill-1 and 2 will be overloaded to 114MVA and 115MVA respectively and will trip. The ratings of the 110kV Otahuhu-Mount Roskill circuits are 101MVA.

The tripping of these circuits will result in the 110kV Mount Roskill-Hepburn -1 and 2 to overload and automatically open as a result of a SPS.

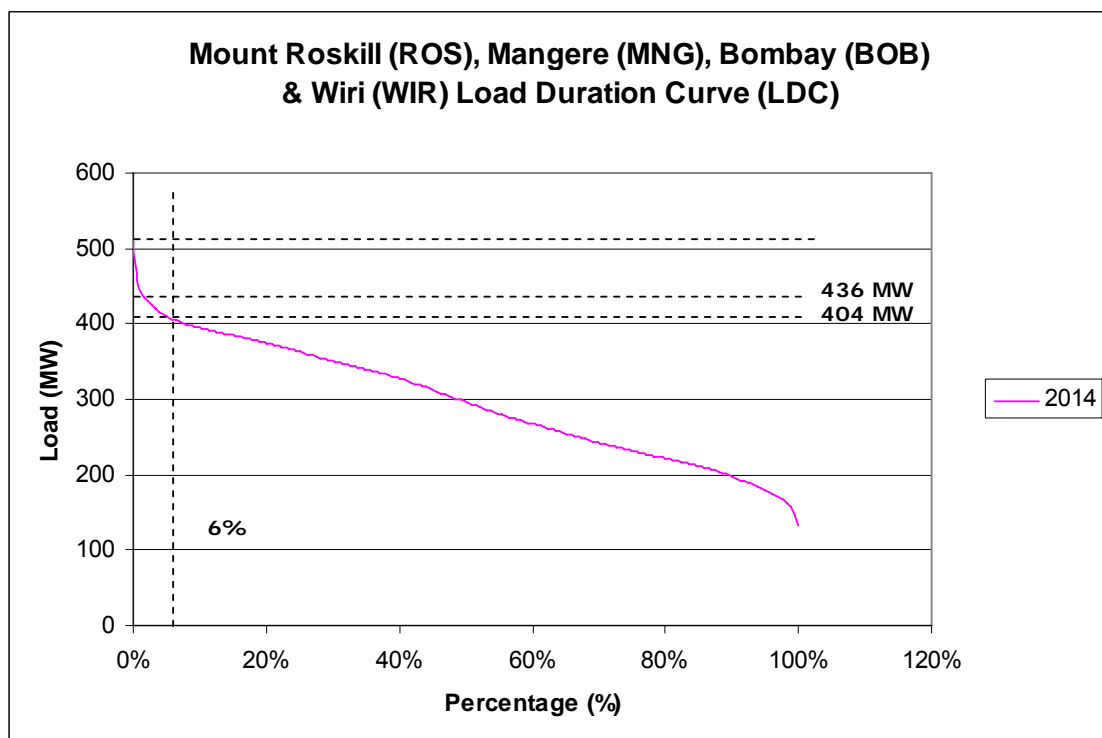
The 110kV Bombay-Hamilton-1 and -2 will each be overloaded to 64MVA. The rating of the 110kV Bombay-Hamilton circuits are 61MVA.

Loss of supply to Mount Roskill, Mangere, Bombay and Wiri.

**Constraint:** Load constraint limit at Mount Roskill, Mangere, Bombay and Wiri is 404MW.

For 2014, the constraint is exceeded for 6% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	436	7.5	20,000	65.4	0.021	0.06	0.082



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 32MW load constraint at Mount Roskill, Mangere, Bombay and Wiri.

**Post event:** The remaining Mount Roskill, Mangere, Bombay and Wiri load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	32	8760	10,000	n/a	n/a	0.06	168.19

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 32MW post event load shedding at Mount Roskill, Mangere, Bombay and Wiri.

**Post event:** The remaining Mount Roskill, Mangere, Bombay and Wiri load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	32	7.5	10,000	2.4	0.021	0.06	0.003

**Event:** Loss of Otahuhu 110kV busbar A2

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** None

**Post event:** Loss of Otahuhu transformers 2 and 3. Loss of Otahuhu-Pakuranga-1 and 2, Otahuhu-Penrose-2, Otahuhu-Mount Roskill- 1 and 2 and loss of Otahuhu synchronous condensers.

**Consequence:** 110kV Pakuranga-Penrose circuit will be overloaded to 157MVA. Winter rating of 110kV Pakuranga -Penrose circuit is 140MVA.

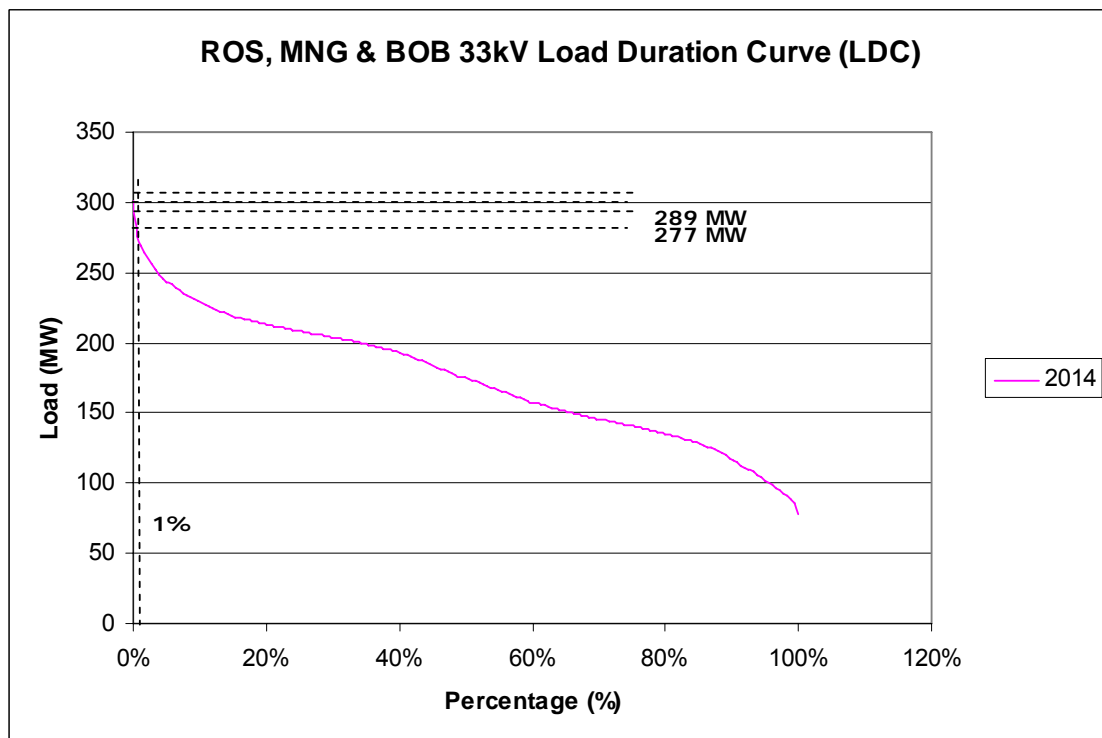
Penrose transformer 10 will be overloaded to 330MVA. Winter 24 hour post contingency rating of Penrose T10 is 293MVA.

110kV Pakuranga-Penrose circuit and Penrose transformer 10 will trip. Loss of supply to Penrose 110kV and Pakuranga 33kV load.

**Constraint:** Load constraint limit at Penrose 110kV and Pakuranga 33kV load is 277MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	136	7.5	20,000	20.40	0.021	0.2	0.086



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 12MW load constraint at Penrose 110kV and Pakuranga 33kV.

**Post event:** The remaining Penrose 110kV and Pakuranga 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	12	8760	10,000	n/a	n/a	0.01	10.51

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 12MW post event load shedding at Penrose 110kV and Pakuranga 33kV.

**Post event:** The remaining Penrose 110kV and Pakuranga 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	12	7.5	10,000	0.9	0.021	0.01	0.00019

**Event:** Loss of Otahuhu 220kV busbar C

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** None

**Post event:** Loss of Otahuhu transformer 5.  
 Loss of 220kV Otahuhu-Huntly-2  
 Loss of 220kV Otahuhu-Southdown

**Consequence:** Otahuhu transformer 3 will be overloaded to 348MVA and will trip.

Winter 24 hour post contingency rating of Otahuhu T3 is 337MVA.

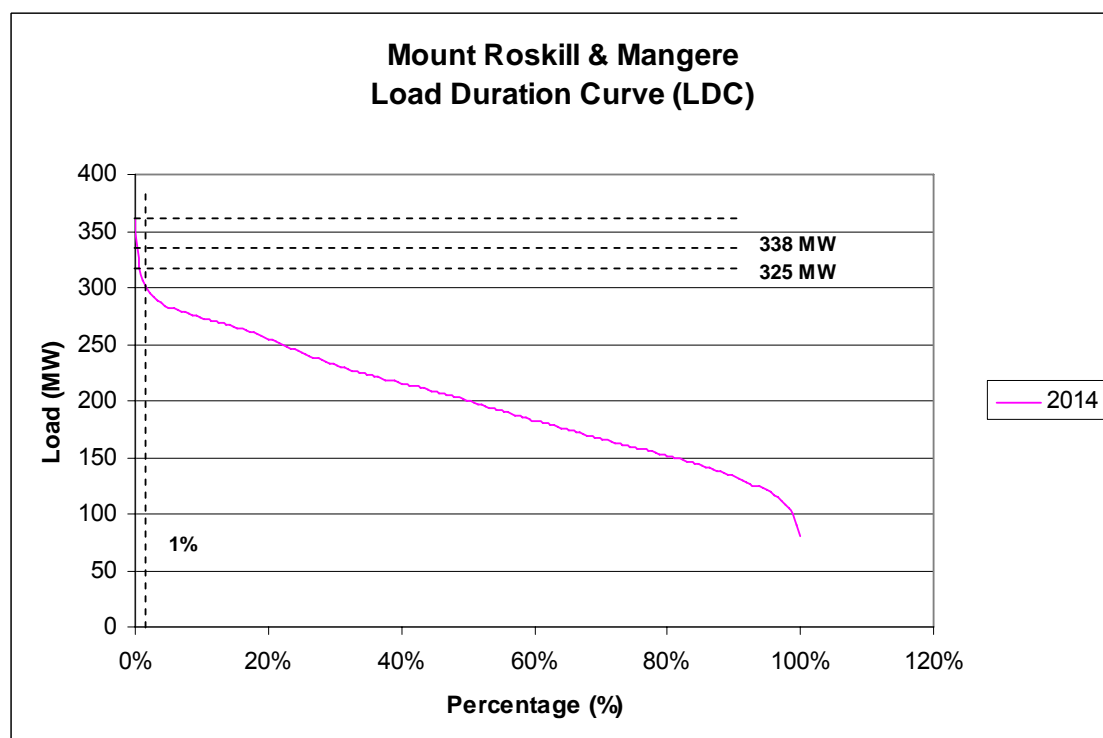
This will result in the 110kV Mount Roskill- Hepburn circuits to overload and cause the operation of the overload protection scheme on these circuits (SPS scheme).

Loss of supply to Mount Roskill and Mangere load.

**Constraint:** Load constraint limit at Mount Roskill and Mangere 325MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	338	7.5	20,000	50.7	0.021	0.01	0.011



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 13MW load constraint at Mount Roskill and Mangere.

**Post event:** The remaining Mount Roskill and Mangere load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	13	8760	10,000	n/a	n/a	0.01	11.39

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 13MW post event load shedding at Mount Roskill and Mangere.

**Post event:** The remaining Mount Roskill and Mangere load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	13	7.5	10,000	0.98	0.021	0.01	0.0002

**Event:** Loss of Otahuhu 220kV busbar D

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** None

**Post event:** Loss of Otahuhu transformer 4 and capacitor 29. Loss of Otahuhu-Henderson and Otahuhu-Glenbrook 220kV circuits.

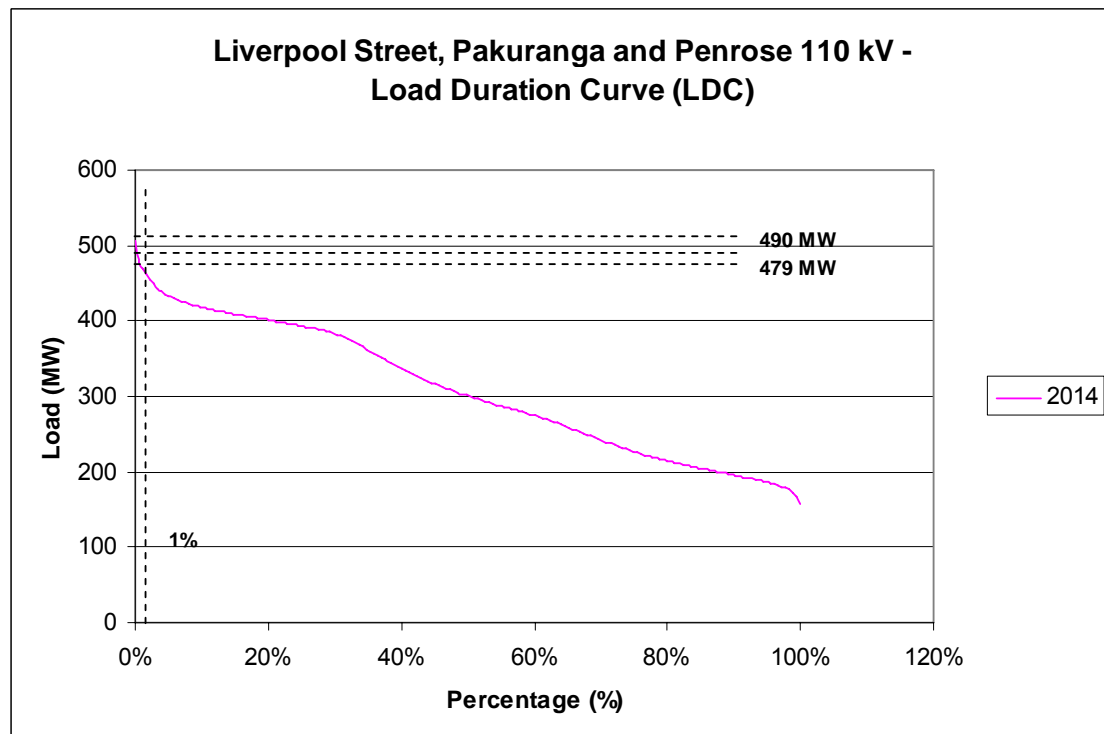
**Consequence:** Otahuhu transformer 2 will be overloaded to 170MVA.  
 Winter 24 hour post contingency rating of Otahuhu transformer 2 is 169MVA.

Loss of supply to Pakuranga, Penrose and Liverpool Street load.

**Constraint:** Load constraint limit at Pakuranga, Penrose and Liverpool Street is 479MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	490	7.5	20,000	73.5	0.021	0.01	0.015



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 11MW load constraint at Pakuranga, Penrose and Liverpool Street.

**Post event:** The remaining Pakuranga, Penrose and Liverpool Street load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	11	8760	10,000	n/a	n/a	0.01	9.64

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 11MW post event load shedding at Pakuranga, Penrose and Liverpool Street.

**Post event:** The remaining Pakuranga, Penrose and Liverpool Street load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	11	7.5	10,000	0.825	0.021	0.01	0.0002

**Event:** Loss of Penrose 220kV busbar section 1

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

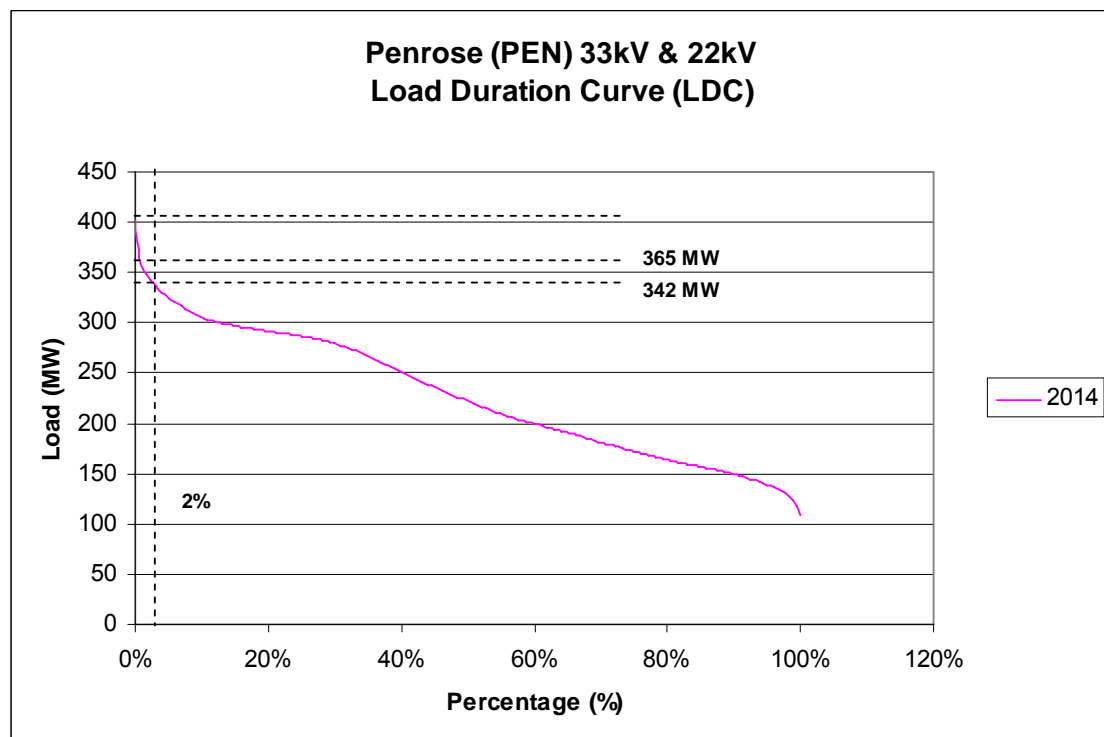
**Assumptions:** None

**Post event:** Loss of Penrose supply transformer 8  
 Loss of 220kV Penrose-Otahuhu-6  
 Loss of Penrose capacitor 1

**Consequence:** Penrose transformer 9 will be overloaded to 217MVA.  
 Winter 24 hour post contingency rating of Penrose T9 is 214MVA.  
 220kV Otahuhu-Penrose-5 will be overloaded to 495MVA.  
 Winter rating of 220kV Otahuhu-Penrose-5 is 455MVA.  
 Loss of supply to Penrose 33kV and 22kV load.

**Constraint:** Load constraint limit at Penrose 22kV and 33kV is 342MW.  
 For 2014, the constraint is exceeded for 2% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	365	7.5	20,000	54.75	0.021	0.02	0.023



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 23MW load constraint at Penrose 33kV and 22kV.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	23	8760	10,000	n/a	n/a	0.02	40.296

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 23MW post event load shedding at Penrose 33kV and 22kV.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	23	7.5	10,000	1.725	0.021	0.02	0.0007

**Event:** Loss of Penrose 220kV busbar section 2

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** None

**Post event:** Loss of Penrose supply transformer 9  
 Loss of Penrose transformer 10

**Consequence:** Penrose supply transformer 8 will be overloaded to 216MVA.

Winter 24 hour post contingency rating of Penrose T8 is 214MVA.

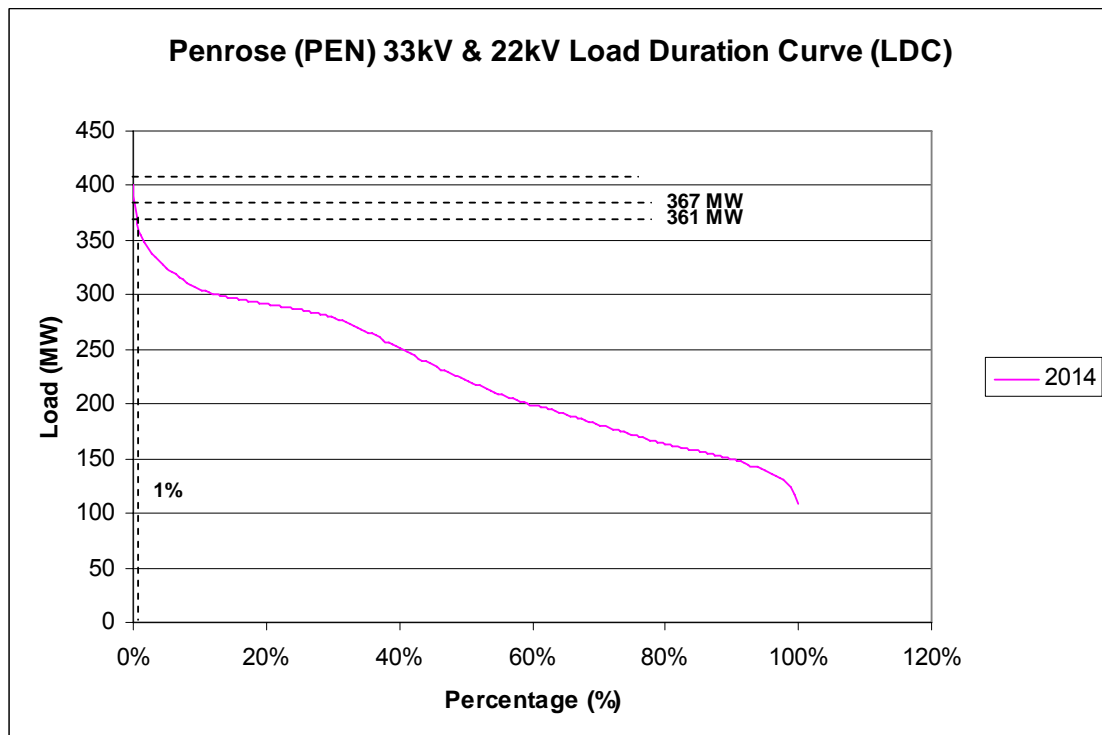
Penrose supply transformer 8 will trip causing Penrose supply transformer 11 also to trip.

Loss of supply to Penrose 33kV and 22kV load.

**Constraint:** Load constraint limit at Penrose 33kV and 22kV is 361MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	367	7.5	20,000	55.05	0.021	0.01	0.012



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 6MW load constraint at the Penrose 33kV and 22kV busbars.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	6	8760	10,000	n/a	n/a	0.01	5.26

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 6MW post event load shedding at the Penrose 33kV and 22kV busbars.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	6	7.5	10,000	0.45	0.021	0.01	0.00009

**Event:** Loss of Penrose 220kV busbar section 3

**Region:** Auckland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** None

**Post event:** Loss of Penrose supply transformer 11  
 Loss of 220kV Penrose-Otahuhu-5

**Consequence:** 220kV Otahuhu-Penrose-6 will be overloaded to 472MVA.

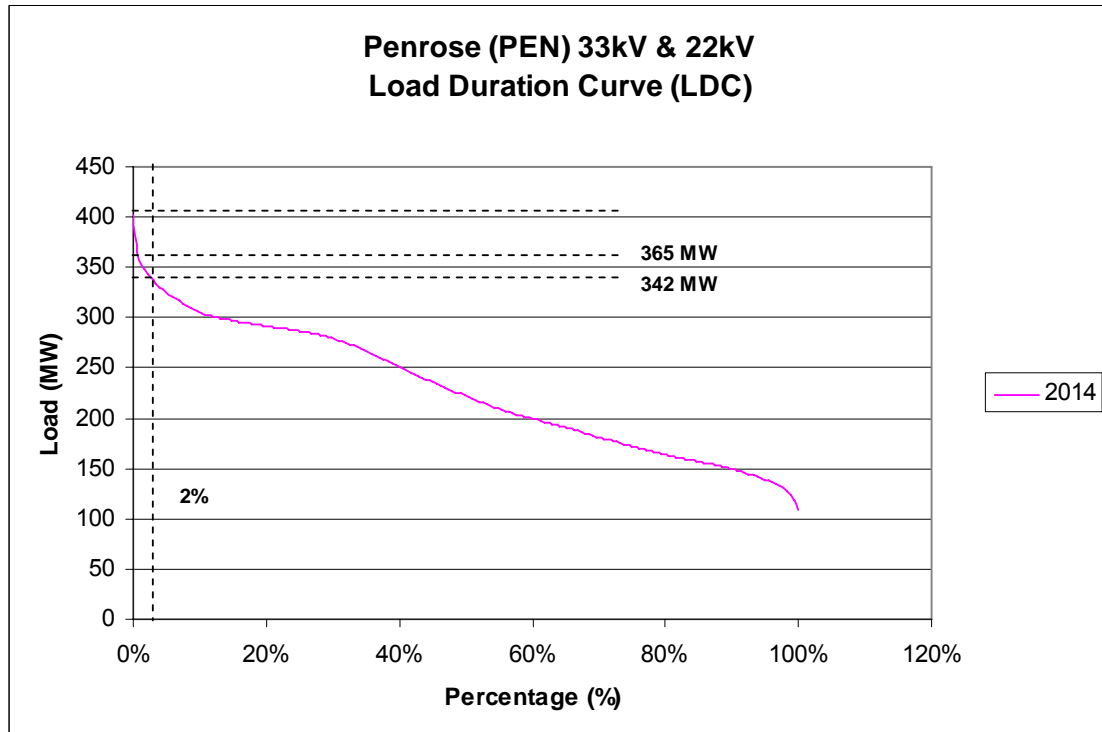
Winter rating of 220kV Otahuhu-Penrose-6 is 455MVA.

Loss of supply to Penrose 33kV and 22kV load.

**Constraint:** Load constraint limit at Penrose 22kV and 33kV is 342MW.

For 2014, the constraint is exceeded for 2% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	365	7.5	20,000	54.75	0.021	0.02	0.023



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 23MW load constraint at Penrose 33kV and 22kV.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	23	8760	10,000	n/a	n/a	0.02	40.296

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 23MW post event load shedding at Penrose 33kV and 22kV.

**Post event:** The remaining Penrose 33kV and 22kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	23	7.5	10,000	1.725	0.021	0.02	0.0007

**Event:** Loss of Atiamuri 220kV busbar section 2

**Region:** Bay of Plenty

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

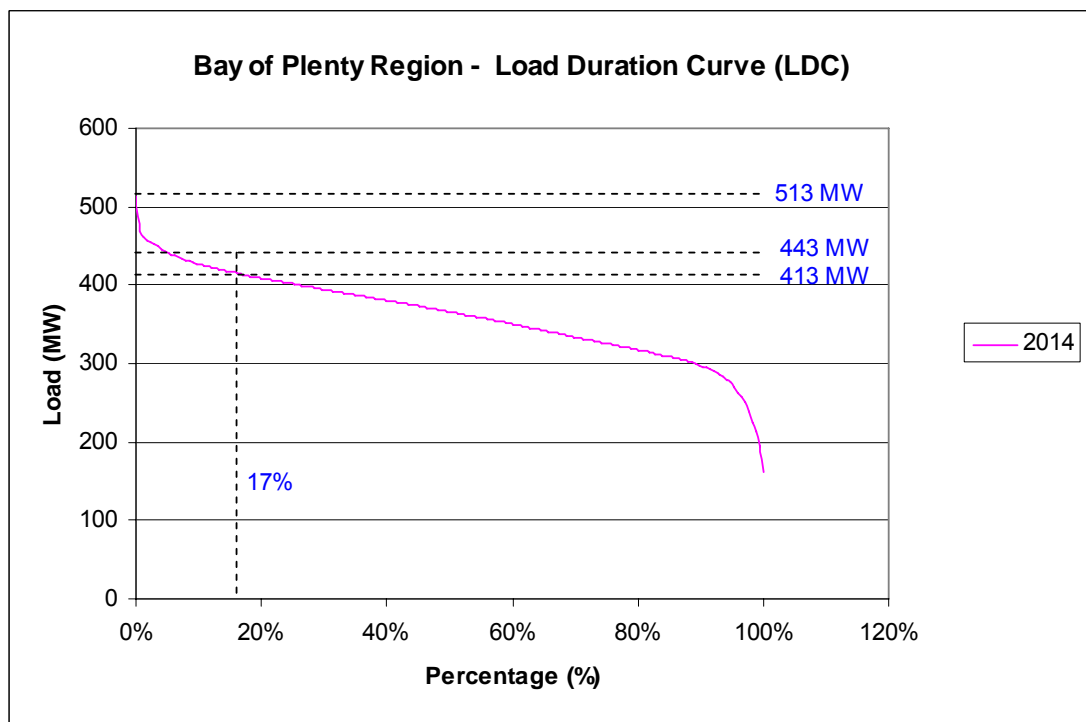
**Assumptions:** Local Generation at Aniwhenua set to 10MW, Matahina at 10MW, Kawerau at 50MW and Wheo at 5MW

**Post event:** Loss of the 220 kV Atiamuri – Ohakuri-1  
 Loss of the 220 kV Atiamuri – Whakamaru-1  
 Loss of the 220 kV Atiamuri – Tarukenga-1

**Consequence:** The loss of the above busbar leads to voltage instability in the Bay of Plenty region. The 220kV Kawerau – Ohakuri-1 circuit overloads way above its rating. Winter rating of the line is 291MVA. Hence it will trip resulting in the loss of supply to the Bay of Plenty region.

**Constraint:** Load constraint limit in the Bay of Plenty region is 413MW.  
 For 2014, the constraint is exceeded for 17% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	443	7.5	20,000	66.45	0.021	0.17	0.237



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 30MW load constraint in the Bay of Plenty region

**Post event:** The remaining Bay of Plenty regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	30	8760	10,000	n/a	n/a	0.17	446.76

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 30MW post event load shedding in the Bay of Plenty region.

**Post event:** The remaining Bay of Plenty regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	30	7.5	10,000	2.25	0.021	0.17	0.008

**Event:** Loss of Ohakuri 220kV busbar

**Region:** Bay of Plenty

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

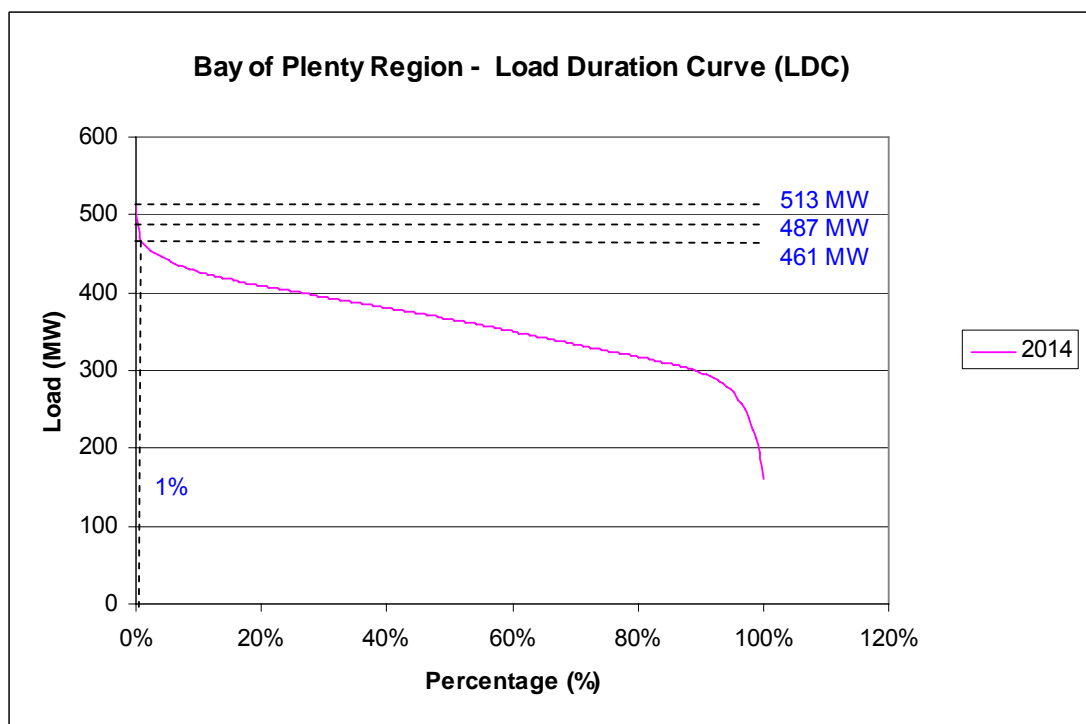
**Assumptions:** Local Generation at Aniwhenua set to 10MW, Matahina at 10MW, Kawerau at 50MW and Wheo at 5MW

**Post event:**  
 Loss of the 220 kV Atiamuri – Ohakuri-1  
 Loss of the 220 kV Kawerau – Ohakuri-1  
 Loss of the 220 kV Ohakuri – Wairakei-1  
 Loss of Ohakuri generators G1, G2, G3 and G4

**Consequence:** The 220 kV Atiamuri – Whakamaru-1 circuit overloads to 415MVA. Winter rating of the line is 358MVA. Hence it will trip resulting in the loss of supply to the Bay of Plenty region

**Constraint:** Load constraint limit in the Bay of Plenty region is 461MW. For 2014 the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	487	7.5	20,000	73.05	0.021	0.01	0.015



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 26MW load constraint in the Bay of Plenty region

**Post event:** The remaining Bay of Plenty regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	26	8760	10,000	n/a	n/a	0.01	22.78

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 26MW post event load shedding in the Bay of Plenty region.

**Post event:** The remaining Bay of Plenty regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	26	7.5	10,000	1.95	0.021	0.01	0.0004

**Event:** Loss of Tarukenga 110kV busbar section 1      **Region:** Bay of Plenty

**Event Risk Factor:** 0.021      **Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

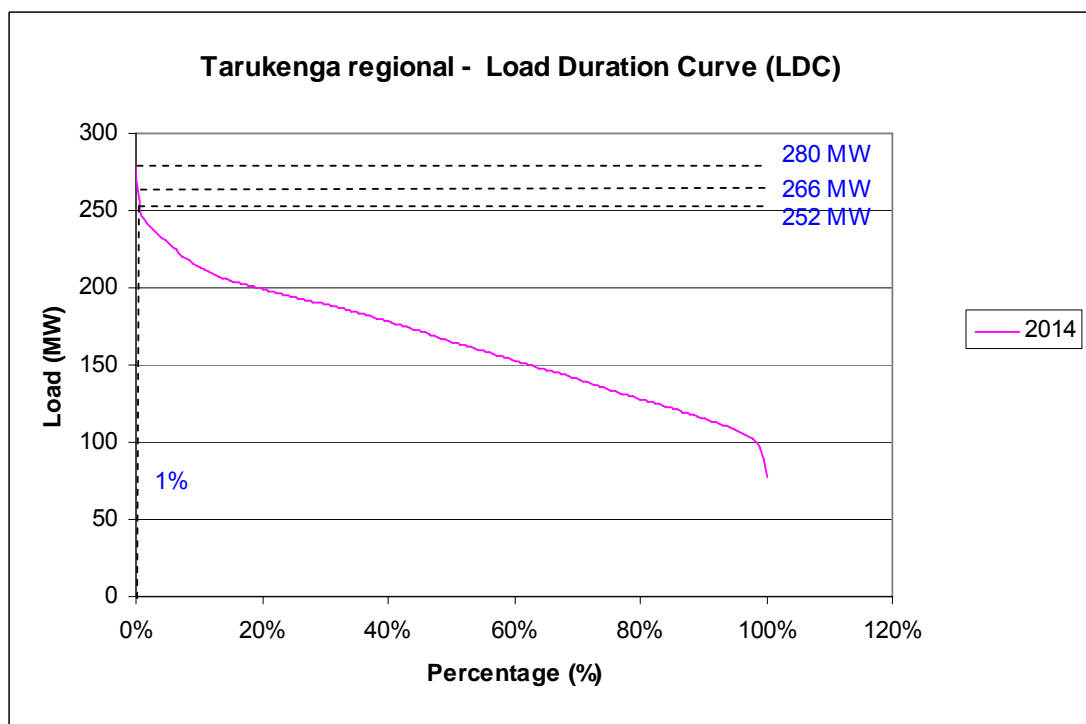
**Assumptions:** Local Generation at Aniwhenua set to 10MW, Matahina at 10MW, Kawerau at 50MW and Wheo at 5MW

**Post event:** Loss of Tarukenga 220/110/11kV transformer T1  
 Loss of the 110 kV Rotorua – Tarukenga-2  
 Loss of the 110 kV Kaitimako – Tarukenga-1  
 Loss of the 220 kV Lichfield – Tarukenga-1

**Consequence:** The remaining Tarukenga 220/110/11kV transformer T2 overloads to 275MVA. Winter 24 h our post contingency rating of the transformer is 273MVA. Hence it will trip resulting in the loss of supply to the Tarukenga region.

**Constraint:** Load constrain limit in the Tarukenga region is 252MW.  
 For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	266	7.5	20,000	39.9	0.021	0.01	0.0084



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 14MW load constraint in the Tarukenga region

**Post event:** The remaining Tarukenga regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	14	8760	10,000	n/a	n/a	0.01	12.26

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 14MW post event load shedding in the Tarukenga region.

**Post event:** The remaining Tarukenga regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	14	7.5	10,000	1.05	0.021	0.01	0.0002

**Event:** Loss of Tarukenga 110kV busbar section 2      **Region:** Bay of Plenty

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

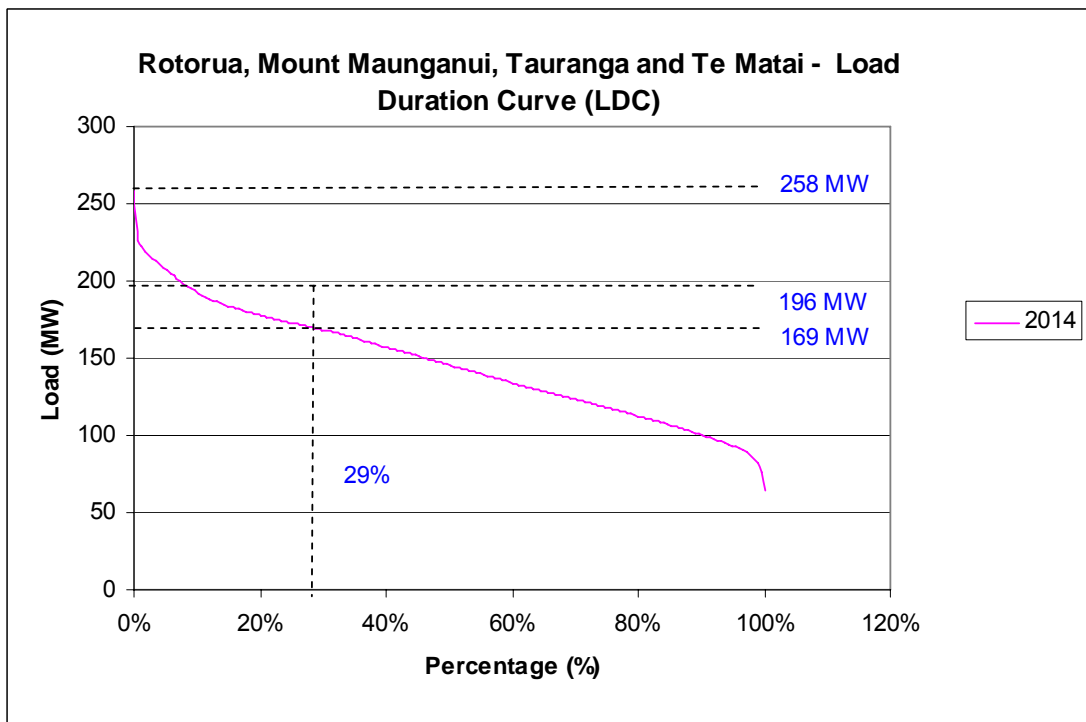
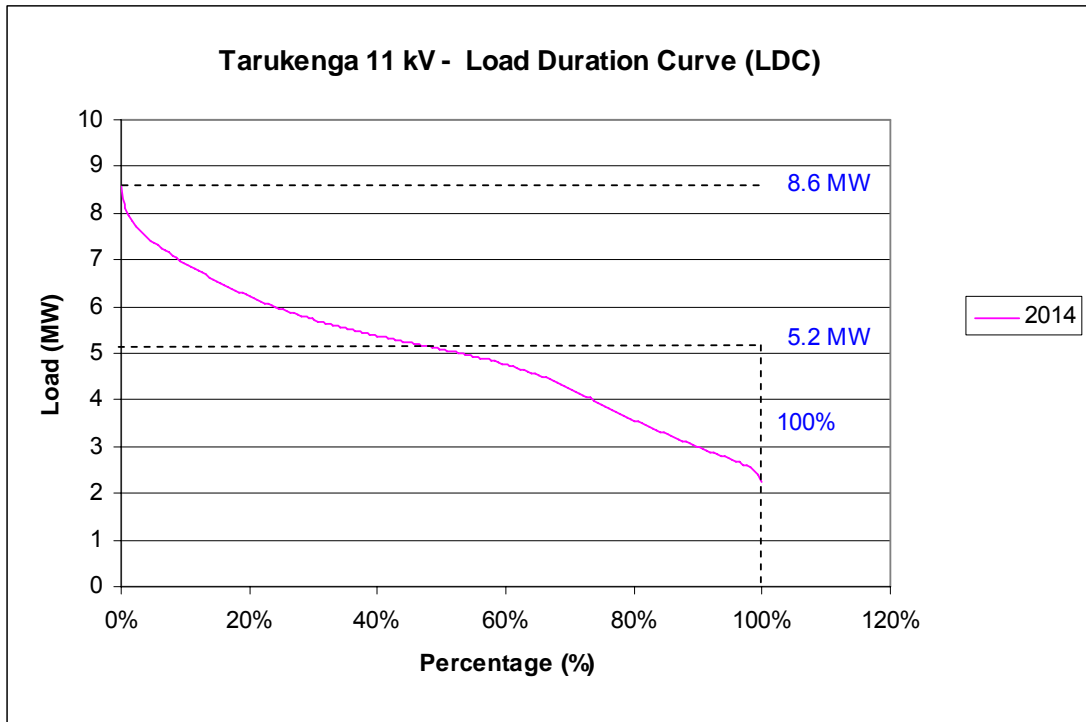
**Assumptions:** Local Generation at Aniwhenua set to 10MW, Matahina at 10MW, Kawerau at 50MW and Wheo at 5MW

**Post event:** Loss of Tarukenga 220/110/11kV transformer T2  
 Loss of Tarukenga 110/11kV transformer T4  
 Loss of the 110 kV Rotorua – Tarukenga-1  
 Loss of the 110 kV Okere – Tarukenga-1  
 Loss of the 110 kV Kaitimako – Tarukenga-2  
 Loss of the 220 kV Lichfield – Tarukenga-2

**Consequence:** The loss of the busbar will result in the loss of supply to the directly connected 11kV load at Tarukenga and the overloading of the Rotorua 110/33kV transformer T2 and the 110kV Kaitimako – Tarukenga-1 circuit to 91MVA and 119MVA respectively. Winter 24 hour post contingency rating of the transformer is 66MVA and that of the line is 99MVA. Hence it will trip resulting in loss of supply to the load at Rotorua, Mount Maunganui, Tauranga and Te Matai.

**Constraint:** Load constraint limit at Rotorua, Mount Maunganui, Tauranga and Te Matai is 169MW.  
 For 2014, the constraint is exceeded for 29% of the time.  
 The Tarukenga 11kV directly connected load is lost for 100% of the time  
 For 2014, the Tarukenga 11kV average load lost for 100% of the time is 5.2MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (TRK 11kV)	5.2	7.5	20,000	0.78	0.021	1	0.0164
Unplanned load shedding (ROT, MT M, TGA & TMI)	196	7.5	20,000	29.4	0.021	0.29	0.18
<b>TOTAL</b>							<b>0.18*</b>



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 27MW load constraint at Rotorua, Mount Maunganui, Tauranga and Te Matai

**Post event:** The remaining load at Rotorua, Mount Maunganui, Tauranga and Te Matai is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (TRK 11kV)	5.2	7.5	20,000	0.78	0.021	1	0.0164
Pre-event load constraint (ROT, MT M, TGA & TMI)	27	8760	10,000	n/a	n/a	0.29	685.9
<b>TOTAL</b>							<b>685.9*</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 27MW post event load shedding at Rotorua, Mount Maunganui, Tauranga and Te Matai

**Post event:** The remaining load at Rotorua, Mount Maunganui, Tauranga and Te Matai is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (TRK 11kV)	5.2	7.5	20,000	0.78	0.021	1	0.0164
Planned load shedding (ROT,MTM, TGA & TMI)	27	7.5	10,000	2.025	0.021	0.29	0.0123
<b>TOTAL</b>							<b>0.0123*</b>

\* Note – The Tarukenga 11kV load is directly connected to the lost busbar and hence there are no mitigation measures to restore its supply. Therefore it has not been included in the costing.

**Event:** Loss of Tarukenga 220kV busbar section 2      **Region:** Bay of Plenty

**Event Risk Factor:** 0.021      **Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

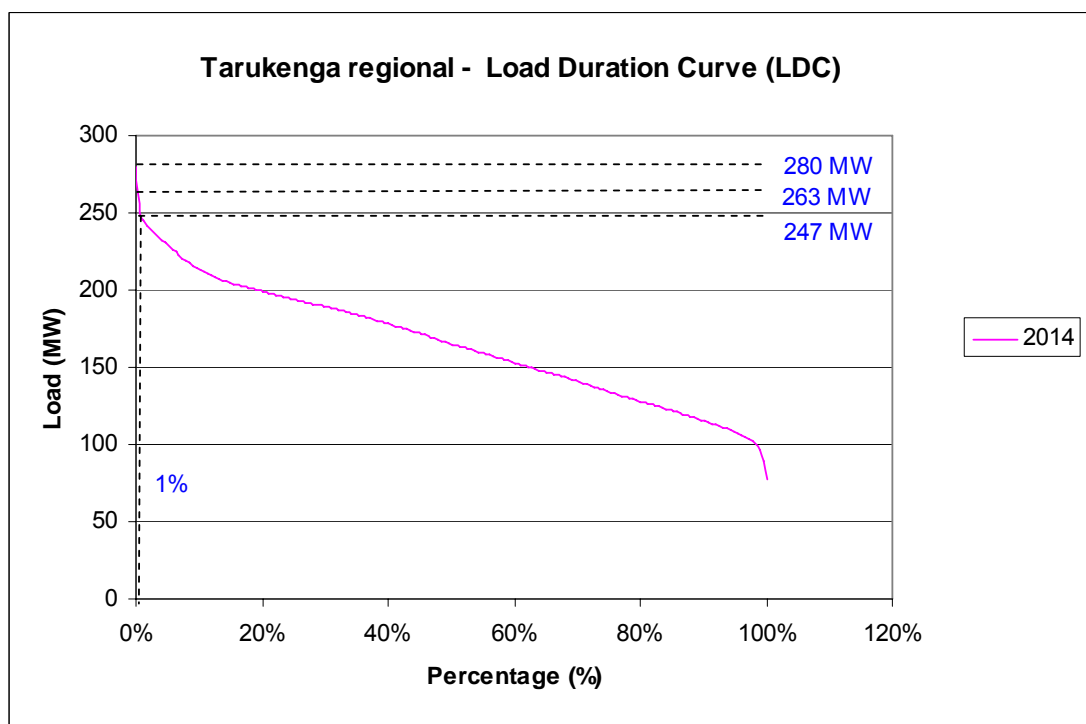
**Assumptions:** Local Generation at Aniwhenua set to 10MW, Matahina at 10MW, Kawerau at 50MW and Wheo at 5MW

**Post event:** Loss of Tarukenga 220/110/11kV transformer T2  
 Loss of the 220 kV Atiamuri – Tarukenga-2  
 Loss of the 220 kV Edgecumbe – Tarukenga-1  
 Loss of the 220 kV Edgecumbe – Tarukenga-2

**Consequence:** The remaining Tarukenga 220/110/11kV transformer T1 overloads to 270MVA. Winter 24 h our post contingency rating of the transformer is 264MVA. Hence it will trip resulting in the loss of supply to the Tarukenga region.

**Constraint:** Load constraint limit in the Tarukenga region is 247MW.  
 For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	263	7.5	20,000	39.45	0.021	0.01	0.0083



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 16MW load constraint in the Tarukenga region

**Post event:** The remaining Tarukenga regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	16	8760	10,000	n/a	n/a	0.01	14.01

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 16MW post event load shedding in the Tarukenga region.

**Post event:** The remaining Tarukenga regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	16	7.5	10,000	1.2	0.021	0.01	0.0003

**Event:** Loss of Bunnythorpe 110kV busbar A

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

Loss of Bunnythorpe transformers 1 and 3. Loss of Bunnythorpe-Mangahao-1, Bunnythorpe-Woodville-1, Bunnythorpe-Wanganui-1 and Bunnythorpe-Mataroa-1 110kV circuits

**Consequence:**

Bunnythorpe transformer 2 will be overloaded to 93MVA. Winter 24 hour post contingency rating of Bunnythorpe T2 is 62MVA.

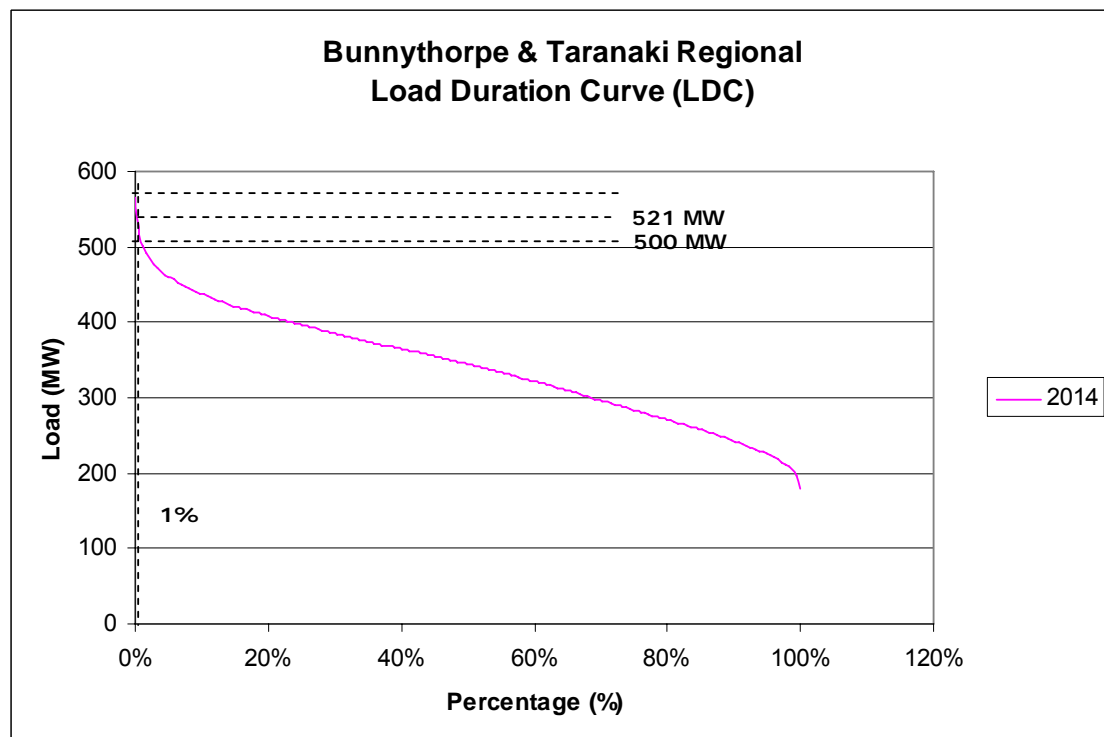
Mangahao transformer 4 will be loaded close to its winter 24 hour post contingency rating of 40MVA.

Bunnythorpe transformer 2 will trip. Loss of supply to Taranaki and Bunnythorpe regions.

**Constraint:**

Load constraint limit in the Bunnythorpe region 500MW.  
 For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	521	7.5	20,000	78.15	0.021	0.01	0.016



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 21MW load constraint in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	21	8760	10,000	n/a	n/a	0.01	18.4

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 21MW post event load shedding in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	21	7.5	10,000	1.58	0.021	0.01	0.0003

**Event:** Loss of Bunnythorpe 110kV busbar A

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC South transfer on Pole 2 – 400MW
- HVDC Pole 1 out of service
- No local generation at Mangahao
- Wind generation at Te Apiti is in service
- Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service.

**Post event:**

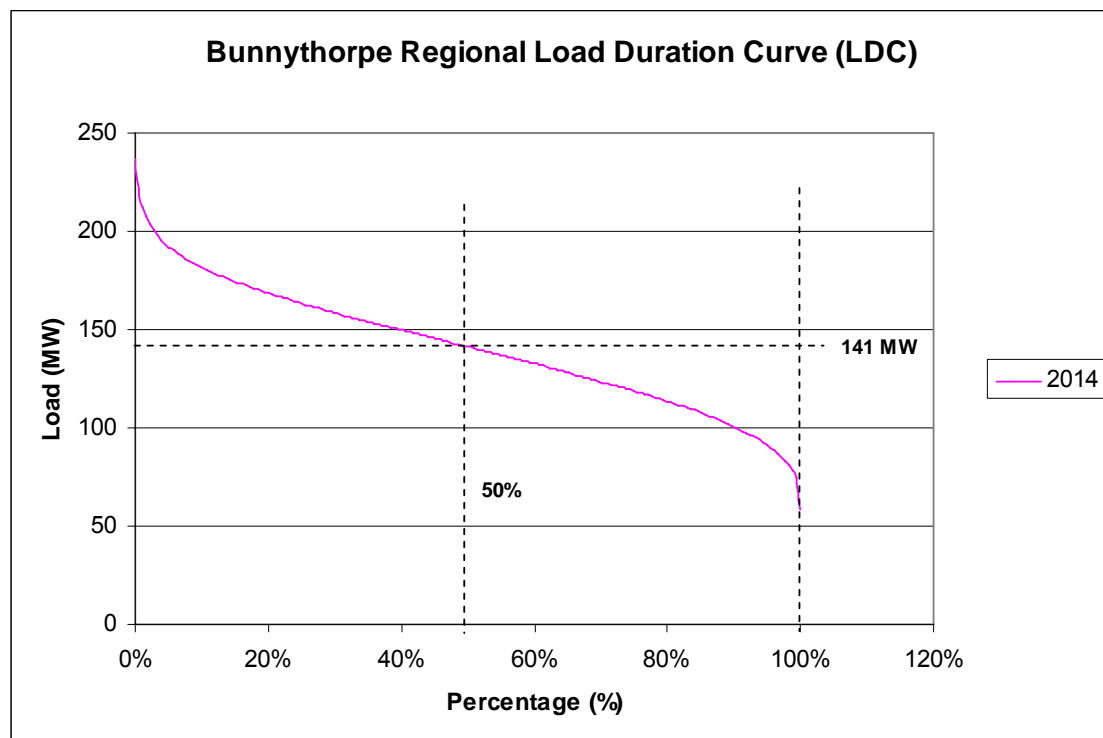
- Loss of Bunnythorpe transformers 1 and 3
- Loss of 110kV Bunnythorpe-Mangahao-1
- Loss of 110kV Bunnythorpe-Woodville-1
- Loss of 110kV Bunnythorpe-Mataroa-1
- Loss of 110kV Bunnythorpe-Wanganui-1

**Consequence:**

The remaining Bunnythorpe transformer 2 will overload and trip resulting in voltage collapse in the Bunnythorpe region.

Loss of Bunnythorpe region.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	141	7.5	20,000	21.15	0.021	1.00	0.444



**CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

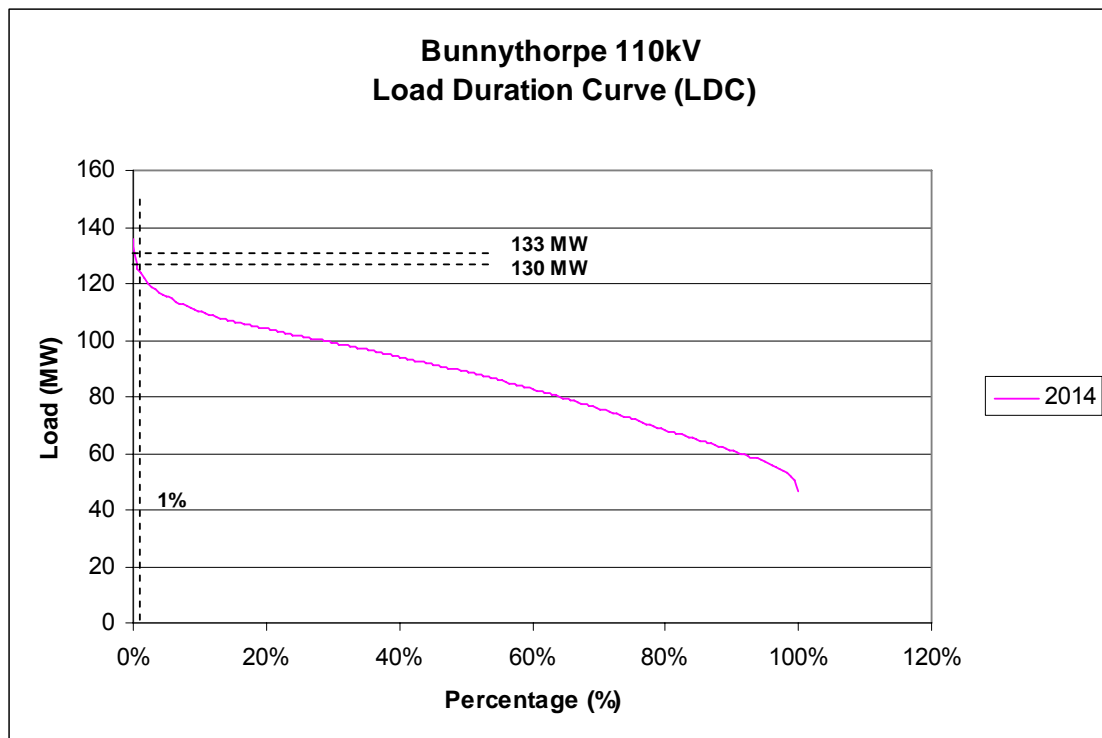
**ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Arrange 3MW post event load shedding at Bunnythorpe 110kV.

Reduce HVDC transfer to 180MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** The remaining Bunnythorpe regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	3	7.5	10,000	0.225	0.021	0.1	0.00047
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>0.00167</b>



***ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)***

**Pre-event measures:** Arrange 3MW post event load shedding at Bunnythorpe 110kV.

Reduce HVDC transfer to 180MW post event from an average load of 290MW.

Average load is greater than 180MW for 9% of the time.

Constrain HVDC by 110MW (average load).

**Post event:** The remaining Bunnythorpe regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	3	7.5	10,000	0.225	0.021	0.1	0.00047
Reduce HV DC (post 2012)	110	-	1250	0.1375	0.021	0.09	0.00026
<b>TOTAL</b>							<b>0.00073</b>

**Event:** Loss of Bunnythorpe 110kV busbar B

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

Loss of Bunnythorpe transformer 2. Loss of Bunnythorpe-Mangahao-2, Bunnythorpe-Wanganui-2 and Bunnythorpe-Woodville-2 110kV circuits

**Consequence:**

Bunnythorpe transformers 1 and 3 will be overloaded to 68MVA each. Winter 24 hour post contingency rating of Bunnythorpe transformers 1 and 3 is 62MVA.

Mangahao transformer 3 will be loaded close to its winter 24 hour post contingency rating of 40MVA.

Bunnythorpe transformers 1 and 3 will trip.

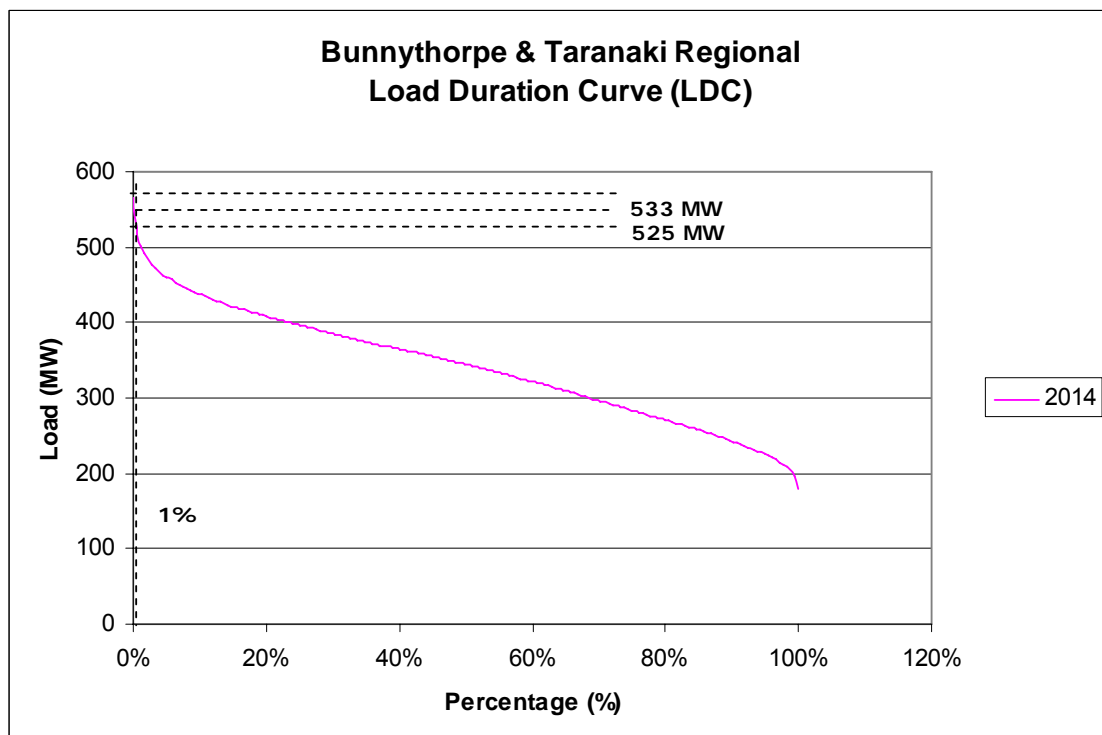
Loss of supply to Taranaki and Bunnythorpe regions.

**Constraint:**

Load constraint limit in the Bunnythorpe region 525MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	533	7.5	20,000	79.95	0.021	0.01	0.017



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 8MW load constraint in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	8	8760	10,000	n/a	n/a	0.01	7.01

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 8MW post event load shedding in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	8	7.5	10,000	0.6	0.021	0.01	0.0001

**Event:** Loss of Bunnythorpe 110kV busbar B

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC South transfer on Pole 2 – 400MW
- HVDC Pole 1 out of service
- No local generation at Mangahao
- Wind generation at Te Apiti is in service
- Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service.

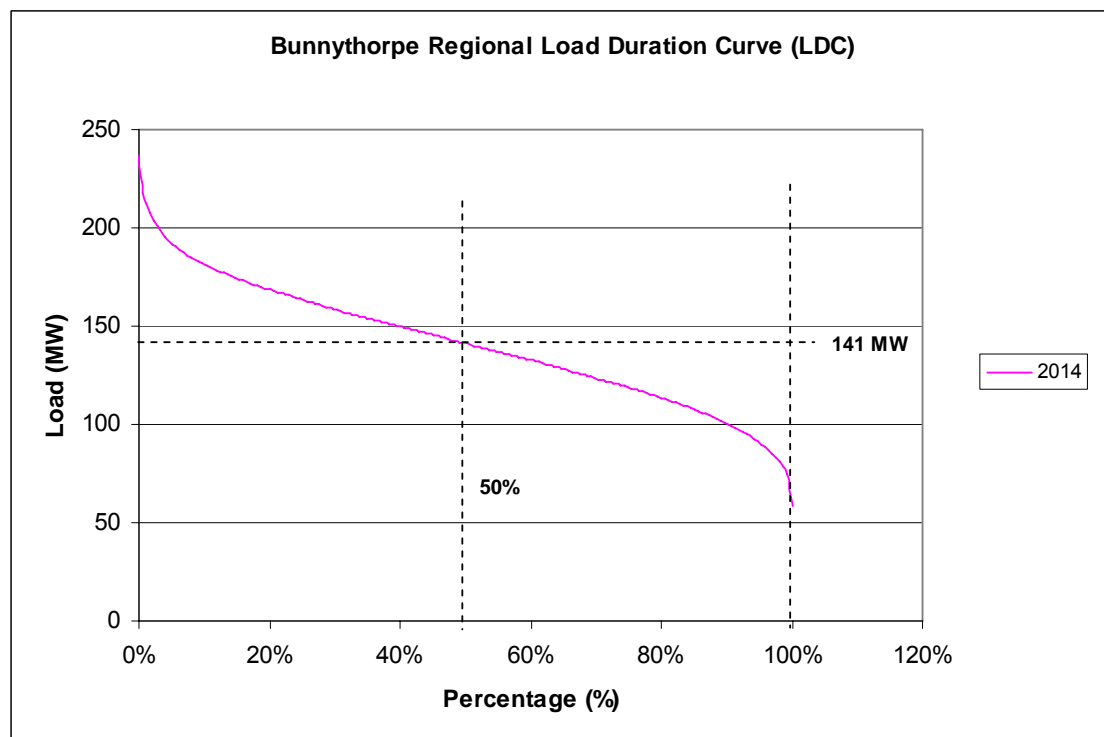
**Post event:**

- Loss of Bunnythorpe transformer 2
- Loss of 110kV Bunnythorpe-Mangahao-1
- Loss of 110kV Bunnythorpe-Woodville-1
- Loss of 110kV Bunnythorpe-Mataroa-1
- Loss of 110kV Bunnythorpe-Wanganui-1

**Consequence:**

- Voltage collapse in the Bunnythorpe region.
- Loss of Bunnythorpe region.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	141	7.5	20,000	21.15	0.021	1.00	0.444



### **CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

### **ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW post event (but since HVDC does not currently have this capability, arrange to trip it).

**Post event:** The remaining Bunnythorpe regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

### **ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW from an average load of 350MW.

Average load is greater than 300MW for 3% of the time.

Constrain HVDC by 50MW (average load).

**Post event:** The remaining Bunnythorpe regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HV DC (post 2012)	50	-	1250	0.0625	0.021	0.03	0.00004

**Event:** Loss of Bunnythorpe 220kV busbar A1

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

Loss of Bunnythorpe transformers 1 and supply transformer 9. Loss of Bunnythorpe-Wilton-1, Bunnythorpe-TWC/Linton-1, Bunnythorpe-Brunswick-2 and Bunnythorpe-Tangiwai-1 220kV circuits.

**Consequence:**

Bunnythorpe transformers 2 and 3 will be overloaded to 67MVA. Winter 24 hour post contingency rating of Bunnythorpe transformers 2 and 3 is 62MVA.

Bunnythorpe transformers 2 and 3 will trip.

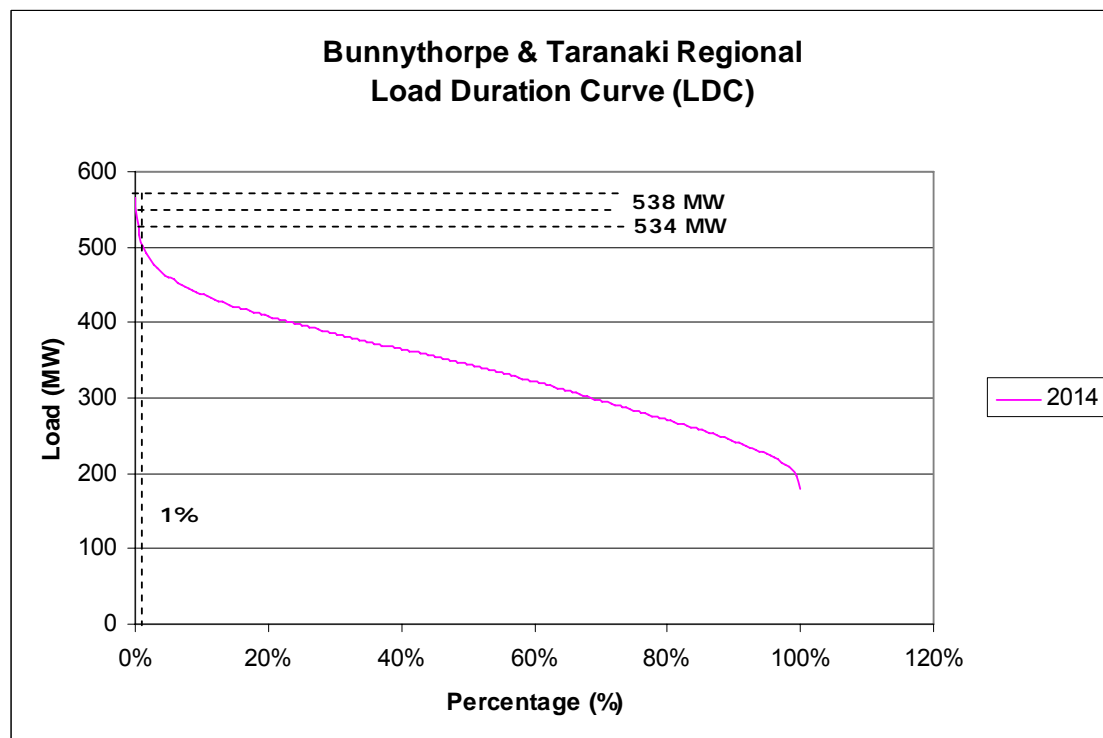
Loss of supply to Bunnythorpe and Taranaki regions.

**Constraint:**

Load constraint limit in Bunnythorpe region is 534MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	538	7.5	20,000	80.7	0.021	0.01	0.017



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 4MW load constraint in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	4	8760	10,000	n/a	n/a	0.01	3.5

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 4MW post event load shedding in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	4	7.5	10,000	0.3	0.021	0.01	0.00006

**Event:** Loss of Bunnythorpe 220kV busbar A1

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

HVDC South transfer on Pole 2 – 400MW

HVDC Pole 1 out of service

No local generation at Mangahao

Wind generation at Te Apiti is in service

Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service

**Post event:**

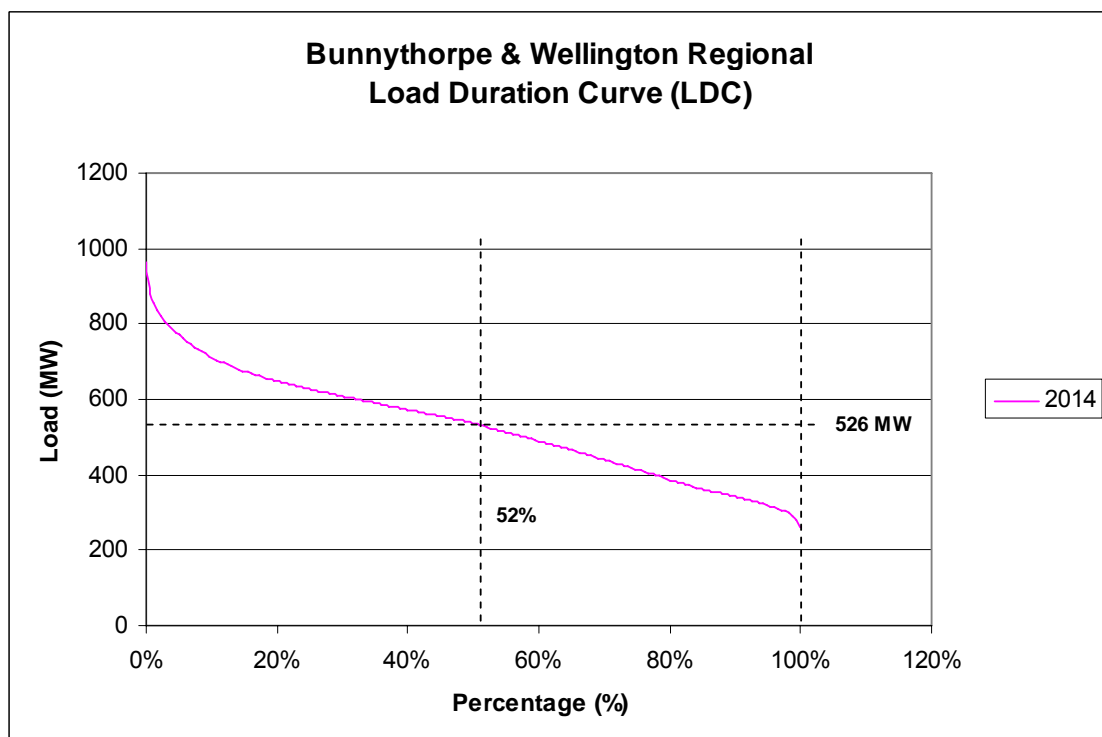
Loss of Bunnythorpe transformer 1 and supply transformer 9. Loss of Bunnythorpe-Wilton-1, Bunnythorpe-TWC/Linton-1, Bunnythorpe-Brunswick-2 and Bunnythorpe-Tangiwhai-1 220kV circuits.

**Consequence:**

Voltage collapse and loss of supply to the Bunnythorpe and Wellington regions.

HVDC will trip.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	526	7.5	20,000	78.9	0.021	1.00	1.657
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>1.6582</b>



### **CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

### **ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 80MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

### **ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 80MW post event from an average load of 240MW

Average load is greater than 80MW for 13% of the time.

Constrain HVDC by 160MW (average load).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HV DC (post 2012)	160	-	1250	0.2	0.021	0.13	0.00055

**Event:** Loss of Bunnythorpe 220kV busbar A2

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

Loss of Bunnythorpe transformer 2 and supply transformer 16. Loss of Bunnythorpe-Tokaanu-1 and Bunnythorpe-Haywards-2 220kV circuits.

**Consequence:**

Bunnythorpe transformers 1 and 3 will be overloaded to 72MVA each. Winter 24 hour post contingency rating of Bunnythorpe transformers 1 and 3 is 62MVA.

Bunnythorpe transformers 1 and 3 will trip.

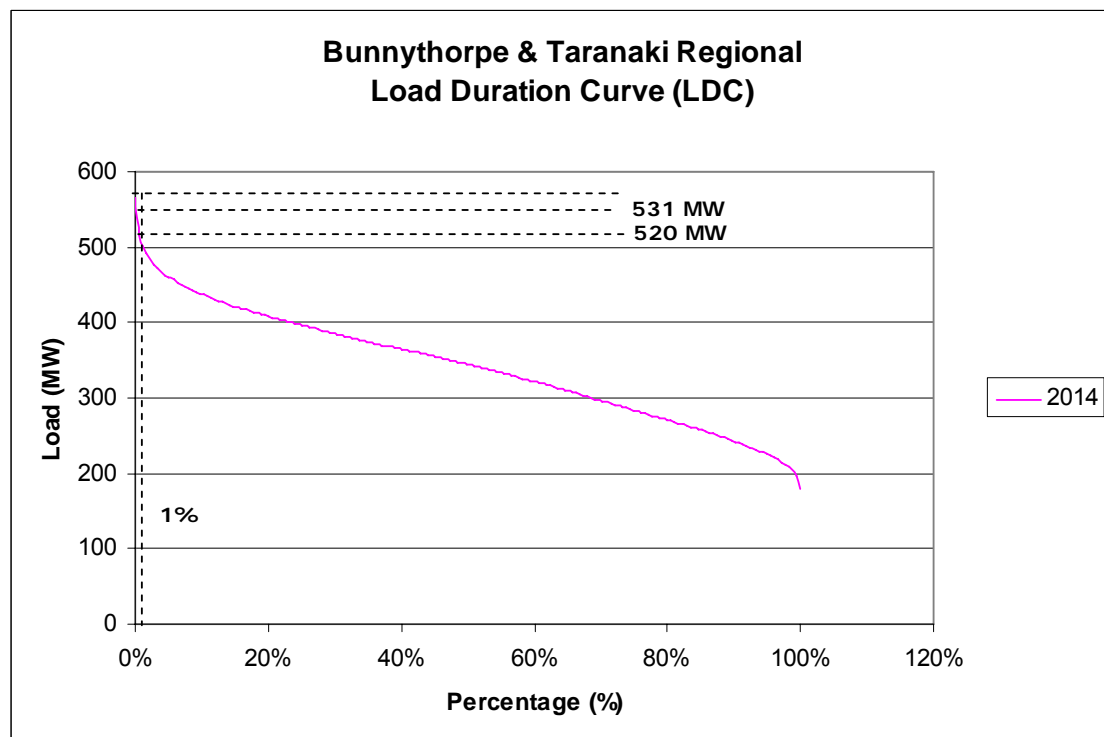
Loss of supply to Bunnythorpe and Taranaki regions.

**Constraint:**

Load constraint limit in the Bunnythorpe region 520MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	531	7.5	20,000	79.65	0.021	0.01	0.017



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 11MW load constraint in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	11	8760	10,000	n/a	n/a	0.01	9.64

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 11MW post event load shedding in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	11	7.5	10,000	0.83	0.021	0.01	0.00018

**Event:** Loss of Bunnythorpe 220kV busbar A2

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

HVDC South transfer on Pole 2 – 400MW

HVDC Pole 1 out of service

No local generation at Mangahao

Wind generation at Te Apiti is in service

Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service.

**Post event:**

Loss of Bunnythorpe transformer 2 and supply transformer 16. Loss of Bunnythorpe-Tokaa nu-2 and Bunnythorpe-Haywards-2 220kV circuits.

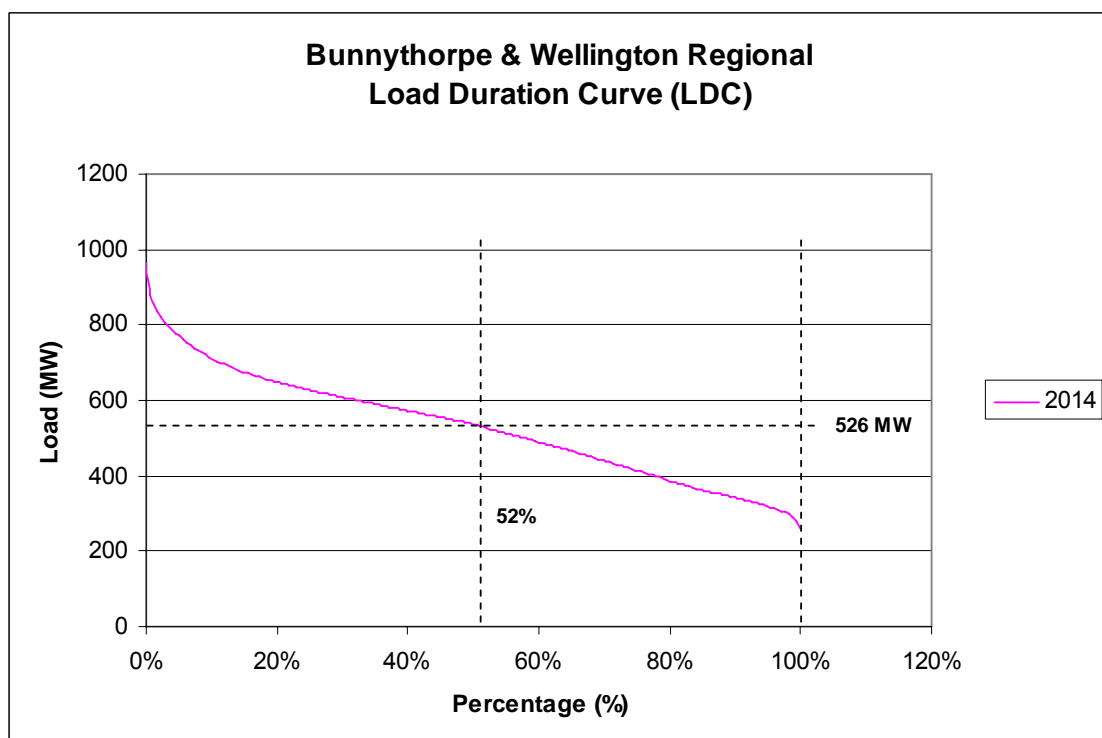
**Consequence:**

Cascade failure and voltage collapse in the Bunnythorpe and Wellington regions.

Loss of Bunnythorpe and Wellington regions.

HVDC will trip.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	526	7.5	20,000	78.9	0.021	1.00	1.657
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>1.6582</b>



### **CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

### **ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 250MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

### **ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 250MW post event from an average load of 325MW.

Average load is greater than 250MW for 5% of the time.

Constrain HVDC by 75MW (average load).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HV DC (post 2012)	75	-	1250	0.094	0.021	0.05	0.00009

**Event:** Loss of Bunnythorpe 220kV busbar B

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

Loss of Bunnythorpe transformer 3 and supply transformer 10. Loss of Bunnythorpe-Hayward s-1 and Bunnythorpe-Brunswick-1 220kV circuits.

**Consequence:**

Bunnythorpe transformers 1 and 2 will be overloaded to 67MVA each. Winter 24 hour post contingency rating of Bunnythorpe transformers 1 and 2 is 62MVA.

Bunnythorpe transformers 1 and 2 will trip.

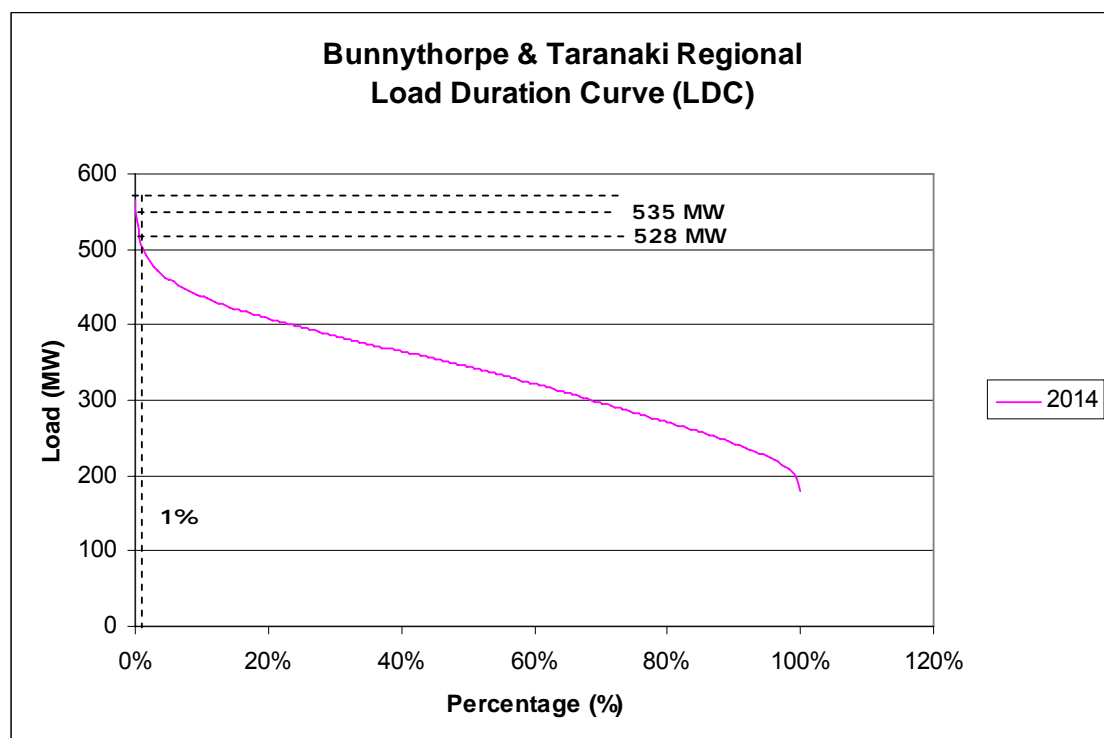
Loss of supply to Bunnythorpe and Taranaki regions.

**Constraint:**

Load constraint limit in the Bunnythorpe region 528MW.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	535	7.5	20,000	80.25	0.021	0.01	0.017



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 7MW load constraint in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	7	8760	10,000	n/a	n/a	0.01	6.13

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 7MW post event load shedding in the Bunnythorpe region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	7	7.5	10,000	0.53	0.021	0.01	0.0001

**Event:** Loss of Bunnythorpe 220kV busbar B

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC South transfer on Pole 2 – 400MW
- HVDC Pole 1 out of service
- No local generation at Mangahao
- Wind generation at Te Apiti is in service
- Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service.

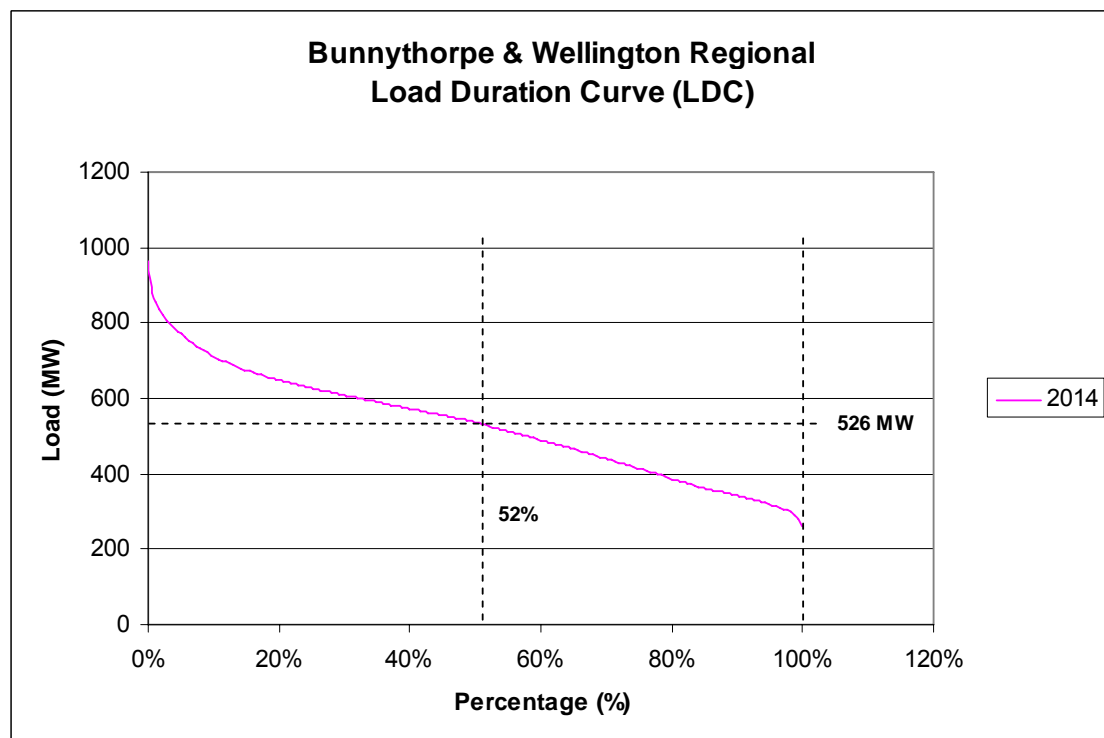
**Post event:**

- Loss of Bunnythorpe supply transformer 10
- Loss of 220kV Bunnythorpe-Brunswick-1
- Loss of 220kV Bunnythorpe-Haywards-1

**Consequence:**

- Cascade failure and voltage collapse in the Bunnythorpe and Wellington regions.
- Loss of Bunnythorpe and Wellington regions.
- HVDC will trip.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	526	7.5	20,000	78.9	0.021	1.00	1.657
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>1.6582</b>



### **CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

### **ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 250MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

### **ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 250MW post event from an average load of 325MW.

Average load is greater than 250MW for 5% of the time.

Constrain HVDC by 75MW (average load).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HV DC (post 2012)	75	-	1250	0.094	0.021	0.05	0.00009

**Event:** Loss of Mangahao 110kV busbar 1

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

- Loss of Mangahao supply transformer 3
- Loss of 110kV Mangahao-Bunnythorpe-1
- Loss of 110kV Mangahao-Paraparaumu-1

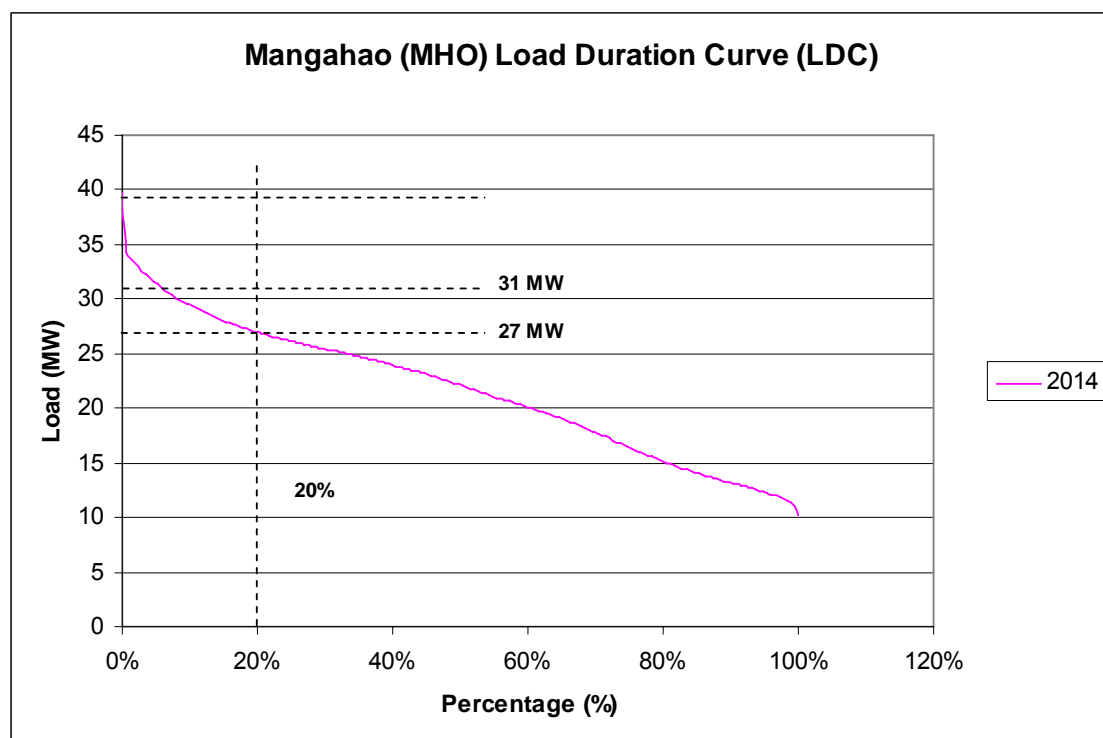
**Consequence:**

- Mangahao supply transformer 4 will be overloaded to 41MVA.
- Winter 24 hour post contingency rating of Mangahao T4 is 40MVA.
- Loss of supply to Mangahao 33kV load.

**Constraint:**

- Load constraint limit at Mangahao 33kV is 27MW.
- For 2014, the constraint is exceeded for 20% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	31	7.5	20,000	4.65	0.021	0.2	0.0195



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 4MW load constraint at Mangahao 33kV.

**Post event:** The remaining Mangahao 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	4	8760	10,000	n/a	n/a	0.2	70.08

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 4MW post event load shedding at Mangahao 33kV.

**Post event:** The remaining Mangahao 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	4	7.5	10,000	0.3	0.021	0.2	0.001

**Event:** Loss of Mangahao 110kV busbar 2

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC North transfer on Pole 2 – 660MW
- HVDC North transfer on Pole 1 – 200MW
- No wind generation at Te Apiti
- No local generation Mangahao

**Post event:**

- Loss of Mangahao supply transformer 4
- Loss of 110kV Mangahao-Bunnythorpe-2
- Loss of 110kV Mangahao-Paraparaumu-2

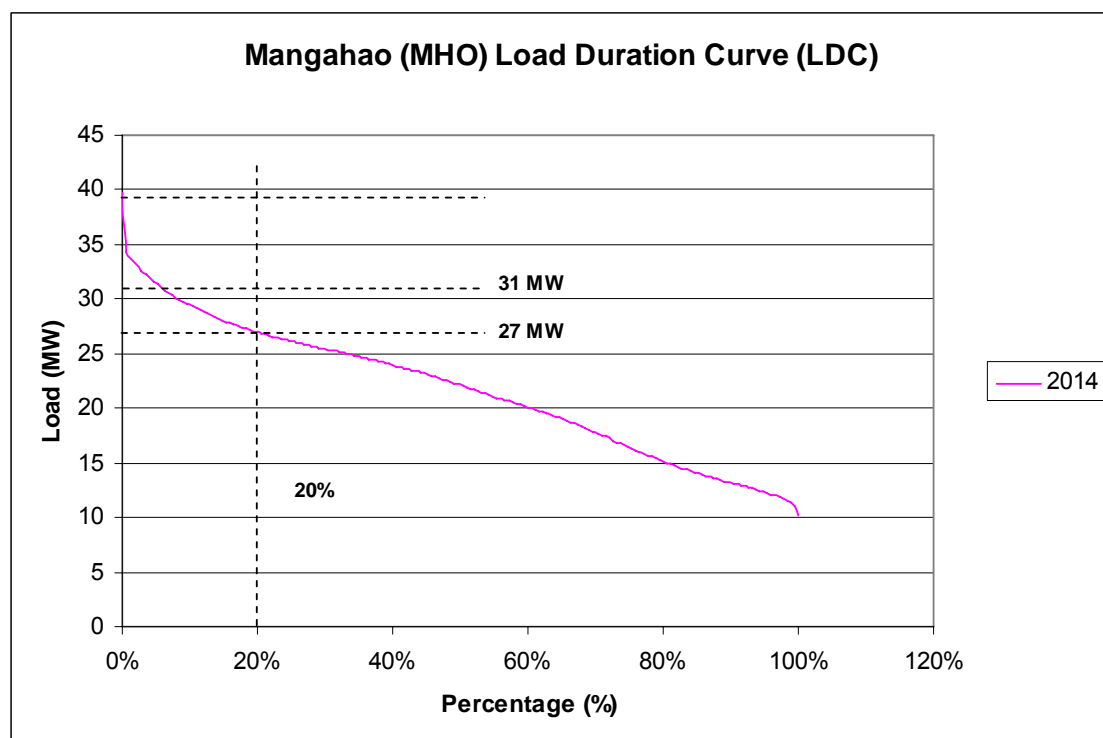
**Consequence:**

- Mangahao supply transformer 3 will be overloaded to 41MVA.
- Winter 24 hour post contingency rating of Mangahao T4 is 40MVA.
- Loss of supply to Mangahao 33kV load.

**Constraint:**

- Load constraint limit at Mangahao 33kV is 27MW.
- For 2014, the constraint is exceeded for 20% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Post-event load shedding	31	7.5	20,000	4.65	0.021	0.2	0.0195



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 4MW load constraint at Mangahao 33kV.

**Post event:** The remaining Mangahao 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	4	8760	10,000	n/a	n/a	0.2	70.08

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 4MW post event load shedding at Mangahao 33kV.

**Post event:** The remaining Mangahao 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	4	7.5	10,000	0.3	0.021	0.2	0.001

**Event:** Loss of Tokaanu 220kV busbar section 1

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC South transfer on Pole 2 – 400MW
- HVDC Pole 1 out of service
- No local generation at Mangahao
- Wind generation at Te Apiti is in service
- Under these conditions, the Wilton interconnector transformer 8 overloads and is switched out of service

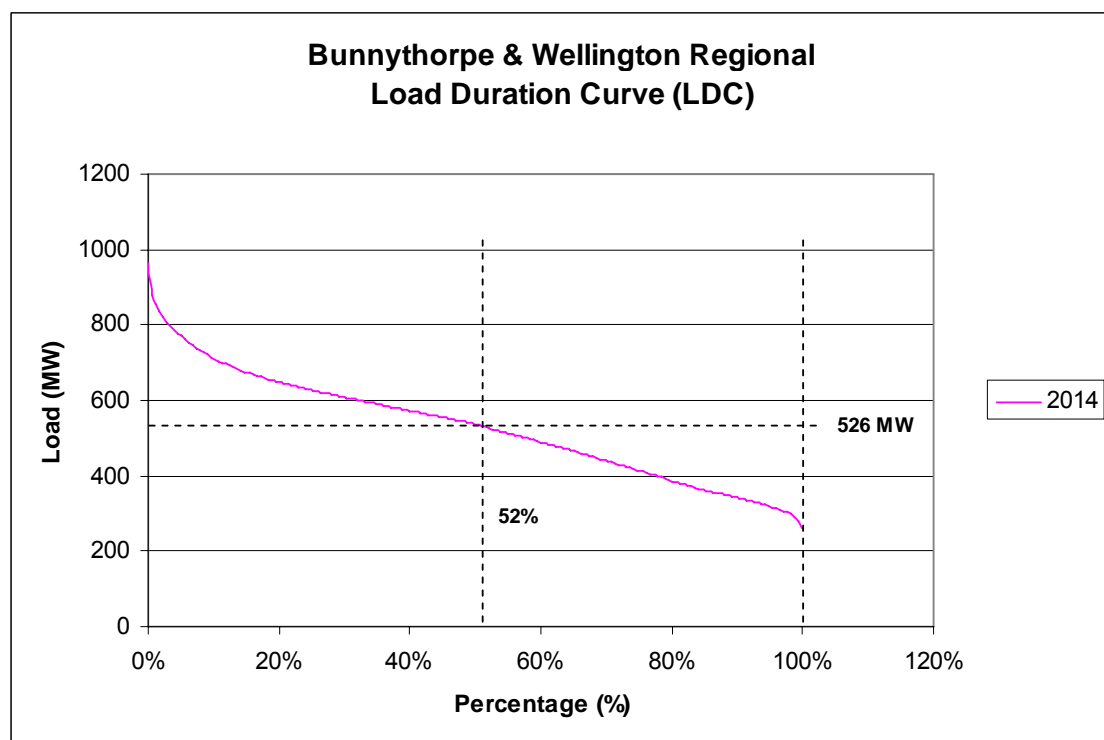
**Post event:**

- Loss of Tokaanu generator transformers 3 and 4
- Loss of Tokaanu supply transformer 22
- Loss of 220kV Tokaanu-Whakamaru-1
- Loss of 220kV Tokaanu-Bunnythorpe-1

**Consequence:**

- Voltage collapse and loss of supply to the Bunnythorpe and Wellington regions.
- HVDC will trip.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	526	7.5	20,000	78.9	0.021	1.00	1.657
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>1.6582</b>



### **CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

### **ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

### **ECE Approach 2: Post-event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW post event from an average load of 350MW.

Average load is greater than 300MW for 3% of the time.

Constrain HVDC by 50MW (average load).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HVDC (post 2012)	50	-	1250	0.0625	0.021	0.03	0.00004

**Event:** Loss of Tokaanu 220kV bus section 2

**Region:** Bunnythorpe

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

- HVDC South Flow on Pole 2 – 400MW
- HVDC Pole 1 out of service
- No local generation at Mangahao
- Wind generation at Te Apiti is in service
- Under these conditions, the Wilton interconnector T8 overloads and is switched out of service.

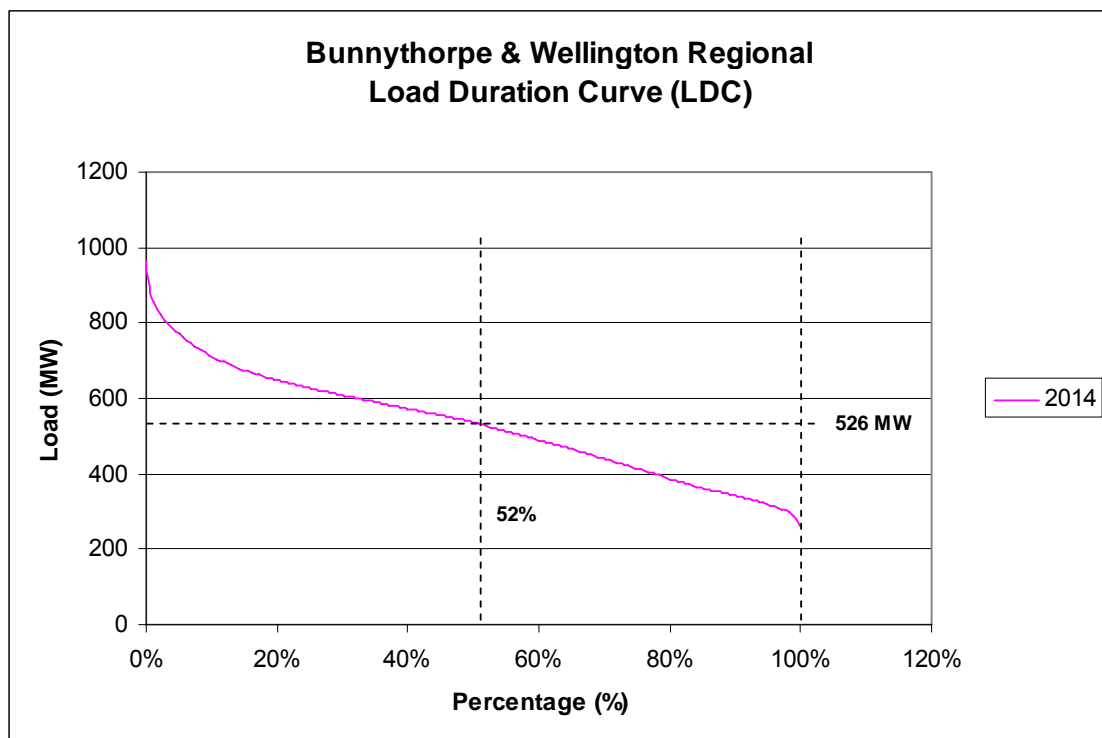
**Post event:**

- Loss of Tokaanu generator transformers 1 and 2
- Loss of Tokaanu supply transformer 21
- Loss of 220kV Tokaanu-Whakamaru-2
- Loss of 220kV Tokaanu-Bunnythorpe-2

**Consequence:**

- Voltage collapse and loss of supply to the Bunnythorpe and Wellington regions.
- HVDC will trip.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	526	7.5	20,000	78.9	0.021	1.00	1.657
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>1.6582</b>



**CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

**ECE Approach 1: Post-event interruption of HVDC south transfer (pre 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW post event (but since HVDC does not currently have this capability, all transfer is interrupted).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC Interruption	220	-	1250	0.275	0.021	0.20	0.0012

**ECE Approach 2: Post event reduction of HVDC south transfer (post 2012)**

**Pre-event measures:** Reduce HVDC transfer to 300MW post event from an average load of 350MW.

Average load is greater than 300MW for 3% of the time.

Constrain HVDC by 50MW (average load).

**Post event:** Bunnythorpe and Wellington regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MW)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Reduce HVDC (post 2012)	50	-	1250	0.0625	0.021	0.03	0.00004

**Event:** Loss of Ashburton 220kV busbar A

**Region:** Canterbury

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No local generation at Highbank, Opuha and Tekapo A  
 Bromley capacitors C5A and C6A are out service

**Post event:** Loss of 220kV Ashburton-Timaru-Twizel-1  
 Loss of Ashburton supply transformers 1, 3 and 8  
 Loss of 220kV Ashburton-Bromley

**Consequence:** Ashburton 66kV and 33kV load will be lost 100% of the time.

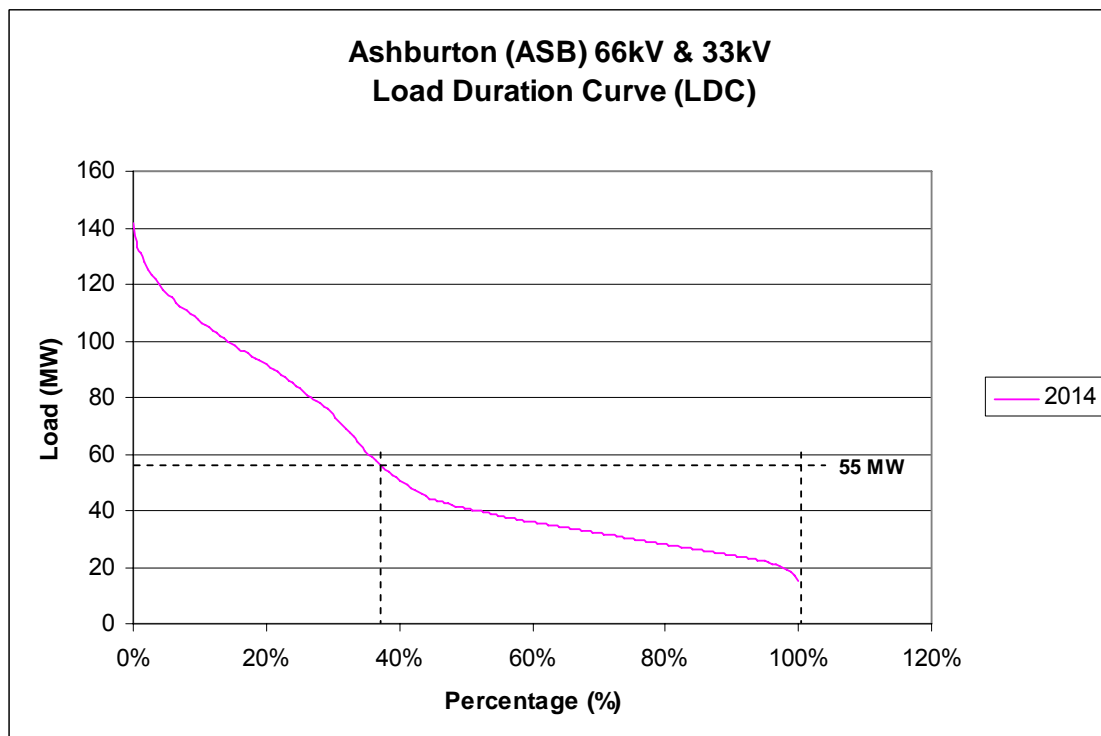
Voltage collapse in the Timaru region.

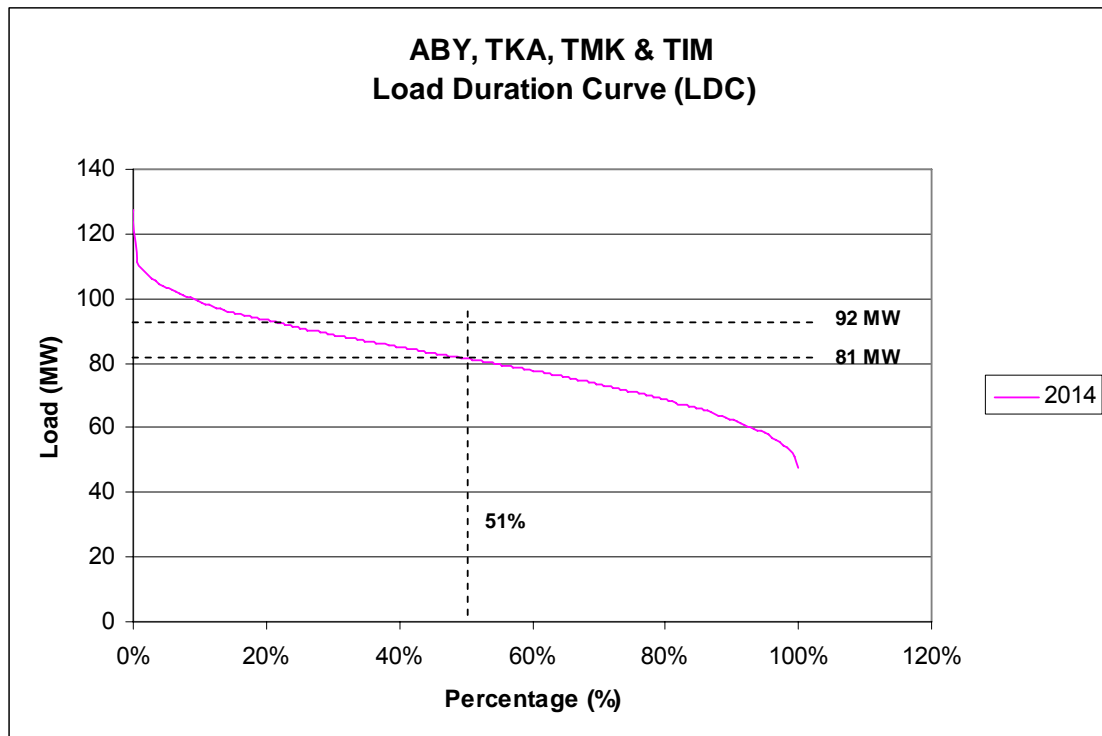
Loss of supply to Albury, Tekapo A, Temuka and Timaru

**Constraint:** Load constraint limit at Albury, Tekapo A, Temuka and Timaru is 81MW.

For 2014, the constraint is exceeded for 51% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ASB)	55	7.5	20,000	8.25	0.021	1.00	0.173
Unplanned load shedding	92	7.5	20,000	13.8	0.021	0.51	0.148
<b>TOTAL</b>							<b>0.148</b>





**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 11MW load constraint at Albury, Tekapo A, Temuka and Timaru.

**Post event:** The remaining load is secured.  
 Ashburton 66kV and 33kV load will be lost 100% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ASB)	55	7.5	20,000	8.25	0.021	1.00	0.173
Pre-event load constraint	11	8760	10,000	n/a	n/a	0.51	491.44
<b>TOTAL</b>							<b>491.44</b>

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 11MW post event load shedding at Albury, Tekapo A, Temuka and Timaru.

**Post event:** The remaining load is secured.  
 Ashburton 66kV and 33kV load will be lost 100% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ASB)	55	7.5	20,000	8.25	0.021	1.00	0.173
Planned load shedding	11	7.5	10,000	0.825	0.021	0.51	0.0088
<b>TOTAL</b>							<b>0.0088</b>

**Event:** Loss of Ashburton 220kV busbar C

**Region:** Canterbury

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

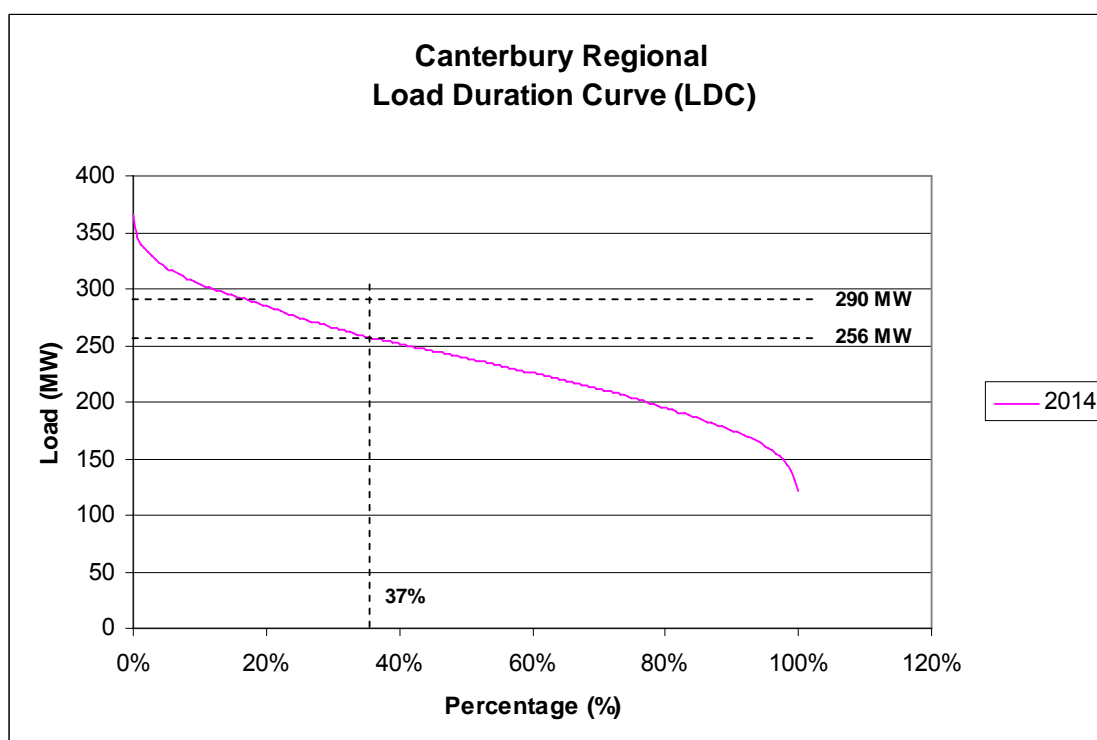
**Assumptions:** No local generation at Highbank, Opuha and Tekapo A  
 Bromley capacitors C5A and C6A are out service

**Post event:** Loss of 220kV Ashburton-Timaru-Twizel-2  
 Loss of 220kV Ashburton-Islington-1

**Consequence:** Voltage collapse in the Canterbury region.  
 Loss of supply to the Canterbury region.

**Constraint:** Load constraint limit in Canterbury region 256MW.  
 For 2014, the constraint is exceeded for 37% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	290	72	20,000	417.6	0.021	0.37	3.245



**CE Approach:** *Pre-event security constraints*

**Pre-event measures:** Arrange 34MW load constraint in the Canterbury region.

**Post event:** The remaining Canterbury regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	34	8760	10,000	n/a	n/a	0.37	1102.01

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 34MW post event load shedding in the Canterbury region.

**Post event:** The remaining Canterbury regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	34	7.5	10,000	2.55	0.021	0.37	0.0198

**Event:** Loss of Bromley 220kV busbar A

**Region:** Canterbury

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No local generation at Highbank, Opuha and Tekapo A  
 Bromley capacitors C5A and C6A are out of service

**Post event:** Loss of 220kV Bromley-Islington

Loss of Bromley supply transformer 5

**Consequence:** Bromley supply transformer 6 will be overloaded to 199MVA.

Winter 24 hour post contingency rating of Bromley supply transformer 6 is 156MVA.

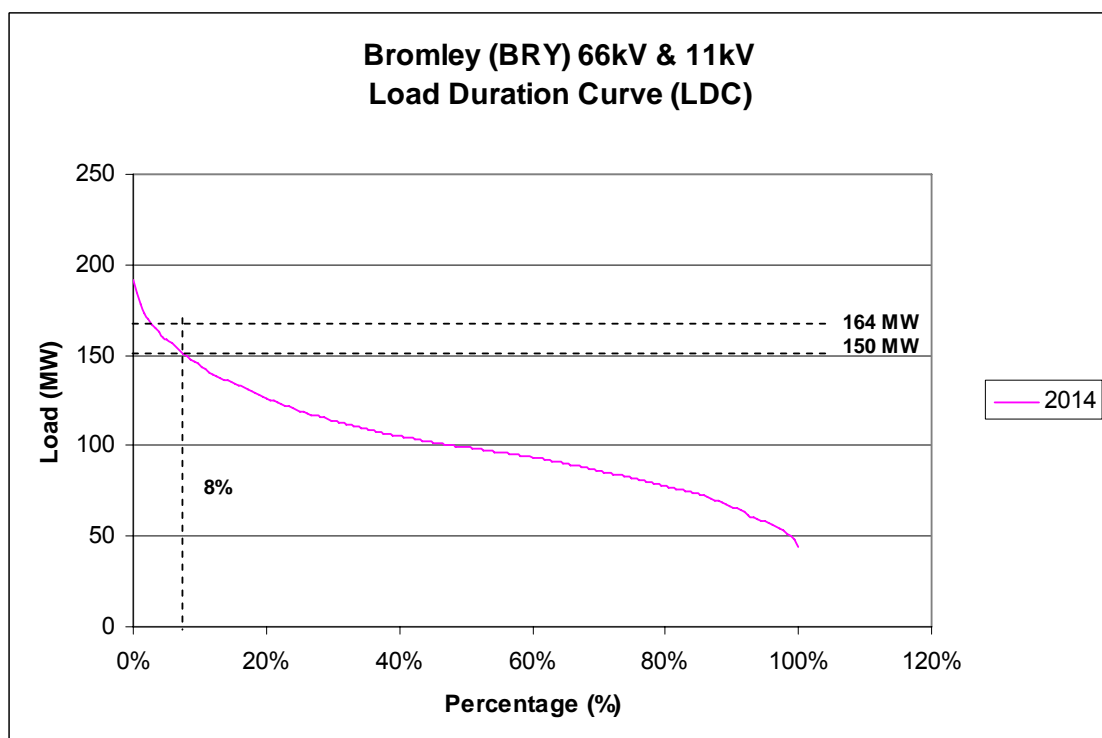
Bromley supply transformer 6 will trip.

Loss of supply to Bromley 66kV and 11kV load.

**Constraint:** Load constraint limit at Bromley 66kV and 11kV is 150MW.

For 2014, the constraint is exceeded for 8% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	164	7.5	20,000	24.6	0.021	0.08	0.0413



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 14MW load constraint at Bromley 66kV and 11kV.

**Post event:** The remaining Bromley 66kV and 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	14	8760	10,000	n/a	n/a	0.08	98.112

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 14MW post-event load shedding at Bromley 66kV and 11kV.

**Post event:** The remaining Bromley 66kV and 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	14	7.5	10,000	1.05	0.021	0.08	0.0018

**Event:** Loss of Bromley 220kV busbar B

**Region:** Canterbury

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

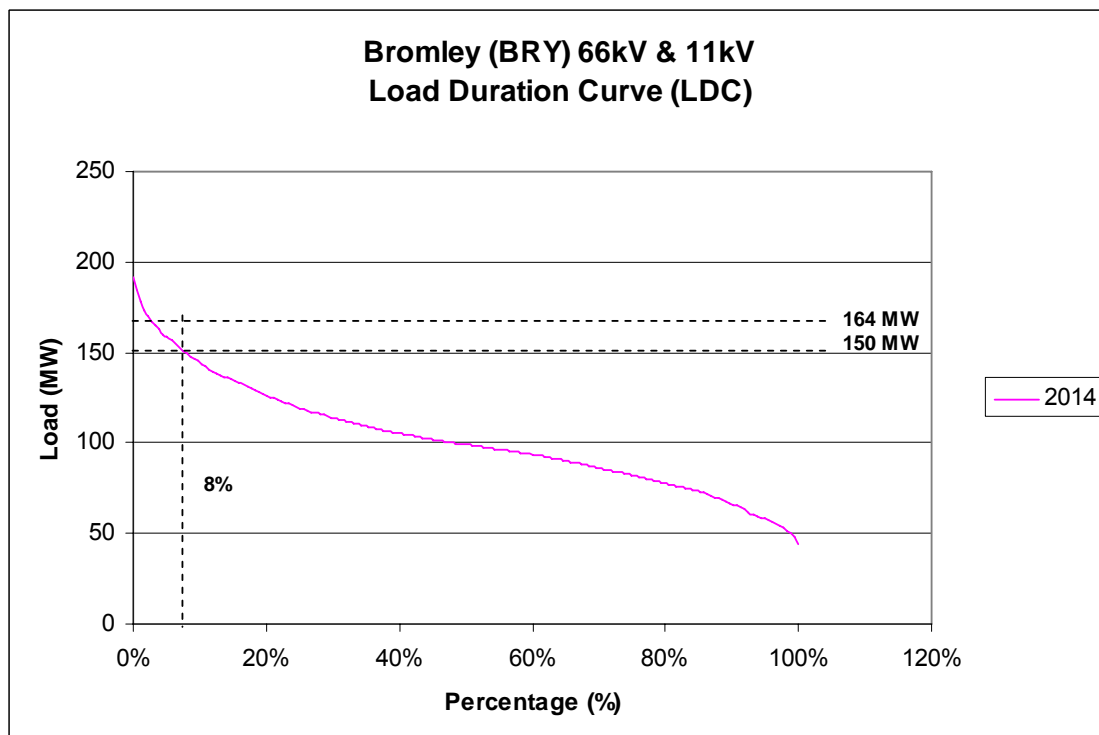
**Assumptions:** No local generation at Highbank, Opuha and Tekapo A  
 Bromley capacitors C5A and C6A are out of service

**Post event:** Loss of Bromley transformer 6  
 Loss of 220kV Bromley-Ashburton

**Consequence:** Bromley transformer 5 will be overloaded to 197MVA.  
 Winter 24 hour post contingency rating of Bromley transformer 5 is 156MVA.  
 Bromley transformer 5 will trip.  
 Loss of supply to Bromley 66kV and 11kV load.

**Constraint:** Load constraint limit at Bromley 66kV and 11kV is 150MW.  
 For 2014, the constraint is exceeded for 8% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	164	7.5	20,000	24.6	0.021	0.08	0.0413



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 14MW load constraint at Bromley 66kV and 11kV.

**Post event:** The remaining Bromley 66kV and 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	14	8760	10,000	n/a	n/a	0.08	98.112

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 14MW post-event load shedding at Bromley 66kV and 11kV.

**Post event:** The remaining Bromley 66kV and 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	14	7.5	10,000	1.05	0.021	0.08	0.0018

**Event:** Loss of Timaru 110kV busbar B

**Region:** Canterbury

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No local generation at Opuha, Highbank and Tekapo A  
 Studholme-Timaru split is open

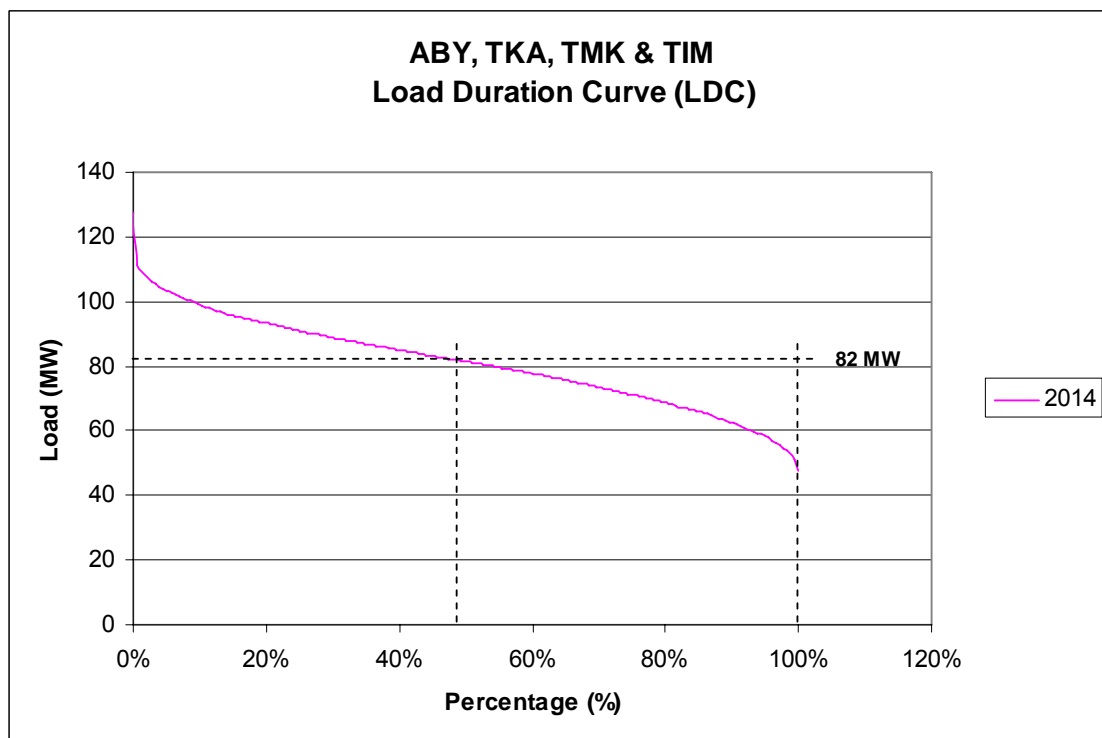
**Post event:** Loss of Timaru transformers 5 and 8  
 Loss of Timaru supply transformers 2, 3 and 4  
 Loss of 110kV Timaru-Temuka-1 and 2  
 Loss of 110kV Timaru-Tekapo A  
 Loss of 110kV Timaru-Studholme – open

**Consequence:** Loss of all load connected to Timaru busbar (Albury, Tekapo A, Temuka and Timaru) for the first 2 hours of the fault.

After 2 hours, all load will be switched over and supplied from the transfer bus (busbar A).

**Constraint:** None

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	82	2	20,000	3.28	0.021	1.00	0.069
Change load to transfer bus	0	5.5	20,000	0	0.021	1.00	0
<b>TOTAL</b>							<b>0.069</b>



***CE Approach: Alternate measures unavailable***

Direct loss of supply unavoidable, managed as described above

***ECE Approach: Alternate measures unavailable***

Direct loss of supply unavoidable, managed as described above

**Event:** Loss of Addington 66kV busbar section 1

**Region:** Christchurch

**Event Risk Factor:** 0.033

**Average Duration:** 6.3 h

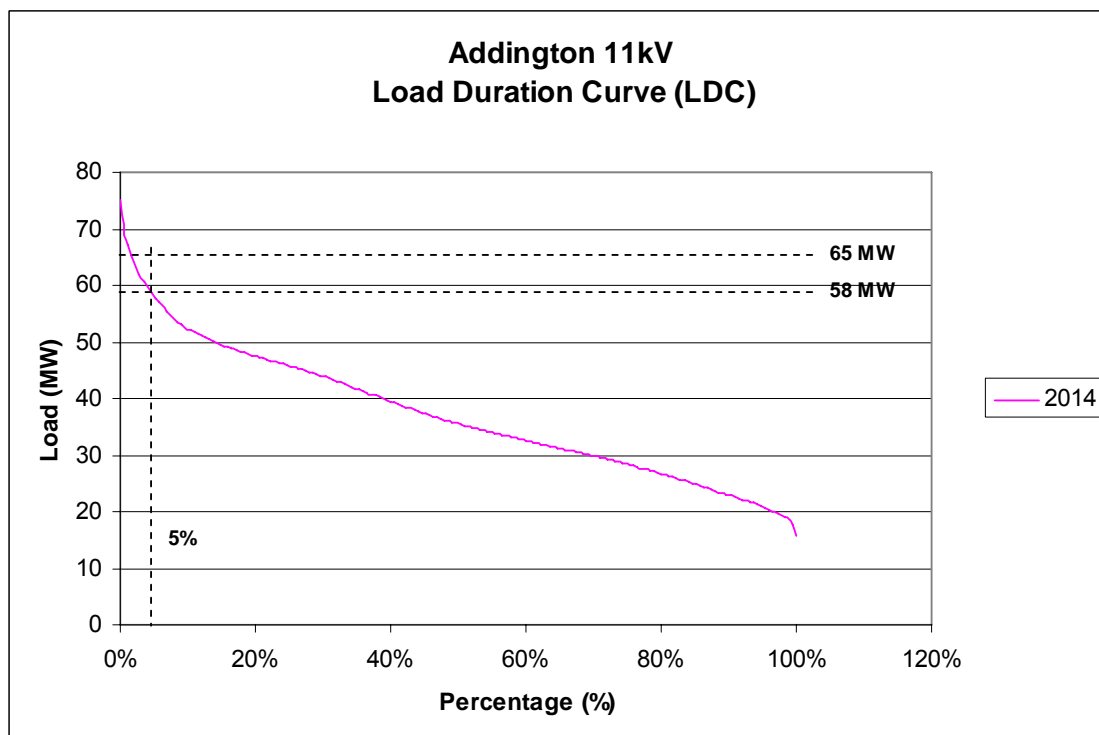
**SE Approach:** *Post-event unplanned load shedding*

**Post event:** Loss of 66kV Addington-Middleton-Islington-1  
 Loss of 66kV Addington-Islington-3  
 Loss of Addington transformer 2  
 Loss of Addington supply transformers 2, 5 and 7  
 Loss of Addington 66kV circuits Oxford, Milton, Fendalton and Armagh

**Consequence:** Addington transformer 6 will be overloaded to 54MVA.  
 Addington transformer 6 will trip.  
 Loss of supply to Addington 11kV busbar B load.  
 Addington transformer 3 supplying the 11kV busbar A will not overload.

**Constraint:** Load constraint limit at Addington 11kV is 58MW.  
 For 2014, the constraint is exceeded for 5% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	65	6.3	20,000	8.19	0.033	0.05	0.0135



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 7MW load constraint at Addington 11kV.

**Post event:** The remaining Addington 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	7	8760	10,000	n/a	n/a	0.05	30.66

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 7MW post event load shedding at Addington 11kV.

**Post event:** The remaining Addington 11kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	7	6.3	10,000	0.441	0.033	0.05	0.0007

**Event:** Loss of Islington 220kV busbar A

**Region:** Christchurch

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** Bromley capacitors 5A and 6A in service

**Post event:** Loss of Islington transformer 7

Loss of 220kV Islington-Kikiwa-1

Loss of 220kV Islington-Waipara-Culverden-Kikiwa-2

Loss of 220kV Islington-Tekapo B

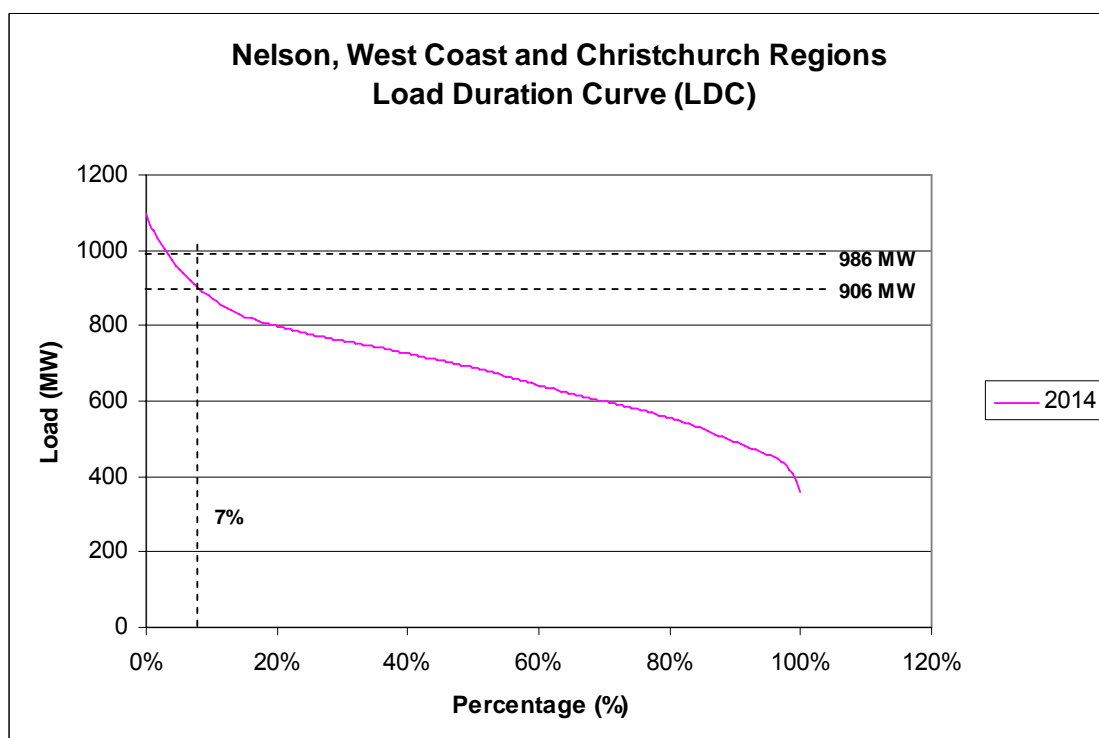
**Consequence:** Islington transformers T3 and T6 will overload and trip.

Voltage collapse and loss of supply across the Nelson, West Coast and Christchurch regions.

**Constraint:** Load constraint limit in Nelson, West Coast and Christchurch regions 906MW.

For 2014, the constraint is exceeded for 7% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	986	72	20,000	1419.84	0.021	0.07	2.087



**CE Approach: Constrained load pre-event**

**Pre-event measures:** Arrange 80MW load constraint in Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	80	8760	10,000	n/a	n/a	0.07	490.56

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 80MW post-event load shedding at Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	80	7.5	10,000	6	0.021	0.07	0.0088

**Event:** Loss of Islington 220kV busbar B

**Region:** Christchurch

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** Bromley capacitors 5A and 6A in service

**Post event:** Loss of Islington transformer 6

Loss of Islington capacitors 25 and 26

Loss of 220kV Islington-Livingston

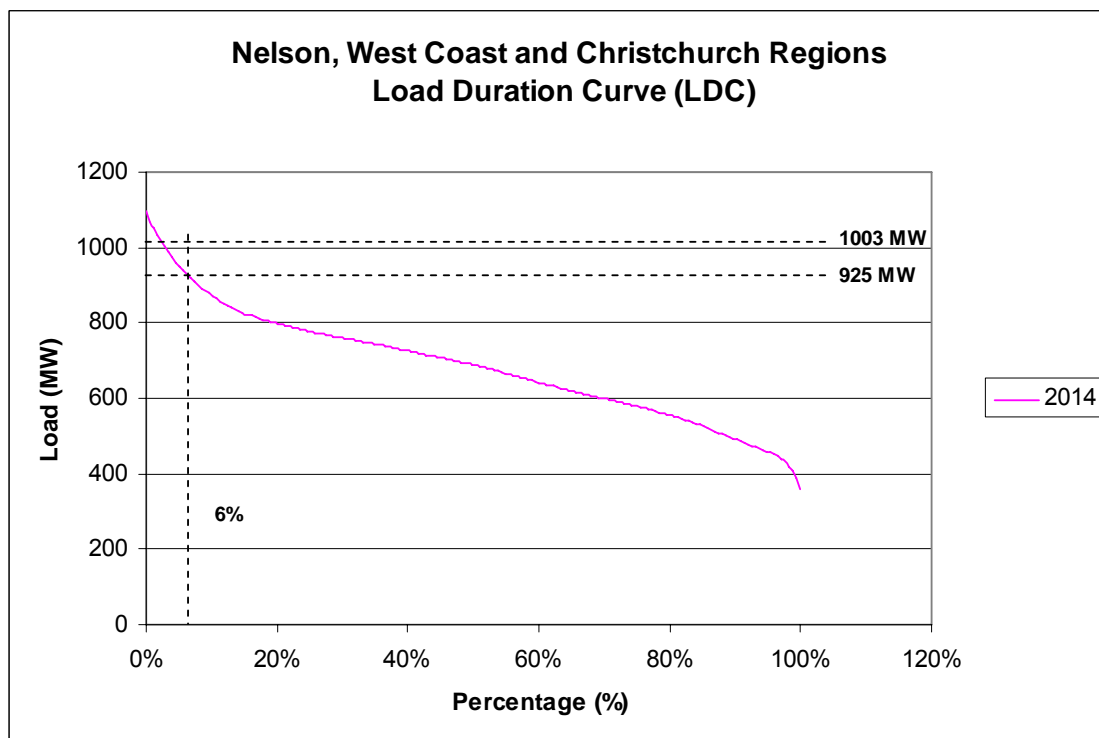
**Consequence:** Islington transformers T3 and T7 overload and trip.

Voltage collapse and loss of supply across the Nelson, West Coast and Christchurch regions.

**Constraint:** Load constraint limit in Nelson, West Coast and Christchurch regions 925MW.

For 2014, the constraint is exceeded for 6% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	1003	72	20,000	1444.32	0.021	0.06	1.82



### **CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 78MW load constraint in Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch regional load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	78	8760	10,000	n/a	n/a	0.06	409.97

### **ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 78MW post-event load shedding at Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	78	7.5	10,000	5.85	0.021	0.06	0.0074

**Event:** Loss of Islington 220kV busbar C

**Region:** Christchurch

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

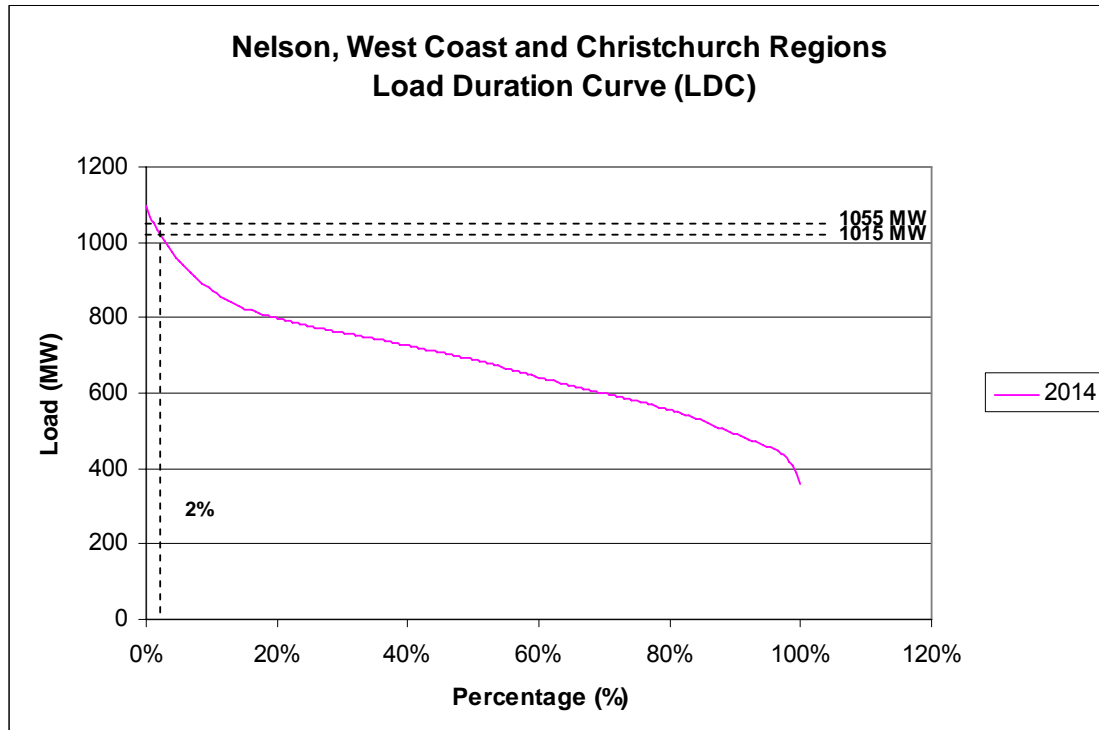
**Assumptions:** None

**Post event:** Loss of Islington transformers 3  
 Loss of Islington supply transformers 1  
 Loss of 220kV Islington-Ashburton-1

**Consequence:** Islington transformers T6 and T7 overload and trip.  
 Voltage collapse and loss of supply across the Nelson, West Coast and Christchurch regions.

**Constraint:** Load constraint limit in Nelson, West Coast and Christchurch regions 1015MW.  
 For 2014, the constraint is exceeded for 2% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	1055	72	20,000	1519.2	0.021	0.02	0.6381



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 40MW load constraint at Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	40	8760	10,000	n/a	n/a	0.02	70.08

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 40MW post-event load shedding at Nelson, West Coast and Christchurch regions.

**Post event:** The remaining Nelson, West Coast and Christchurch load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	40	7.5	10,000	3	0.021	0.02	0.0013

**Event:** Loss of Islington 66kV busbar C

**Region:** Christchurch

**Event Risk Factor:** 0.033

**Average Duration:** 6.3 h

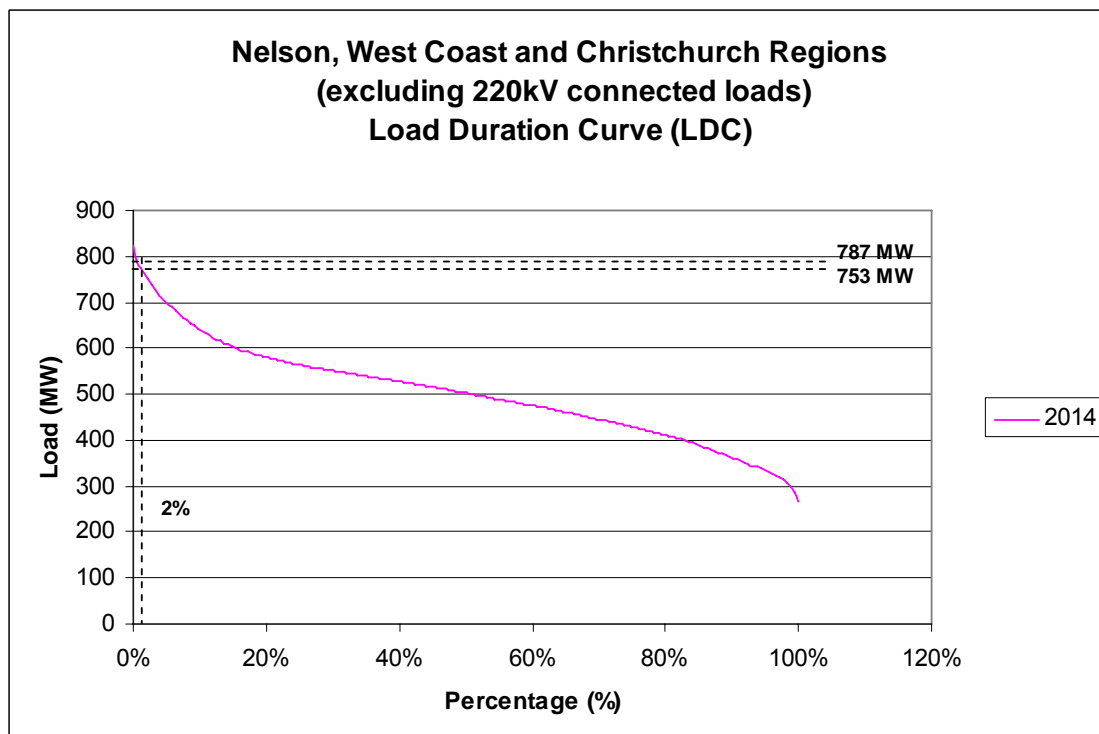
**SE Approach:** *Post-event unplanned load shedding*

**Post event:** Loss of Islington transformer 6  
Loss of 66kV Islington-Papanui-3  
Loss of 66kV Islington-Addington-2  
Loss of Islington 66kV feeder Hawthornden T1

**Consequence:** Remaining Islington T3 and T7 transformers overload.  
Islington T3 and T7 transformers trip out.  
Voltage collapse and loss of supply to the Nelson, West Coast and Christchurch regions.

**Constraint:** Load constraint limit in Nelson, West Coast and Christchurch regions (excluding 220kV connected load) 753MW.  
For 2014, the constraint is exceeded for 2% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	787	72	20,000	1133.28	0.033	0.02	0.7480



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 34MW load constraint in the Nelson, Christchurch and West Coast regions.

**Post event:** The remaining Nelson, Christchurch and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	34	8760	10,000	n/a	n/a	0.02	59.568

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 34MW post-event load shedding in the Nelson, Christchurch and West Coast regions.

**Post event:** The remaining Nelson, Christchurch and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	34	6.3	10,000	2.142	0.033	0.02	0.0014

**Event:** Loss of Hamilton 220kV busbar section 1

**Region:** Hamilton

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

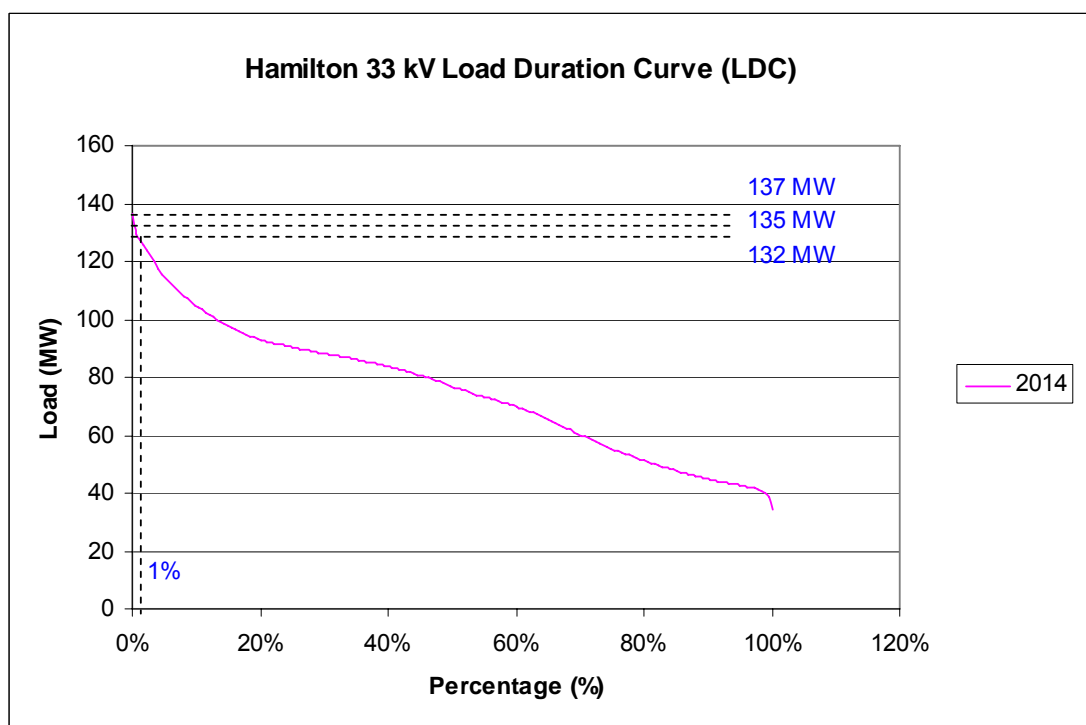
**Assumptions:** Local Generation at Arapuni set to 100MW and Karapiro at 40MW

**Post event:** Loss of the 220 kV Hamilton – Ohinewai-1  
 Loss of Hamilton 220/33kV transformer T5  
 Loss of Hamilton 220/110kV transformer T6

**Consequence:** The Hamilton 220/33kV transformer T4 overloads to 142MVA. Winter 24 hour post contingency rating of the transformer is 132MVA. Hence it will trip resulting in loss of supply to the Hamilton 33kV load.

**Constraint:** Load constraint limit at Hamilton 33kV is 132MW.  
 For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	135	7.5	20,000	20.25	0.021	0.01	0.004



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 3MW load constraint in Hamilton 33kV region.

**Post event:** The remaining Hamilton 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	3	8760	10,000	n/a	n/a	0.01	2.63

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 3MW post event load shedding in Hamilton 33kV region.

**Post event:** The remaining Hamilton 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	3	7.5	10,000	0.225	0.021	0.01	0.00005

**Event:** Loss of Hamilton 220kV busbar section 2

**Region:** Hamilton

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 hours

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** Local Generation at Arapuni set to 100MW and Karapiro at 40MW

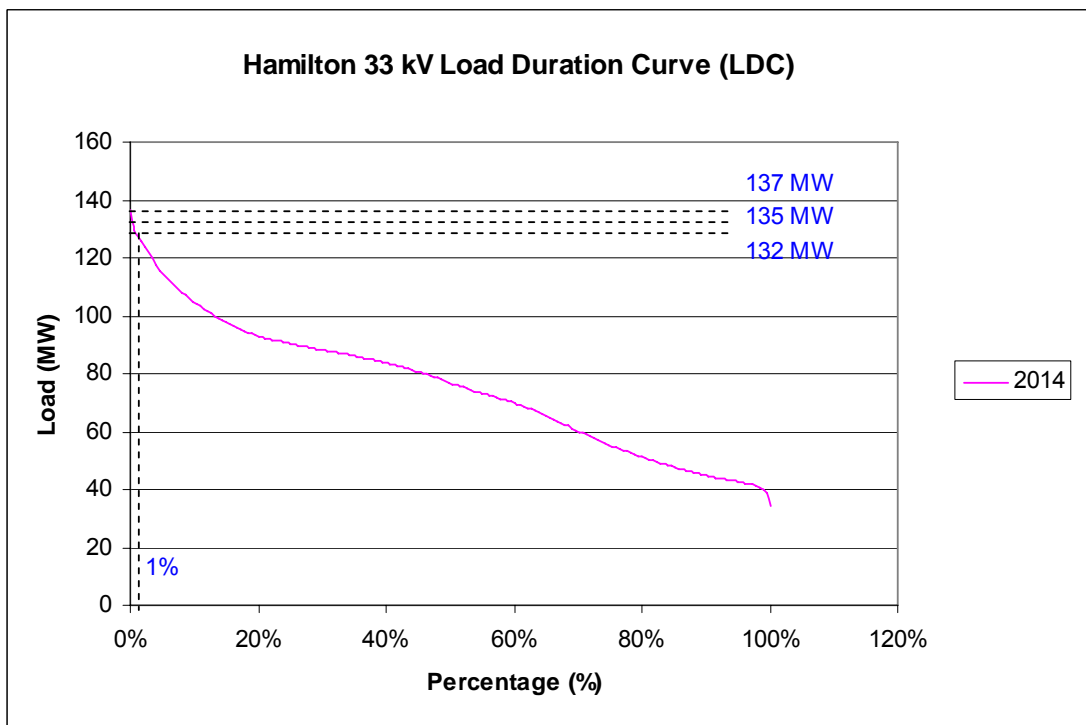
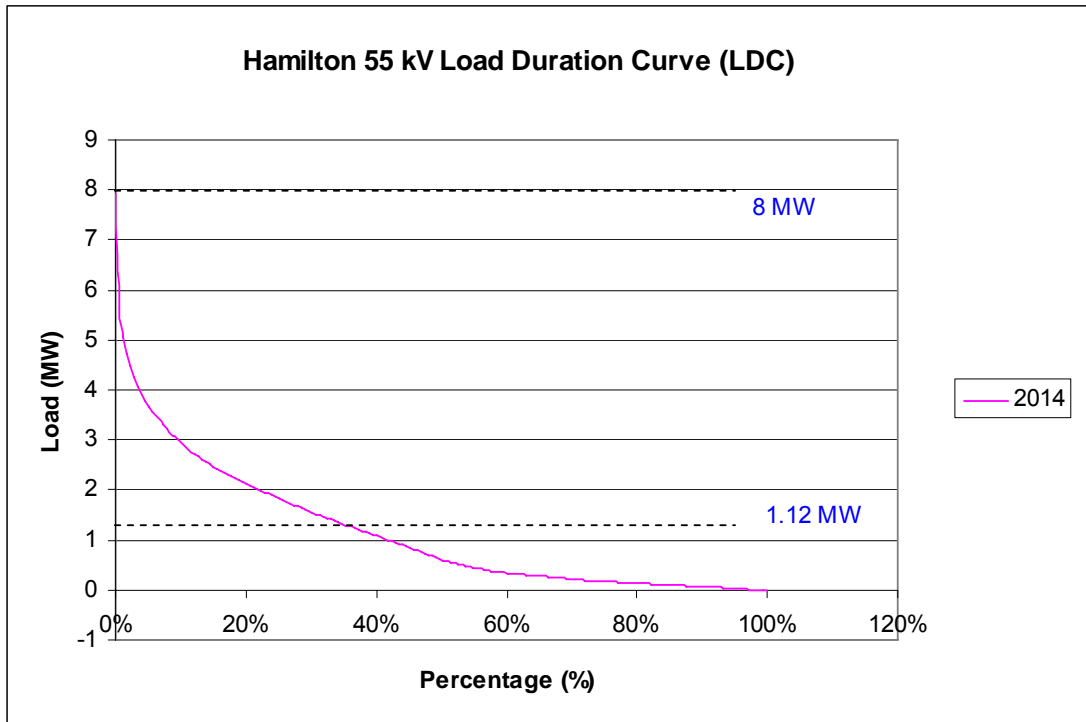
**Post event:** Loss of the 220 kV Hamilton – Whakamaru-1  
 Loss of Hamilton 220/33kV transformer T4  
 Loss of Hamilton 220/110kV transformer T9  
 Loss of the Hamilton 55kV load

**Consequence:** The loss of the busbar will result in the loss of supply to the directly connected Hamilton 55kV load and the overloading of the Hamilton 220/33kV transformer T5 overloads to 142MVA. Winter 24 hour post contingency rating of the transformer is 132MVA. Hence it will trip resulting in loss of supply to the Hamilton 33kV load.

**Constraint:** Load constraint limit at the Hamilton 33kV load is 132MW. For 2014, the Hamilton 33kV load constraint is exceeded for 1% of the time.

The Hamilton 55kV directly connected load is lost for 100% of the time. For 2014, the Hamilton 55kV average load lost for 100% of the time is 1.12MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (55kV load)	1.1	7.5	20,000	0.165	0.021	1	0.0035
Unplanned load shedding (33kV load)	135	7.5	20,000	20.25	0.021	0.01	0.004
<b>TOTAL</b>							<b>0.004*</b>



**CE Approach : Pre-event security constraints**

**Pre-event measures:** Arrange 3MW load constraint in Hamilton 33kV region.

**Post event:** The remaining Hamilton 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Post-event load lost (55kV load)	1.1	7.5	20,000	0.165	0.021	1	0.0035
Pre-event load constraint(33kV load)	3	8760	10,000	n/a	n/a	0.01	2.63
<b>TOTAL</b>							<b>2.63*</b>

**ECE Approach : Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 3MW post event load shedding in Hamilton 33kV region.

**Post event:** The remaining Hamilton 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Load shedding (55kV load)	1.1	7.5	20,000	0.165	0.021	1	0.0035
Planned load shedding (33kV load)	3	7.5	10,000	0.225	0.021	0.01	0.00005
<b>TOTAL</b>							<b>0.00005*</b>

\* Note – The Hamilton 55kV load is directly connected to the lost busbar and hence there are no mitigation measures to restore its supply. Therefore it has not been included in the costing.

**Event:** Loss of Redclyffe 220kV busbar A

**Region:** Hawkes Bay

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** Tuai generation set to 18MW

**Post event:** Loss of Redclyffe transformer 3

Loss of 220kV Redclyffe-Whirinaki-1

Loss of 220kV Redclyffe-Whakatu-1

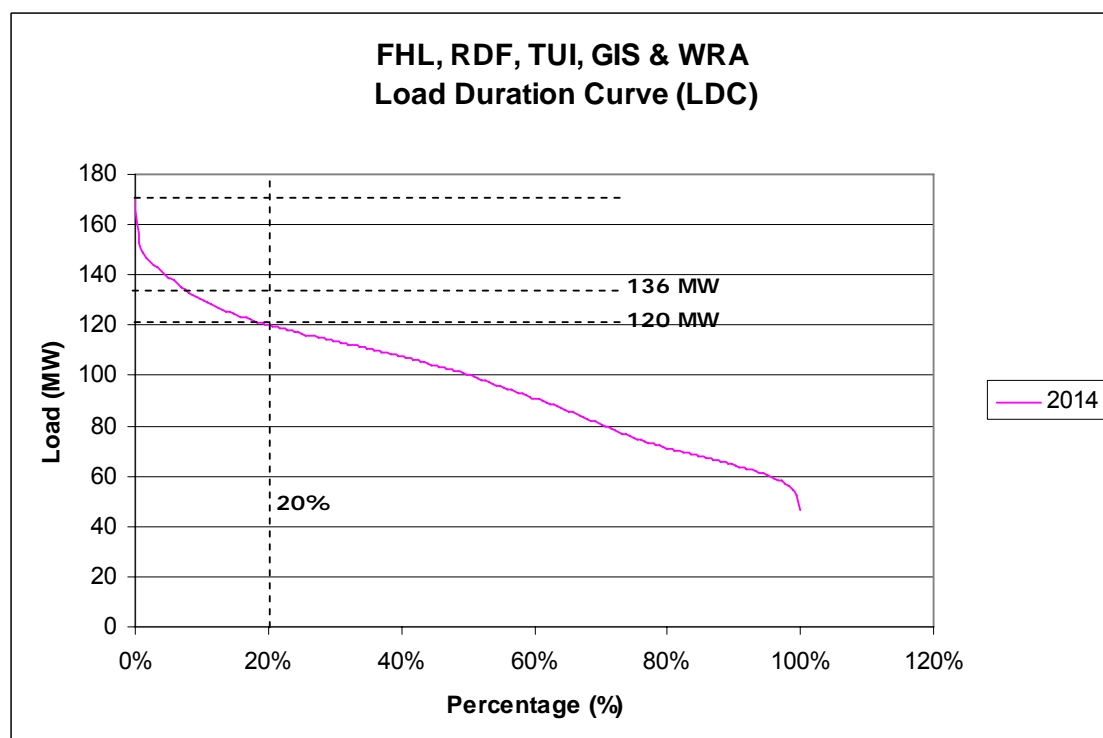
**Consequence:** Redclyffe transformer 4 will be overloaded to 158MVA.

Winter 24 hour post contingency rating of Redclyffe T4 is 120MVA.

Loss of supply to Redclyffe, Tuai, Gisborne, Wa iroa and Fernhill load.

**Constraint:** Load constraint limit in the Hawkes Bay region 120MVA.  
 For 2014, the constraint is exceeded for 20% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	136	7.5	20,000	20.40	0.021	0.2	0.086



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 16MW load constraint in the Hawkes Bay region.

**Post event:** The remaining load in the Hawkes Bay region will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	16	8760	10,000	n/a	n/a	0.2	280.32

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 16MW post event load shedding in the Hawkes Bay region.

**Post event:** The remaining load in the Hawkes Bay region will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	16	7.5	10,000	1.20	0.021	0.2	0.005

**Event:** Loss of Redclyffe 220kV busbar B

**Region:** Hawkes Bay

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** Tuai generation set to 18MW

**Post event:** Loss of Redclyffe transformer 4

Loss of 220kV Redclyffe-Wairakei-1

Loss of 220kV Redclyffe-Whakatu-2

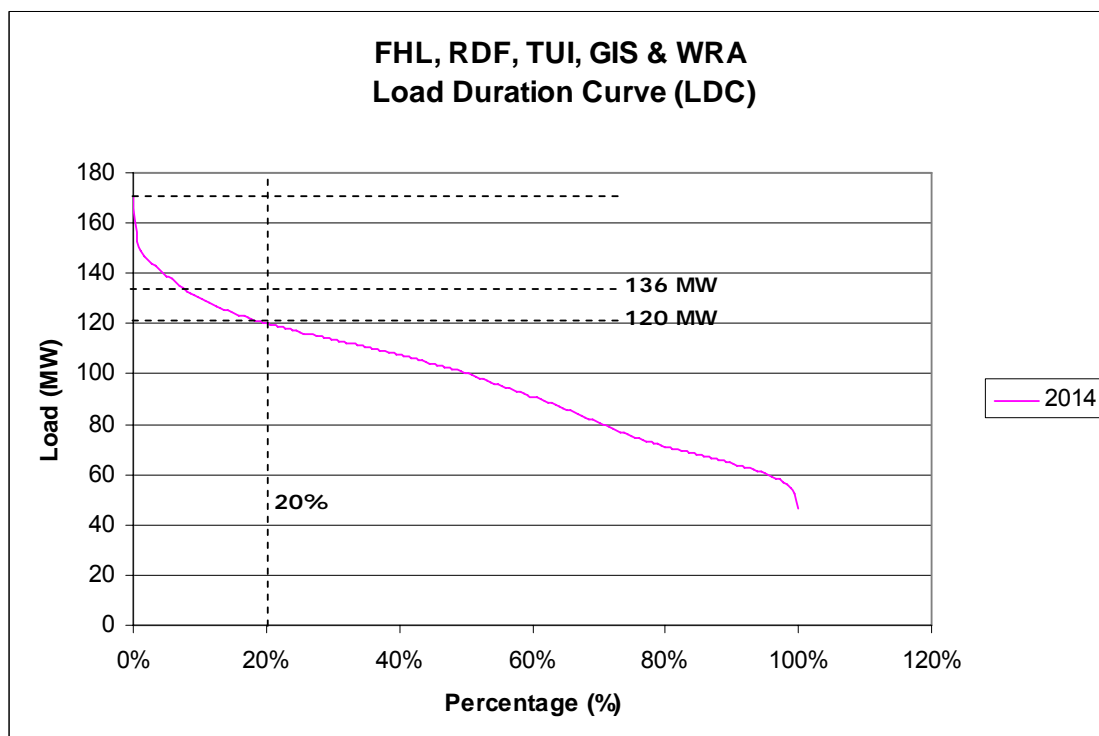
**Consequence:** Redclyffe transformer 3 will be overloaded to 158MVA.

Winter 24 hour post contingency rating of Redclyffe T3 is 120MVA.

Loss of supply to Redclyffe, Tuai, Gisborne, Wa iroa and Fernhill load.

**Constraint:** Load constraint limit in the Hawkes Bay region 120MVA.  
 For 2014, the constraint is exceeded for 20% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	136	7.5	20,000	20.40	0.021	0.2	0.086



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 16MW load constraint in the Hawkes Bay region.

**Post event:** The remaining load in the Hawkes Bay region will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	16	8760	10,000	n/a	n/a	0.2	280.32

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 16MW post event load shedding in the Hawkes Bay region.

**Post event:** The remaining load in the Hawkes Bay region will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	16	7.5	10,000	1.20	0.021	0.2	0.005

**Event:** Loss of Atarau 110kV busbar

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

No generation at Cobb and Argyle

Greymouth capacitors C1, C2 and C3 are in service

Kumara

generation is in service

**Post event:**

Loss of 110kV Atarau-Dobson

Loss of 110kV Atarau-Reefton-Inangahua

Loss of Atarau 110kV feeder Logburn Rd

**Consequence:**

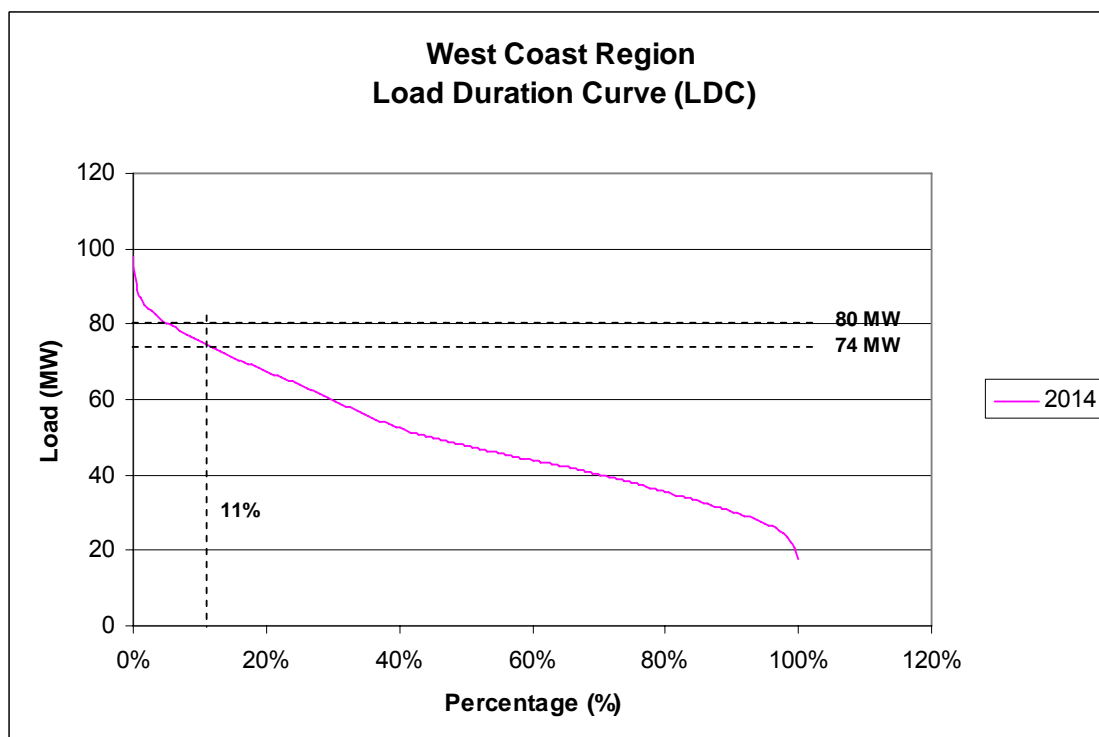
Voltage collapse and loss of supply across the West Coast region.

**Constraint:**

Load constraint limit in the West Coast region 74MW.

For 2014, the constraint is exceeded for 11% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	80	72	20,000	115.2	0.021	0.11	0.266



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 6MW load constraint for the West Coast region.

**Post event:** The remaining West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	6	8760	10,000	n/a	n/a	0.11	57.82

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 6MW post-event load shedding for the West Coast region.

**Post event:** The remaining West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	6	7.5	10,000	0.45	0.021	0.11	0.001

**Event:** Loss of Inangahua 110kV busbar

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:**

No generation at Cobb and Argyle

Greymouth capacitors C1, C2 and C3 are in service

Kumara

generation is in service

**Post event:**

Loss of 110kV Inangahua-Reefton-Atarau-1, Inangahua-Murchison-Kikiwa-1, Inangahua-Robertson Street-Westport circuits 1 and 2, Inangahua-Kikiwa-1 and Inangahua-Reefton-2.

**Consequence:**

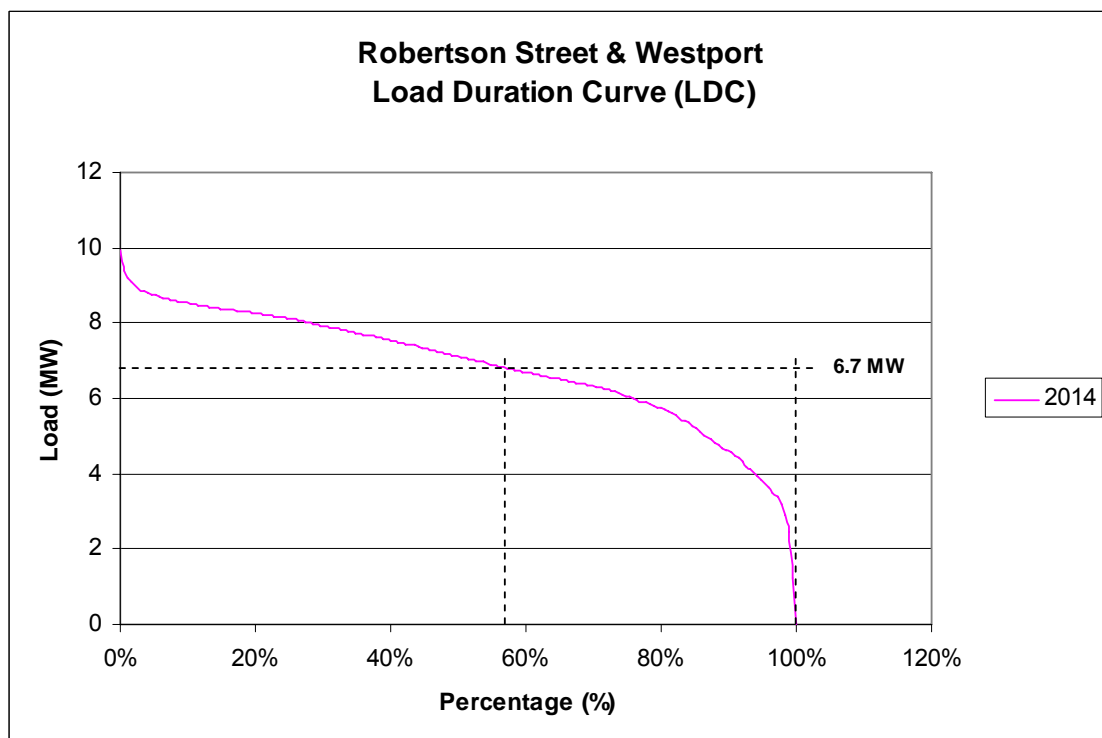
Voltage collapse and loss of supply from Inangahua to Islington (Reefton, Atarau and West Coast region)

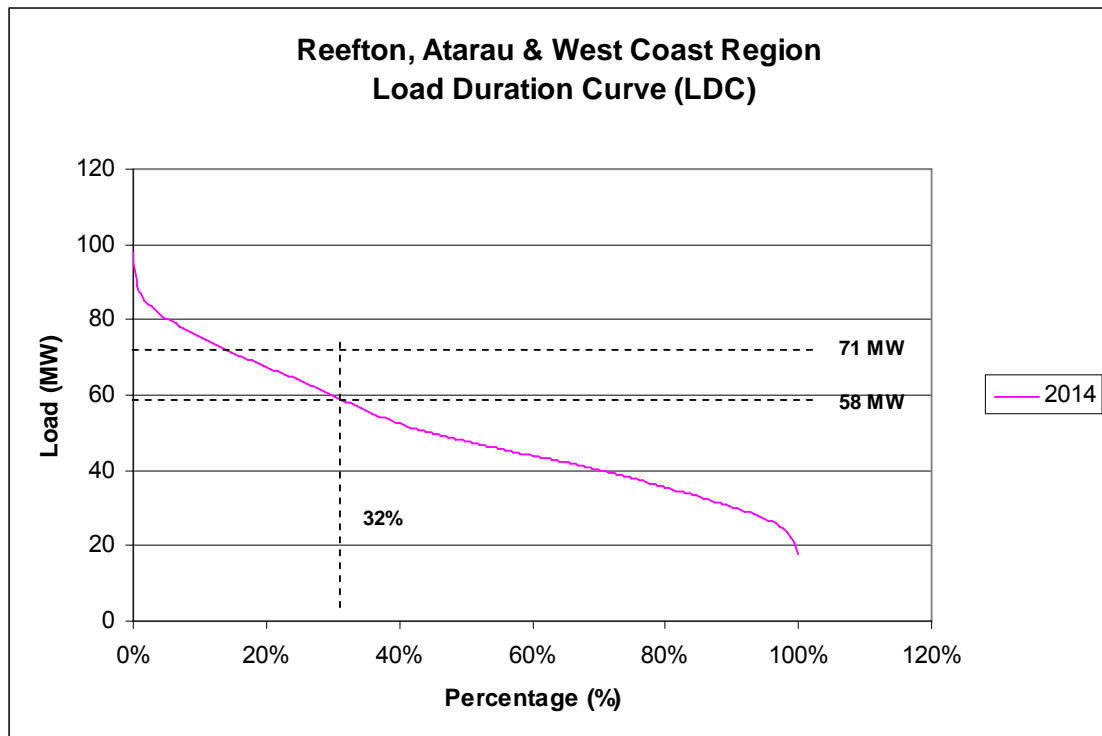
Robertson Street and Westport load directly connected to Inangahua will be lost 100% of the time

**Constraint:**

Load constraint limit at Reefton, Atarau and West Coast is 58MW. For 2014, the constraint is exceeded for 32% of the time

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ROB and WPT)	6.7	72	20,000	9.65	0.021	1.00	0.203
Unplanned load shedding	71	72	20,000	102.24	0.021	0.32	0.687
<b>TOTAL</b>							<b>0.687</b>





**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 13MW load constraint from Inangahua to Islington

**Post event:** The remaining load from Inangahua to Islington is secured

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ROB and WPT)	6.7	72	20,000	9.65	0.021	1.00	0.203
Pre-event load constraint	13	8760	10,000	N/A	N/A	0.32	364.42
<b>TOTAL</b>							<b>364.42</b>

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 13MW post-event regional load shedding

**Post event:** The remaining load from Inangahua to Islington is secured

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (ROB and WPT)	6.7	72	20,000	9.65	0.021	1.00	0.203
Planned load shedding	13	7.5	10,000	0.975	0.021	0.32	0.0066
<b>TOTAL</b>							<b>0.0066</b>

**Event:** Loss of Kikiwa 110kV busbar

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

No generation at Cobb and Argyle

Greymouth capacitors C1, C2 and C3 are in service

Kumara

generation is in service

**Post event:**

Kikiwa transformers 1 and 2

Loss of 110kV Kikiwa-Argyle-Blenheim

Loss of 110kV Kikiwa-Inangahua-2

Loss of 110kV Kikiwa-Murchison-Inangahua-1

Loss of 110kV Kikiwa-Stoke-3

**Consequence:**

Voltage collapse in the West Coast affecting the load between Kikiwa 110kV busbar (Nelson) and Islington 66kV busbar (West Coast).

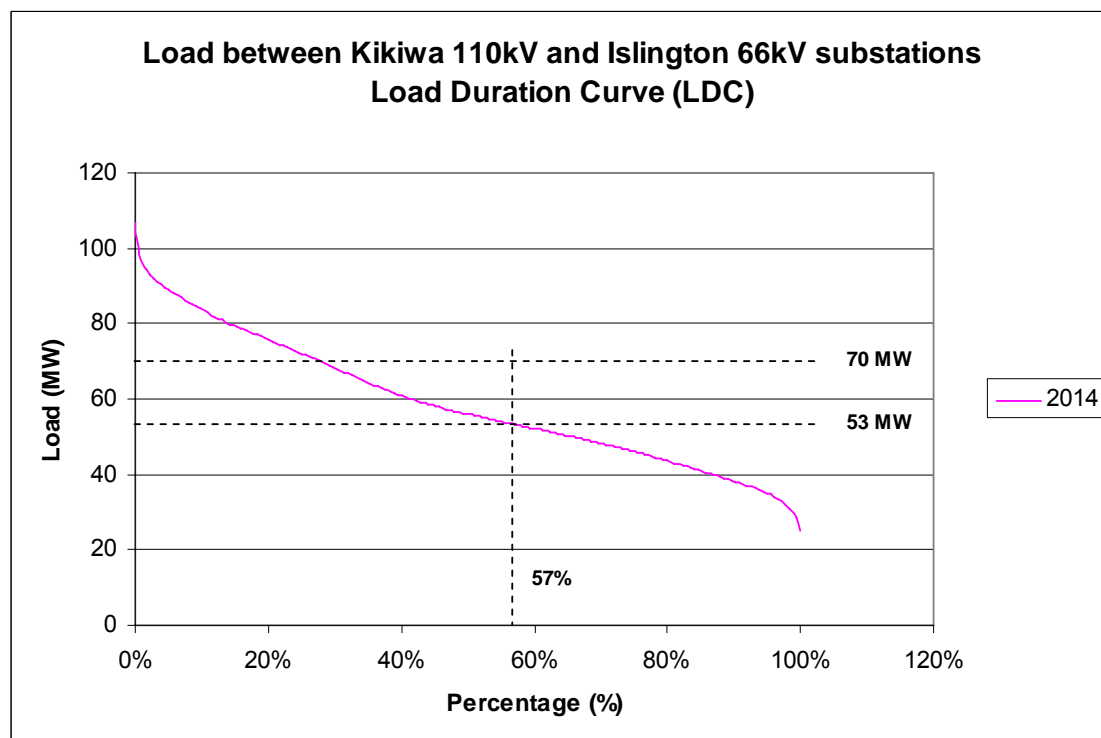
The West Coast and some of the Nelson load (between Kikiwa 110kV and West Coast region) will be lost.

**Constraint:**

Load constraint limit between Kikiwa 110kV and Islington 66kV is 53MW.

For 2014, the constraint is exceeded for 57% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	70	72	20,000	100.8	0.021	0.57	1.207



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 17MW of load constraint in the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	17	8760	10,000	n/a	n/a	0.57	848.84

**ECE Approach: Pre-arranged post-event load shedding (\$10,000/MWh)**

**Pre-event measures:** Arrange 17 MW post-event load shedding in the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	17	7.5	10,000	1.275	0.021	0.57	0.0153

**Event:** Loss of Kikiwa 220kV busbar A

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No generation at Cobb and Argyle

**Post event:** Loss of Kikiwa transformer 2

Loss of 220kV Kikiwa-Islington-1

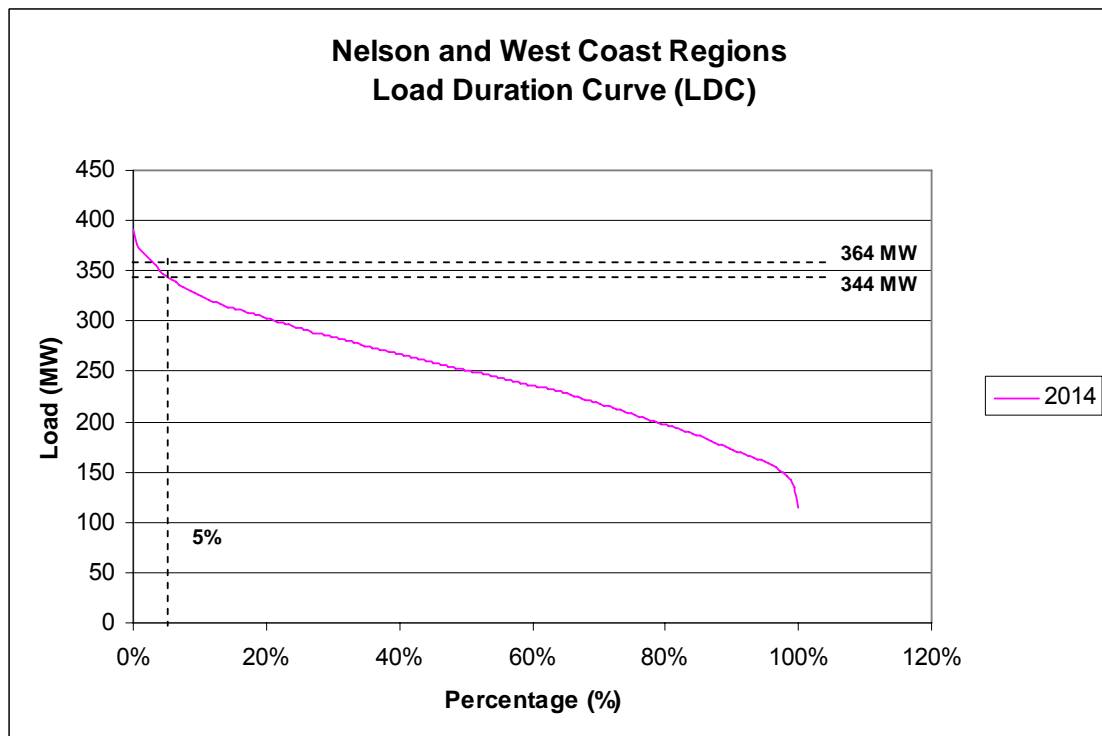
**Consequence:** Voltage collapse in the Nelson and West Coast regions.

Loss of supply to the Nelson and West Coast regions.

**Constraint:** Load constraint limit in the West Coast and Nelson regions 344MW.

For 2014, the constraint is exceeded for 5% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	364	72	20,000	524.16	0.021	0.05	0.5504



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 20MW load constraint in the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	20	8760	10,000	n/a	n/a	0.05	87.6

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 20MW post event load shedding in the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	20	7.5	10,000	1.5	0.021	0.05	0.0016

**Event:** Loss of Stoke 110kV busbar

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No generation at Cobb and Argyle

**Post event:** Loss of Stoke transformer 7  
 Loss of Stoke supply transformer 3  
 Loss of 110kV Stoke-Blenheim-1 and 2  
 Loss of 110kV Stoke-Kikiwa-3

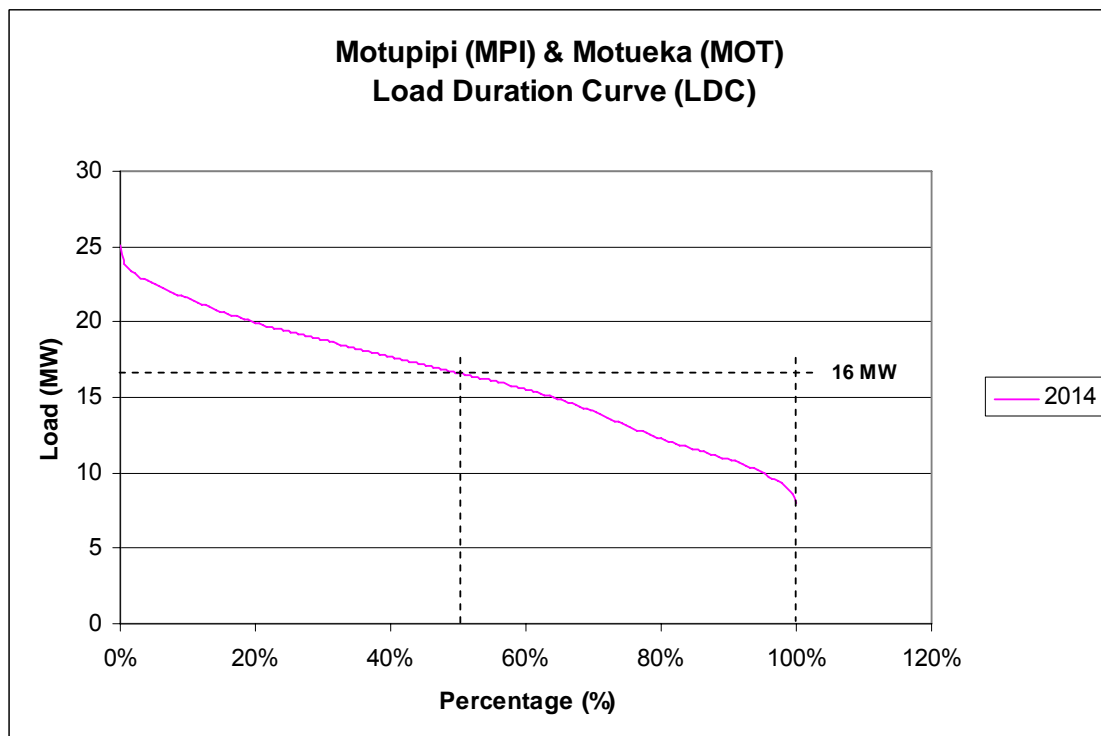
**Consequence:** Loss of supply to Motueka and Motupipi for 100% of the time.

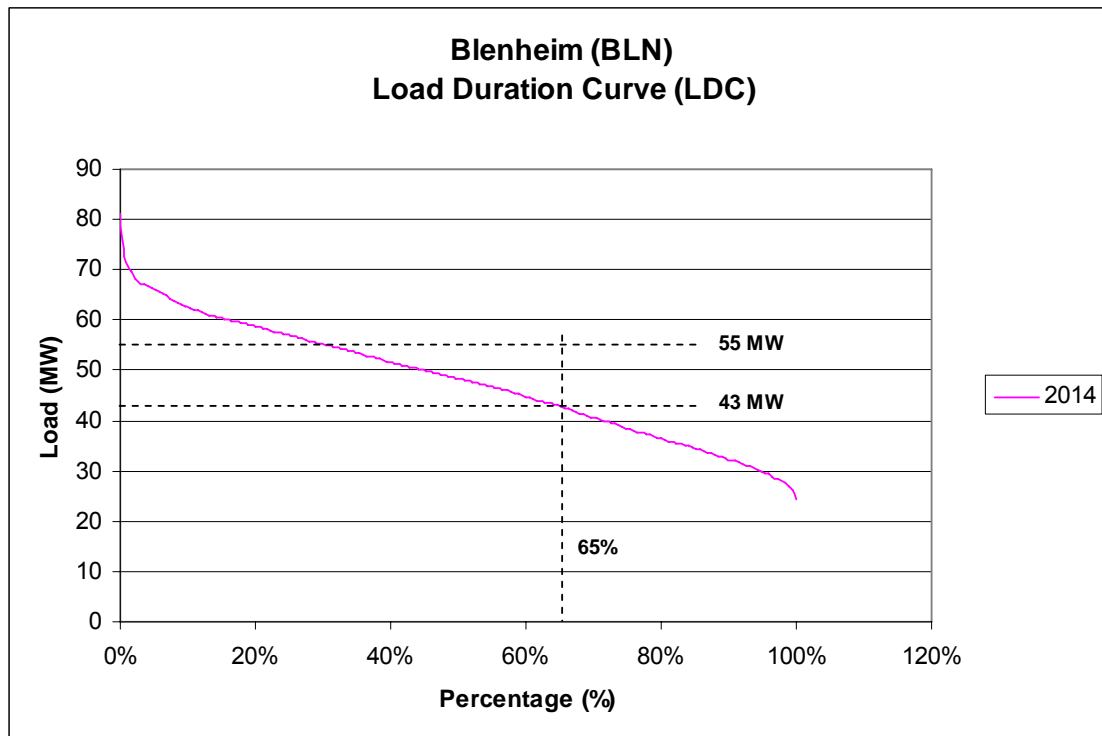
Overload of Argyle-Blenheim and Argyle-Kikiwa 110kV circuits will overload and trip.

Loss of supply to Blenheim due to circuit overloads.

**Constraint:** Load constraint limit at Blenheim 33kV is 43MW.  
 For 2014, the constraint is exceeded for 65% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (MOT & MPI)	16	7.5	20,000	2.4	0.021	1.00	0.0504
Unplanned load shedding	55	7.5	20,000	8.25	0.021	0.65	0.113
<b>TOTAL</b>							<b>0.113</b>





**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 12MW load constraint at Blenheim 33kV.

**Post event:** The remaining Blenheim 33kV load is secured.  
 Loss of supply to Motueka and Motupipi for 100% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (MOT & MPI)	16	7.5	20,000	2.4	0.021	1.00	0.0504
Pre-event load constraint	12	8760	10,000	n/a	n/a	0.65	683.28
<b>TOTAL</b>							<b>683.28</b>

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 12MW post event load shedding at Blenheim 33kV.

**Post event:** The remaining Blenheim 33kV load is secured.  
 Loss of supply to Motueka and Motupipi for 100% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding (MOT & MPI)	16	7.5	20,000	2.4	0.021	1.00	0.0504
Planned load shedding	12	7.5	10,000	0.9	0.021	0.65	0.0123
<b>TOTAL</b>							<b>0.0123</b>

**Event:** Loss of Stoke 220kV busbar A

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

No Local generation at Cobb and Argyle

**Post event:**

Loss of Stoke transformer 7 and supply transformer 8

Loss

of 220kV Stoke-Kikiwa-2

**Consequence:**

Stoke supply transformers 9 and 10 will be overloaded to 68MVA each. Winter 24 hour post contingency rating of Stoke transformer 9 is 57MVA and Stoke transformer 10 is 59MVA. Stoke transformer 3 will be overloaded to 33MVA. Winter 24 hour post contingency rating of Stoke transformer 3 is 31MVA.

Loss of supply to Motueka, Motupipi, Blenheim and Stoke 33kV load

Overload of 110kV Stoke-Kikiwa-3.

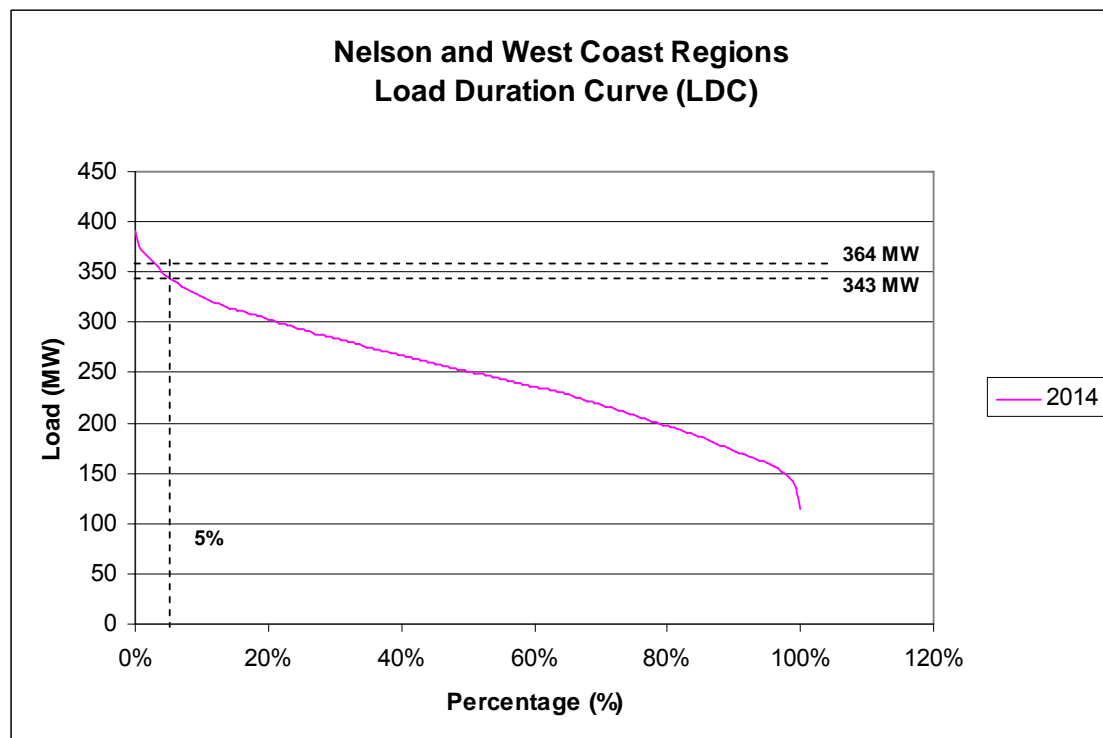
Voltage collapse across the Nelson and West Coast regions.

**Constraint:**

Load constraint limit in Nelson and West Coast regions 343MW.

For 2014, the constraint is exceeded for 5% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	364	72	20,000	524.16	0.021	0.05	0.550



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 21MW load constraint across the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	21	8760	10,000	n/a	n/a	0.05	91.98

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 21 MW post event load shedding across the Nelson and West Coast regions.

**Post event:** The remaining Nelson and West Coast load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	21	7.5	10,000	1.575	0.021	0.05	0.0017

**Event:** Loss of Stoke 220kV busbar B

**Region:** Nelson

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No generation at Cobb and Argyle

**Post event:** Loss of Stoke supply transformers 9 and 10

Loss of 220kV Stoke-Kikiwa-1

**Consequence:** Stoke supply transformer 8 will be overloaded to 140MVA.

Winter 24 hour post contingency rating of Stoke transformer 8 is 57MVA.

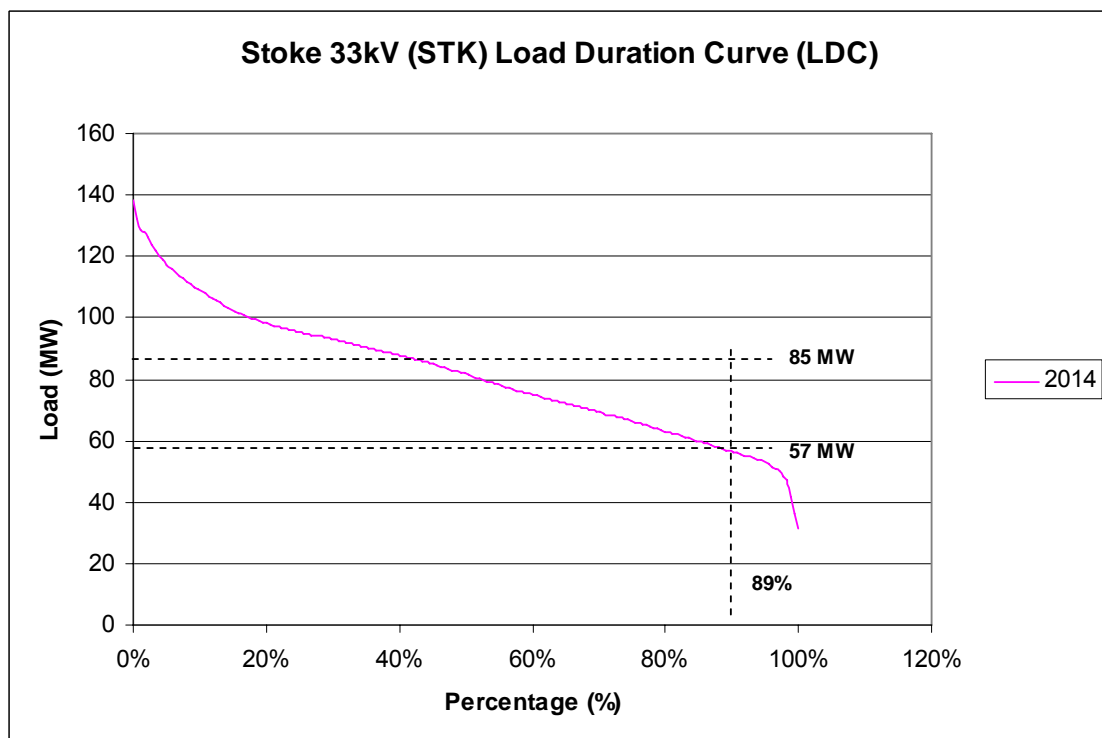
Stoke supply transformer 8 will trip.

Loss of supply to Stoke 33kV load.

**Constraint:** Load constraint limit at Stoke 33kV is 57MW.

For 2014, the constraint is exceeded for 89% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	85	7.5	20,000	12.75	0.021	0.89	0.2383



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 28MW load constraint at Stoke 33kV.

**Post event:** The remaining Stoke 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	28	8760	10,000	n/a	n/a	0.89	2182.99

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 28MW post event load shedding at Stoke 33kV.

**Post event:** The remaining Stoke 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	28	7.5	10,000	2.1	0.021	0.89	0.0392

**Event:** Loss of Albany 110kV busbar section 1

**Region:** Northland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Ngawha generation set to 0MW.  
 Total Northland load is 940MW.

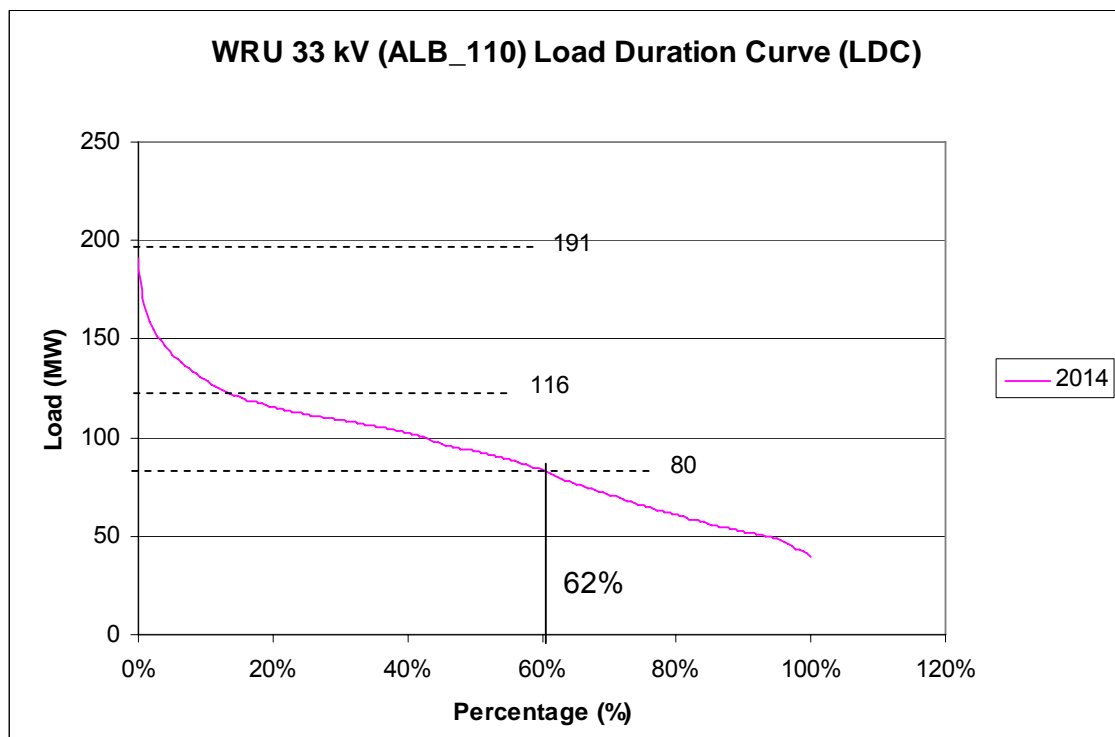
**Post event:** Loss of 110kV Albany-Wairau-1 and 2.  
 Loss of Albany transformer T4.

**Consequence:** Wairau supply transformer T3 will be overloaded to 110MVA.  
 Winter 24 hour post-contingency rating of Wairau supply transformer T3 is 80MVA.

Loss of supply to Wairau 33kV (ALB\_110) load.

**Constraint:** Load constraint limit at Wairau 33kV (ALB\_110) 80MW.  
 For 2014 the constraint is exceeded for 62% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	116	7.5	20,000	17.4	0.021	0.62	0.23



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 36MW load constraint at Wairau 33kV.

**Post event:** The remaining Wairau Road load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	36	8760	10,000	n/a	n/a	0.62	1955.23

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 36MW post event load shedding at Wairau 33kV.

**Post event:** The remaining Wairau Road load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	36	7.5	10,000	2.7	0.021	0.62	0.0356

**Event:** Loss of Albany 110kV busbar section 2

**Region:** Northland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Nhawha generation set to 0MW.

Total Northland load is 940MW.

**Post event:** Loss of 110kV Albany-Wairau-3.

Loss of 110kV Albany-Henderson-1 and 2.

Loss of Albany Capacitor C1.

**Consequence:** Wairau supply transformers T1 and T2 will be overloaded to 97MVA each.

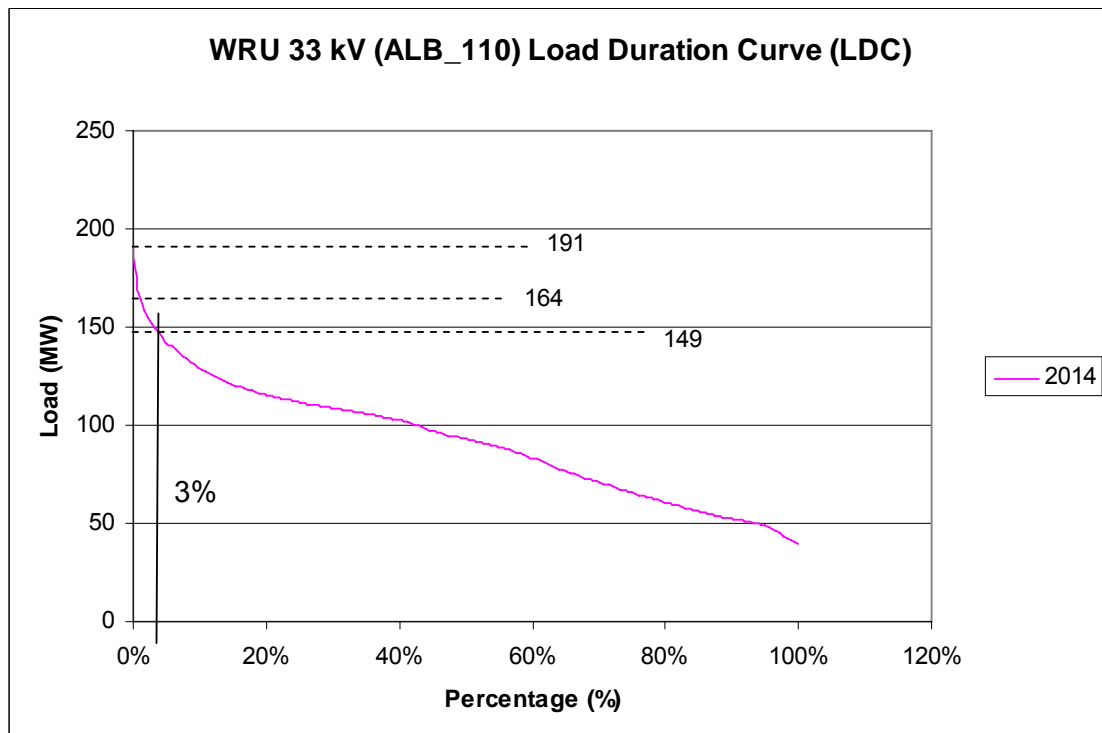
Winter 24 hour post-contingency rating of Wairau supply transformers T1 and T2 is 80MVA.

Loss of supply to Wairau 33kV (ALB\_110) load.

**Constraint:** Load constraint limit at Wairau 33kV (ALB\_110) 149MW.

For 2014 the constraint is exceeded 3% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	164	7.5	20,000	24.6	0.021	0.03	0.016



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 15MW load constraint at Wairau 33kV.

**Post event:** The remaining Wairau Road load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	15	8760	10,000	n/a	n/a	0.03	39.42

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 15MW post event load shedding at Wairau 33kV.

**Post event:** The remaining Wairau Road load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	15	7.5	10,000	1.125	0.021	0.03	0.0007

**Event:** Loss of Albany 220kV busbar section 1

**Region:** Northland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Ngawha generation set to 0MW and total Northland load is 940MW.

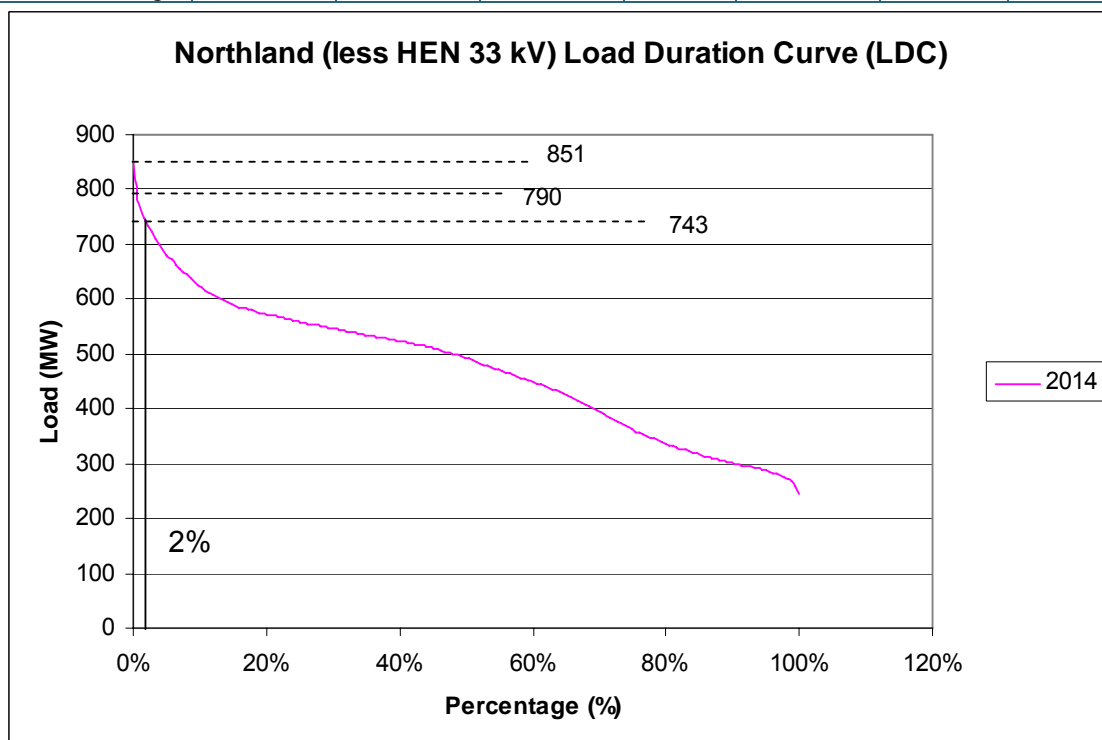
**Post event:** Loss of 2 20kV Albany-Henderson-3, 220kV Albany-Silverdale-2 and supply transformer T8.

**Consequence:** The 220kV Henderson-Huapai-1 will be overloaded to 514MVA. Winter rating of 220kV Henderson-Huapai-1 is 457MVA.

If this circuit trips cascade failure would result in loss of supply to Breamba y, Albany, Silverdale, Marsden, MMAungaturoto, Wellsford, Maun gatapere, Kaitoke, Kensington, Kaitaia & Dargarville. Henderson 33kV load would still be supplied via Henderson 220kV.

**Constraint:** Load constraint limit in Northland region ( excluding Henderson 33kV) 743MW. For 2 014, the constraint is exceeded 2% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	790	7.5	20,000	118.5	0.021	0.02	0.050



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 47MW load constraint in the Northland region.

**Post event:** The Northland load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	47	8760	10,000	n/a	n/a	0.02	82.344

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 47MW post-event load shedding in the Northland region.

**Post event:** The Northland load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	47	7.5	10,000	3.525	0.021	0.02	0.0015

**Event:** Loss of Henderson 220kV busbar section 1

**Region:** Northland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Ngawha generation set to 0MW.

Total Northland load is 940MW and Mount Roskill load is 198MW.

**Post event:** Loss of 220kV Henderson-Albany-3 , 220kV Henderson-Otahuhu-1, Henderson 220/110 kV transformer T1, Henderson supply transformer T2 and Henderson Capacitor C1.

**Consequence:** The 220kV Henderson-Southdown-1 will be overloaded to 893MVA. Winter rating is 814MVA.

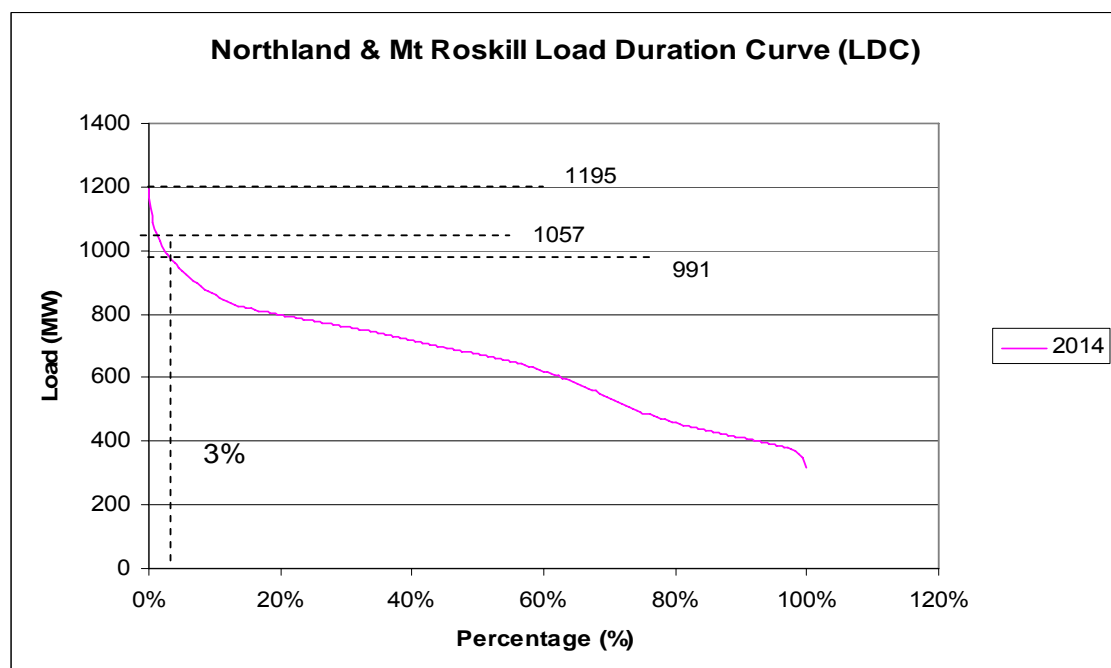
The 220kV Henderson-Huapai-1 will be overloaded to 532MVA. Winter rating is 457MVA.

The 110kV Mangere-Roskill-1 and 2 will be overloaded to 104MVA. Winter rating is 101MVA.

These circuits will trip and result in loss of supply to the Northland area and Mount Roskill.

**Constraint:** Load constraint limit in Northland and Mt Roskill 991MW. For 2014 the constraint is exceeded for 3% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	1057	7.5	20,000	158.55	0.021	0.03	0.101



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 66MW load constraint in the Northland area and Mount Roskill.

**Post event:** The remaining Northland and Mount Roskill load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	66	8760	10,000	n/a	n/a	0.03	173.448

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 66MW post event load shedding in the Northland area and Mount Roskill.

**Post event:** The remaining Northland and Mount Roskill load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	66	7.5	10,000	4.95	0.021	0.03	0.0032

**Event:** Loss of Maungatapere 110kV busbar section 1      **Region:** Northland  
**Event Risk Factor:** 0.021      **Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Ngawha generation set to 0MW and total Northland load is 940MW. Bus coupler and bus zone, circuit fail and duplicate line protection in place (approved for completion by the end of 2010).

**Post event:** Loss of 110kV Maungatapere-Kensington-1, 110kV Maungatapere-Marsden-1, 110kV Maungatapere-Maungaturoto-1, 110kV Maungatapere-Kaikohe-1, 110kV Maungatapere-Dargaville-1 and Maungatapere supply transformer T4.

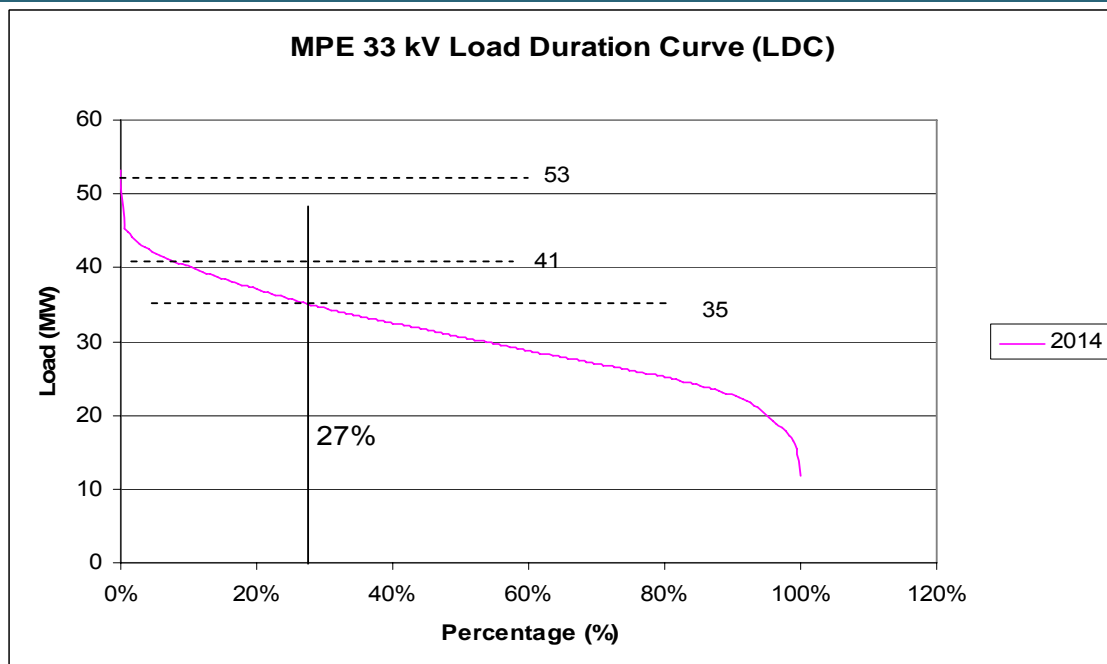
**Consequence:** Maungatapere supply transformer T2 will be overloaded to 52MVA. Winter 24 hour post contingency rating of Maungatapere supply transformer T2 is 40MVA.

Kensington supply transformer T2 will be overloaded to 56MVA. Winter 24 hour post contingency rating of Kensington supply transformer T2 is 56MVA.

Loss of supply to Maungatapere 33kV load.

**Constraint:** Load constraint limit at Maungatapere 33kV 35MW.  
 For 2014 the constraint is exceeded 27% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	41	7.5	20,000	6.15	0.021	0.27	0.035



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 6MW load constraint at Maungatapere 33kV.

**Post event:** The remaining Maungatapere 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	6	8760	10,000	n/a	n/a	0.27	141.912

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 6MW post event load shedding at Maungatapere 33kV.

**Post event:** The remaining Maungatapere 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	6	7.5	10,000	0.45	0.021	0.27	0.0026

**Event:** Loss of Maungatapere 110kV busbar section 2

**Region:** Northland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** Ngawha generation set to 0MW and total Northland load is 940MW. Bus coupler and bus zone, circuit fail and duplicate line protection has been approved for completion by the end of 2010.

**Post event:** Loss of 110kV Maungatapere-Kensington-2, 110kV Maungatapere-Marsden-2, 110kV Maungatapere-Maungaturoto-2, 110kV Maungatapere-Kaikohe-2, 110kV Maungatapere-Dargaville-2 and Maungatapere supply transformer T2.

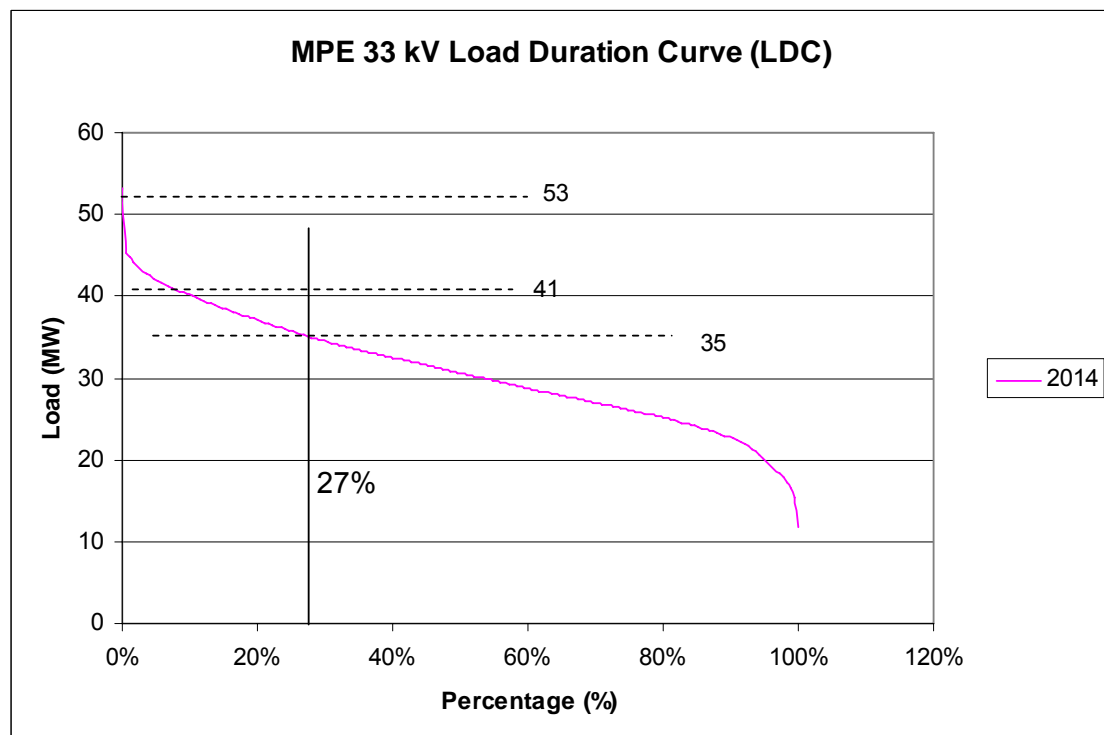
**Consequence:** Maungatapere supply transformer T4 will be overloaded to 52MVA. Winter 24 hour post contingency rating of Maungatapere supply transformer T4 is 40MVA.

Loss of supply to Maungatapere 33kV load

**Constraint:** Load constraint limit at Maungatapere 33kV 35MW.

For 2014 the constraint is exceeded for 27% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	41	7.5	20,000	6.15	0.021	0.27	0.035



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 6MW load constraint at Maungatapere 33kV.

**Post event:** The remaining Maungatapere 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	VoLL (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	6	8760	10,000	n/a	n/a	0.27	141.912

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 6MW post event load shedding at Maungatapere 33kV.

**Post event:** The remaining Maungatapere 33kV load is secured.

Event Measure	Average Load (MW)	Duration (h)	VoLL (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	6	7.5	10,000	0.45	0.021	0.27	0.0026

**Event:** Loss of Tekapo B 220kV busbar

**Region:** Otago

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

HVDC Pole 1 out of service  
 North transfer HVDC Pole 2 660MW

**Post event:**

Loss of Tekapo B generator transformers 2 and 3  
 Loss of 220kV Islington-Tekapo B-1  
 Loss of 220kV Tekapo B-Twizel-1

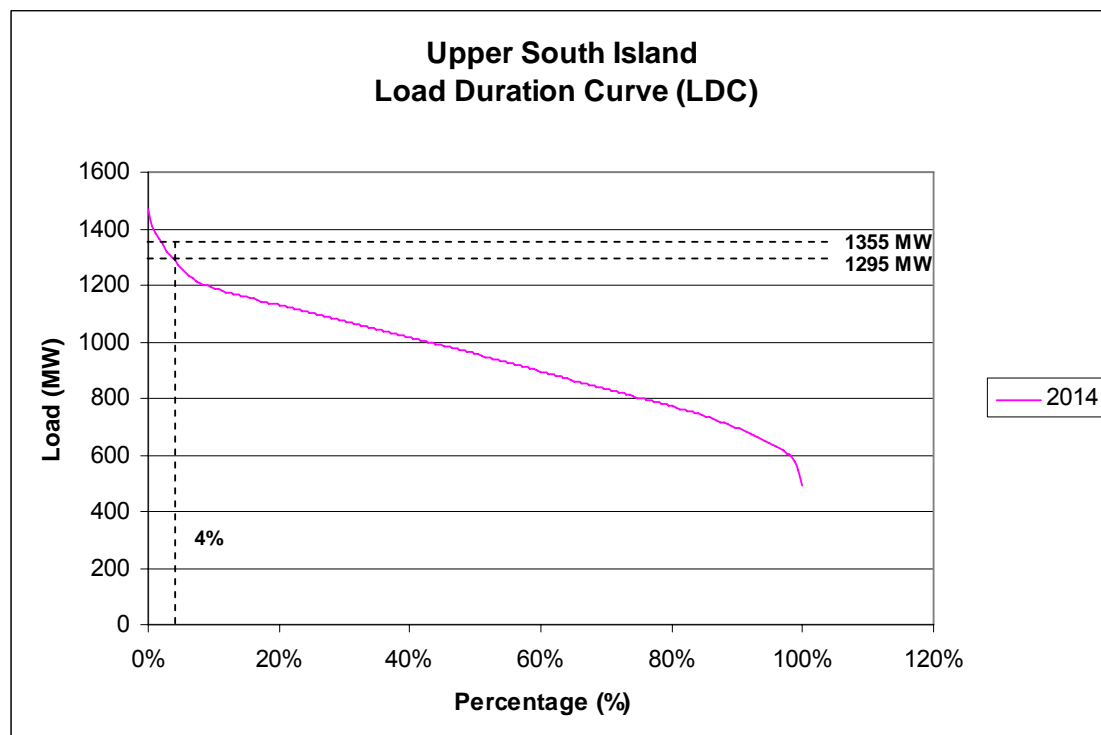
**Consequence:**

Voltage collapse in the Upper South Island (Nelson, Christchurch, Canterbury and West Coast regions).  
 Loss of supply to the Upper South Island.

**Constraint:**

Load constraint limit in the Upper South Island 1295MW.  
 For 2014, the constraint is exceeded for 4% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	1355	72	20,000	1951.2	0.021	0.04	1.639



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 60MW load constraint across the Upper South Island.

**Post event:** The remaining Upper South Island load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	60	8760	10,000	n/a	n/a	0.04	210.24

***ECE Approach: Pre-arranged post-event planned load shedding***

**Pre-event measures:** Arrange 60 MW post event load shedding across the Upper South Island.

**Post event:** The remaining Upper South Island load is secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	60	7.5	10,000	4.5	0.021	0.04	0.0038

**Event:** Loss of Berwick 110kV busbar section

**Region:** Southland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No 110kV generation at Roxburgh and Waipori and no wind generation at White Hill

**Post event:** Loss of Berwick – Halfway Bush – 110kV circuit

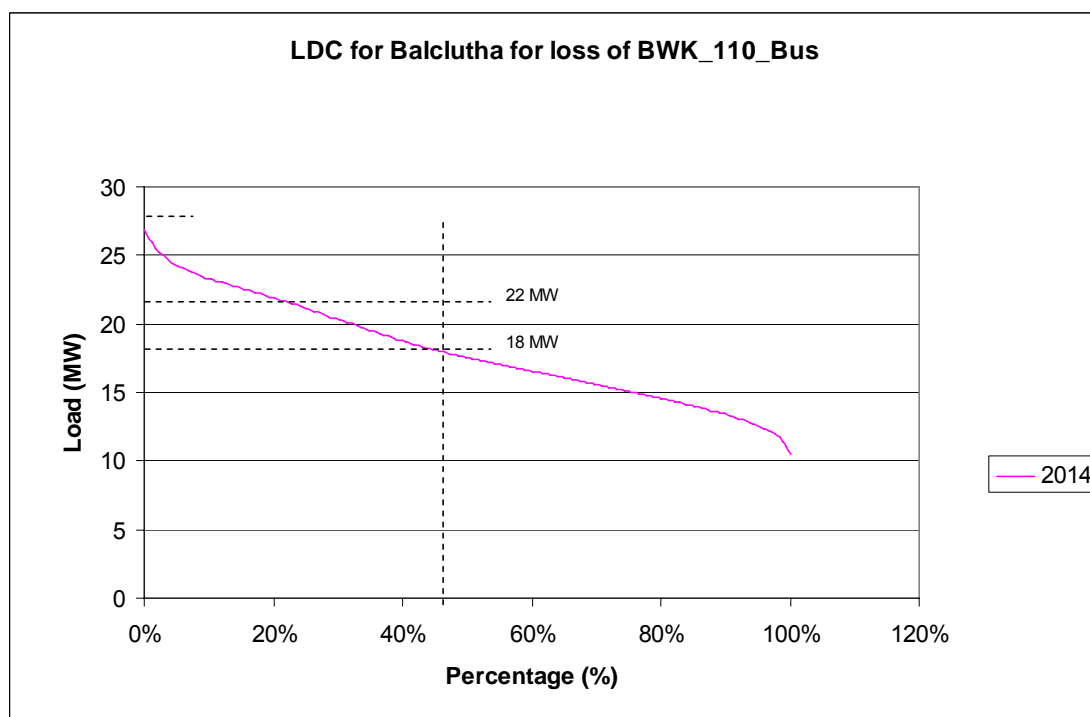
Loss of Berwick – Balclutha – 110 circuit

**Consequence:** Low voltages on the 110kV busbar at Balclutha

**Constraint:** Constrain load at Balclutha to 18MW

For 2014, the constraint is exceeded for 46% of the time. The average value of the load above this constrained limit of 18MW is 22MW

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	22	7.5	20,000	3.3	0.021	0.46	0.031



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 4MW of load constraint to avoid low voltages at Balclutha

**Consequence:** Load at the Balclutha is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	4	8760	10,000	N/A	N/A	0.46	161.18

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 4MW of post-event load shedding

**Consequence:** Load at Balclutha is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	4	7.5	10,000	0.3	0.021	0.46	0.002

**Event:** Loss of Halfway Bush 220 busbar section A

**Region:** Southland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

No 110kV generation at Roxburgh and Waipori

**Post event:**

Loss of the interconnecting transformer T4

Loss of both 220kV Halfway Bush-South Dunedin circuits

**Consequence:**

The Roxburgh interconnecting transformer overloads and trips. This may cause cascading failure of the Invercargill interconnecting transformer and causing loss of supply to six GXP's – Halfway Bush – 33kV, Palmerston, Balclutha, Gore, Brydone and Edendale.

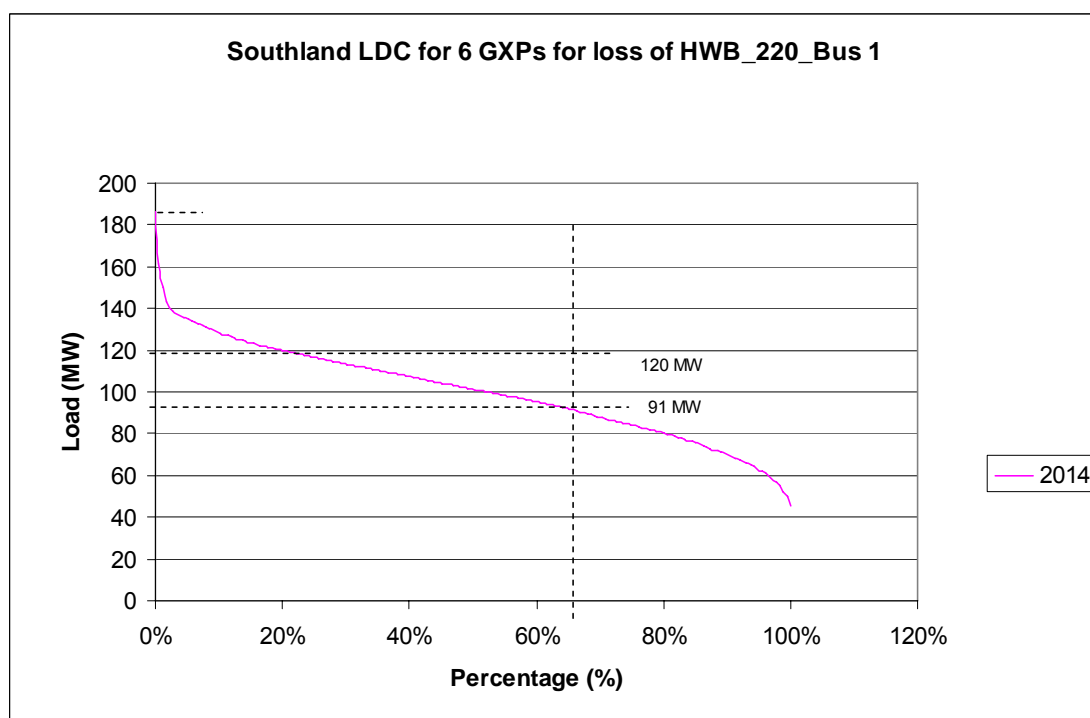
**Constraint:**

Load constraint to 91MW for the six GXPs to avoid overloading of the Roxburgh interconnecting transformer T10 above its 24h post-contingency winter rating of 58.5MVA.

For 2014, the constraint is exceeded for 66% of the time.

From the LDC for the six GXPs for 2014, the average value of the load above the constrained limit of 91MW is 120MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	120	7.5	20,000	18.00	0.021	0.66	0.249



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 29MW of load constraint to avoid cascading failure of the Roxburgh interconnecting transformer T10.

**Consequence:** The load in the area is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	29	8760	10,000	N/A	N/A	0.66	1676.66

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 29MW of post-event load shedding

**Consequence:** The load in the area is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	29	7.5	10,000	2.175	0.021	0.66	0.03

**Event:** Loss of Invercargill 110kV busbar

**Region:** Southland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No 110kV generation at Roxburgh and Waipori and no wind generation at White Hill

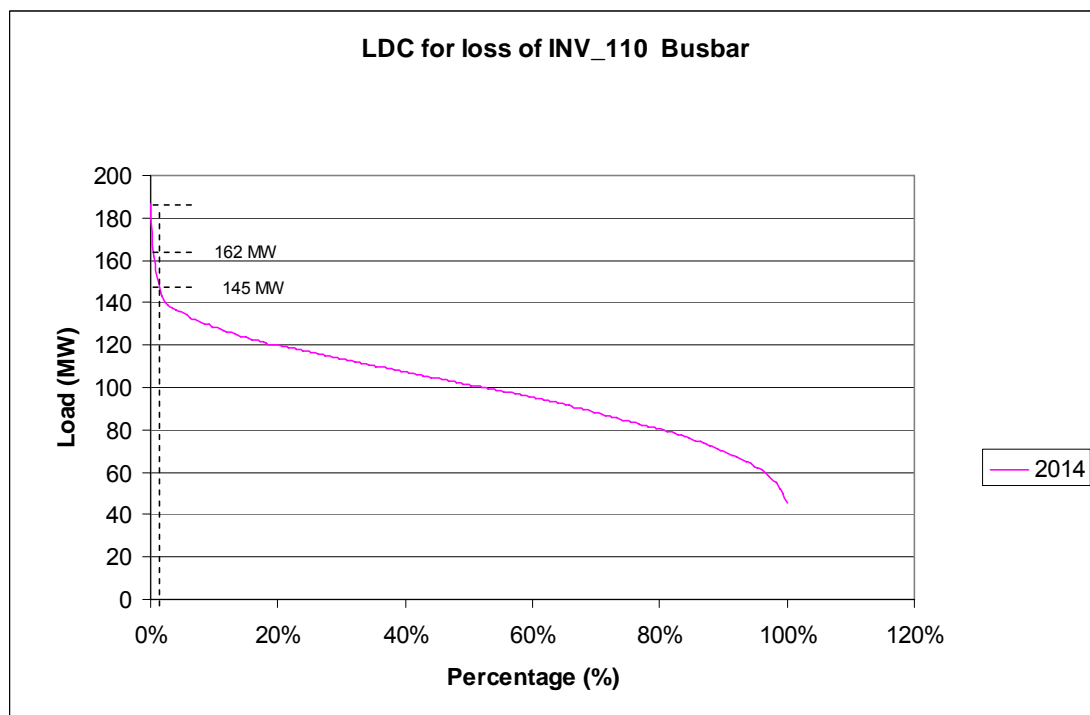
**Post event:** Loss of the interconnecting transformer T1  
 Loss of the 110kV Invercargill – Edendale circuit

**Consequence:** The Roxburgh transformer may exceed capacity, trip and cause cascading tripping of Halfway Bush transformer T4. Loss of supply to the Southland 110kV network.

Low voltages at the 110kV busbars at Edendale, Brydone, Gore, Balclutha

**Constraint:** Constrain load at the six GXP to 145MW  
 For 2014, the constraint is exceeded for 1% of the time. The average value above the constraint is 162MW

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	162	7.5	20,000	24.3	0.021	0.01	0.005



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 17MW of load constraint to avoid cascading failure of the other transformers

**Consequence:** Load at the four GXPs is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	17	8760	10,000	N/A	N/A	0.01	14.89

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 17MW of post-event load shedding

**Consequence:** Load at the four GXPs is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	17	7.5	10,000	1.27	0.021	0.01	0.0003

**Event:** Loss of Invercargill 220 busbar 1

**Region:** Southland

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** No 110kV generation at Roxburgh and Waipori and no wind generation at White Hill

**Post event:** Loss of the interconnecting transformer T1  
 Loss of the 110kV Invercargill – Edendale circuit

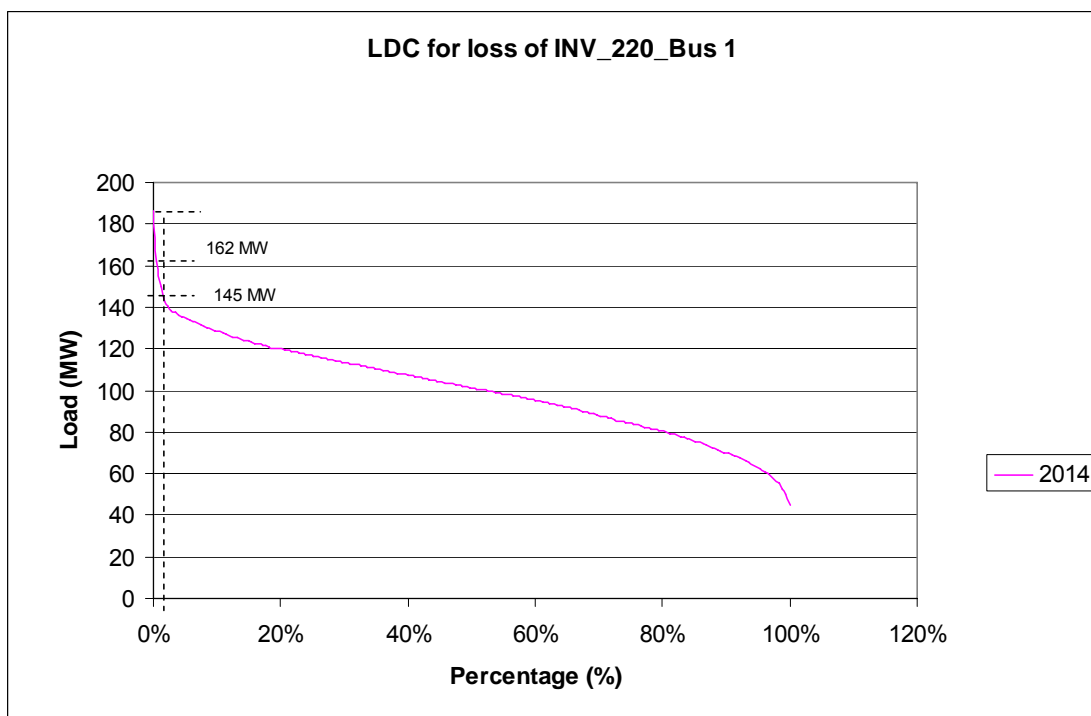
**Consequence:** The Roxburgh transformer may exceed capacity, trip and cause cascading tripping of Halfway Bush transformer T4. Loss of supply to the Southland 110kV network.

Low voltages at the 110kV busbars at Edendale, Brydone, Gore, Balclutha

**Constraint:** Constrain load at the six GXP to 145MW

For 2014, the constraint is exceeded for 1% of the time. The average value above the constraint is 162MW

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	162	7.5	20,000	24.3	0.021	0.01	0.005



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 17MW of load constraint to avoid cascading failure of the other transformers

**Consequence:** Load at the four GXPs is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	17	8760	10,000	N/A	N/A	0.01	14.89

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 17MW of post-event load shedding

**Consequence:** Load at the four GXPs is secured for this fault

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	17	7.5	10,000	1.27	0.021	0.01	0.0003

**Event:** Loss of Stratford 110kV busbar section 1

**Region:** Taranaki

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

**Assumptions:** No local generation at Kapuni, Patea and Whareroa

**Post event:** Loss of Stratford interconnecting transformer 10

Loss of Stratford supply transformer 5

Loss of 110kV Stratford-Carrington Street-1

Loss of 110kV Stratford-Opunake-2

**Consequence:** Stratford supply transformer 6 will be overloaded to 24.5MVA.

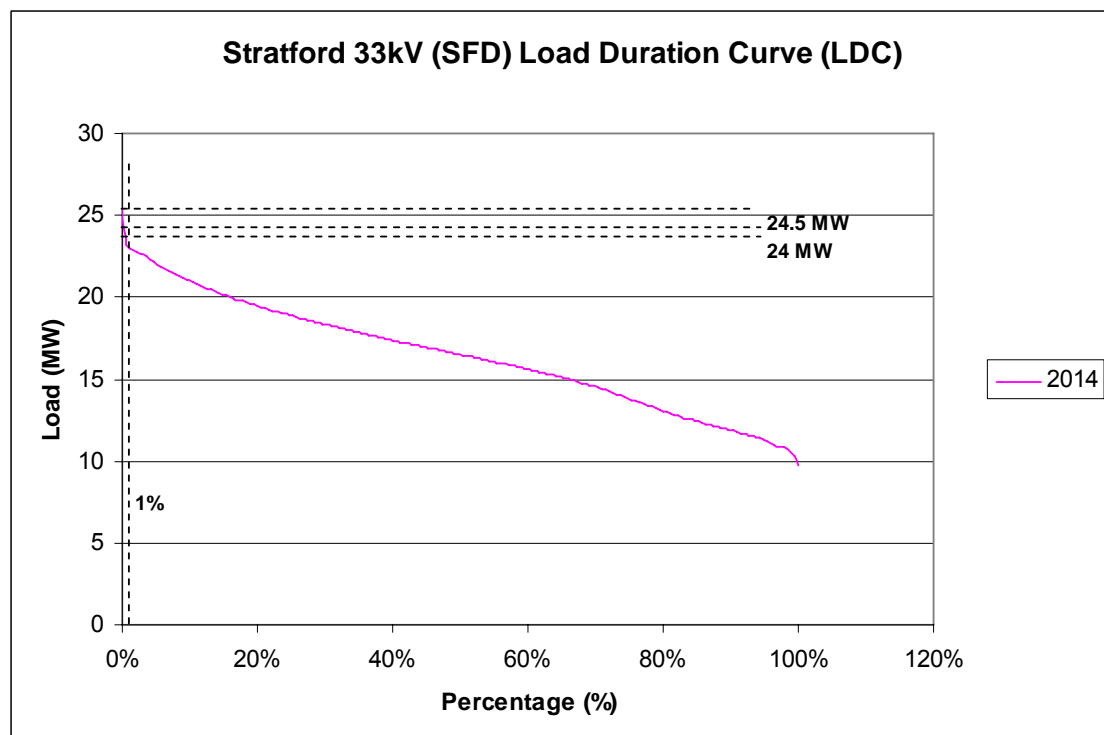
Winter 24 hour post contingency rating of Stratford T6 is 24MVA.

Loss of Stratford 33kV load.

**Constraint:** Load constraint limit at Stratford 33kV is 24MVA.

For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	24.5	7.5	20,000	3.68	0.021	0.01	0.0008



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 0.5MW load constraint at Stratford 33kV.

**Post event:** The remaining Stratford 33kV load will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	0.5	8760	10,000	n/a	n/a	0.01	0.44

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 0.5MW post event load shedding at Stratford 33kV.

**Post event:** The remaining Stratford 33kV load will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	0.5	7.5	10,000	0.04	0.021	0.01	0.00001

**Event:** Loss of Stratford 110kV busbar section 2

**Region:** Taranaki

**Event Risk Factor:** 0.021

**Average Duration:** 7.5 h

**SE Approach:** *Post event unplanned load shedding*

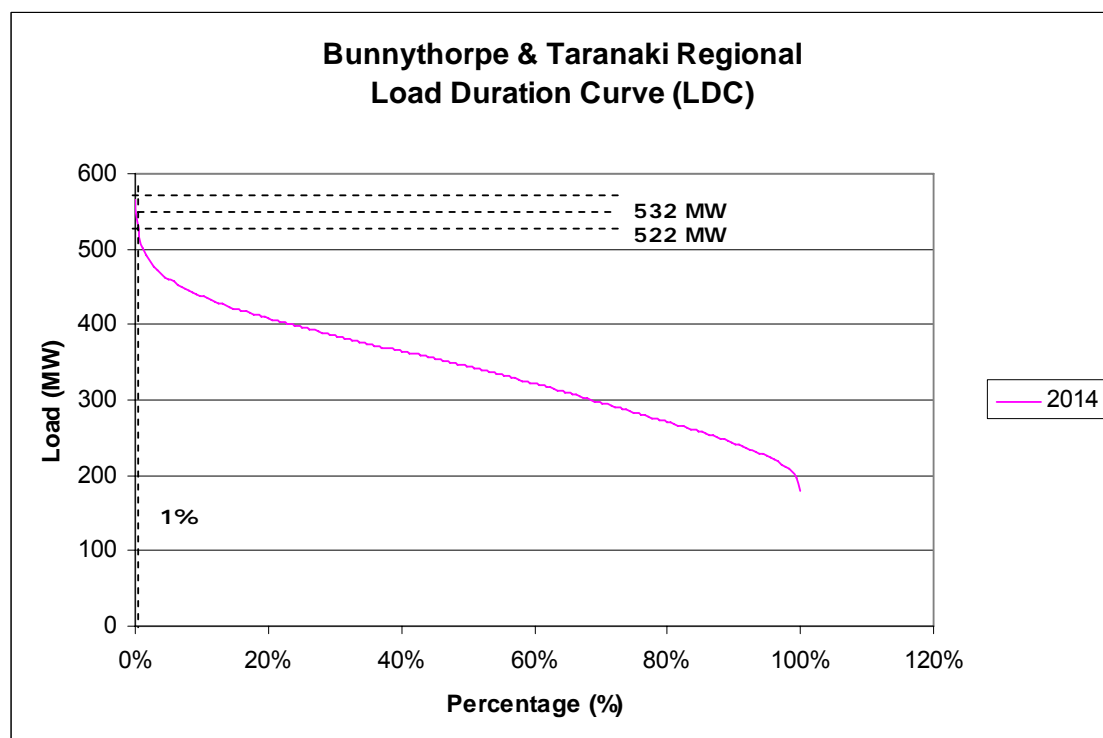
**Assumptions:** No local generation at Kapuni, Patea and Whareroa

**Post event:** Loss of Stratford supply transformer 6. Loss of Stratford-Motunui-1, Stratford-Opunake-1 and Stratford-Hawera-1 110kV circuits.

**Consequence:** Stratford supply transformer 5 will be overloaded to 24.5MVA.  
 Winter 24 hour post contingency rating of Stratford supply transformer 5 is 24MVA.  
 Loss of supply to Stratford 33kV load.  
 Bunnythorpe transformers 1, 2 and 3 will be overloaded to 66MVA.  
 Winter 24 hour post contingency rating of Bunnythorpe transformers 1, 2 and 3 is 62MVA.  
 Loss of supply to Bunnythorpe and Taranaki regions.

**Constraint:** Load constraint limit in the Taranaki region 522MVA.  
 For 2014, the constraint is exceeded for 1% of the time.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	532	7.5	20,000	79.8	0.021	0.01	0.017



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 10MW load constraint in the Taranaki region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	10	8760	10,000	n/a	n/a	0.01	8.76

**ECE Approach: Pre-arranged post-event planned load shedding**

**Pre-event measures:** Arrange 10MW post event load shedding in the Taranaki region.

**Post event:** The remaining Bunnythorpe and Taranaki regional load will be secured.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	10	7.5	10,000	0.75	0.021	0.01	0.0002

**Event:** Loss of Haywards 110kV busbar section B

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW

HVDC Pole 1 out of service

Te Apiti Generation of 90MW to avoid overload of the 110kV Bunnythorpe – Woodville circuits

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilt on interconnector is overloading. For this study, the Wilton T8 is switched off.

**Post event:**

Loss of one of the three interconnecting transformers

Loss of reactive support

Loss of one 110kV Haywards – Takapu Road circuit

Loss of one 110kV Haywards – Melling circuit

Loss of one 110kV Haywards – Upper Hutt circuit

Loss of one 110kV Haywards – Greyfield circuit

Loss of one Haywards supply transformer

**Consequence:**

The remaining two interconnecting transformers at Haywards will overload and trip, losing a ll Wellington region load.

Low voltages in the Wellington region, Loss of HVDC

**Constraint:**

Load constraint of 480MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 10% of the time.

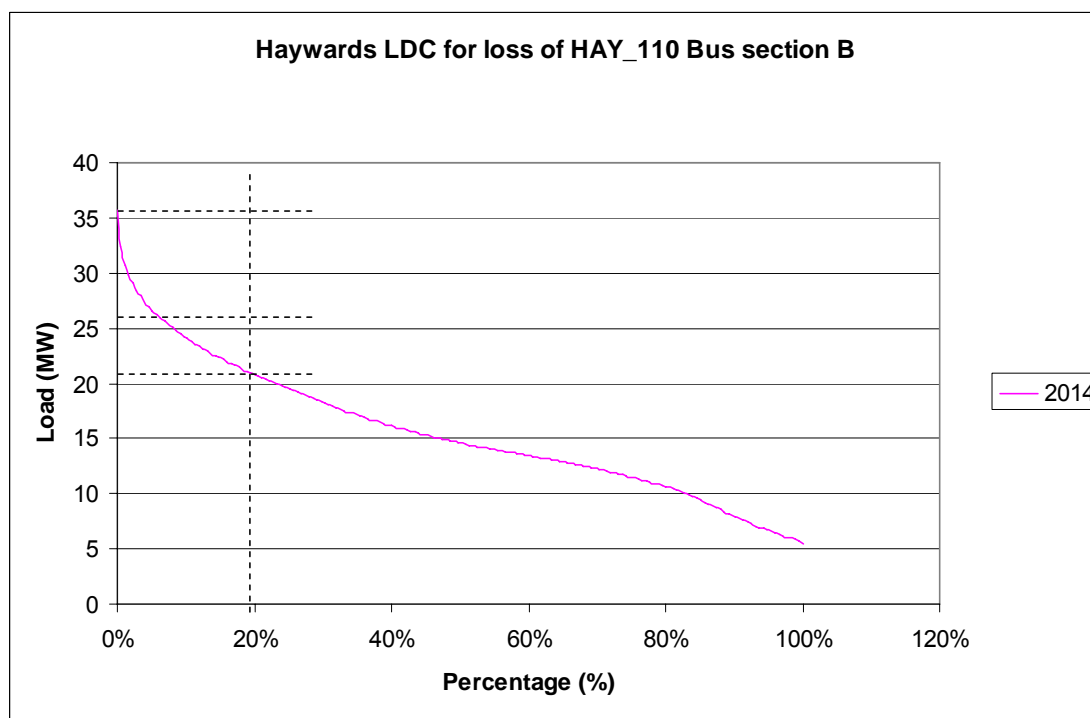
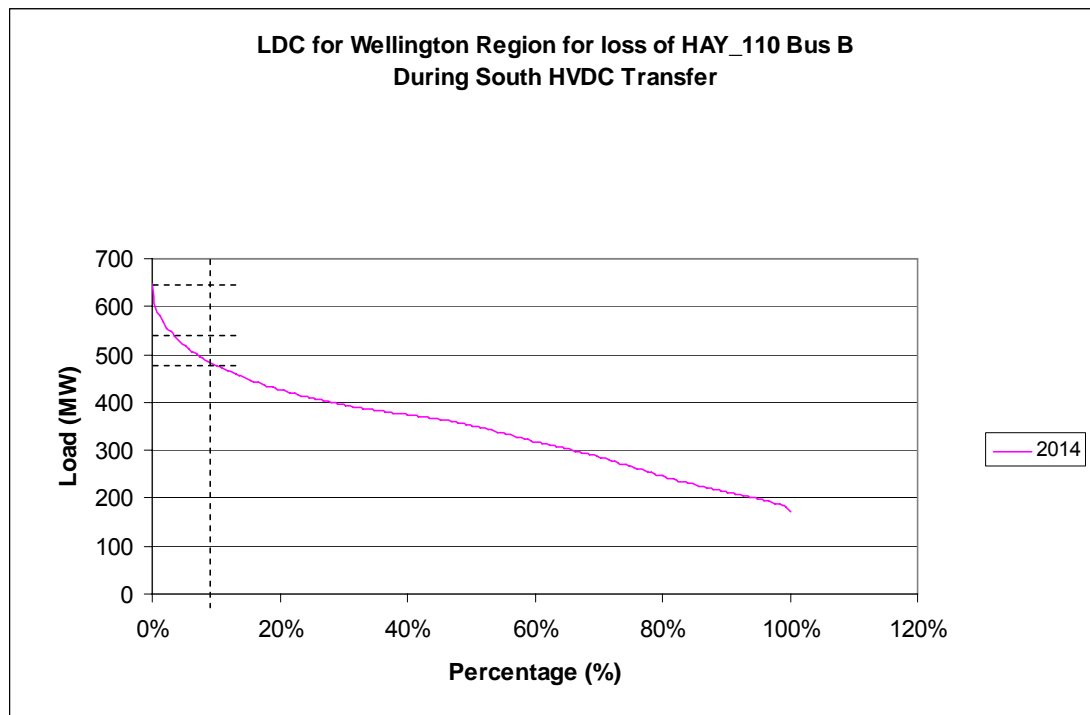
From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 480MW is 540MW.

Load constraint of 21MW for the Haywards load to avoid overloading of the remaining supply transformer.

For 2014, constraint is exceeded for 19% of the time.

From the LDC, the average value above the constraint limit of 21MW is 26MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	540	7.5	20,000	81.0	0.021	0.1	<b>0.170</b>
HVDC trip	220		1250.00	0.275	0.021	0.2	<b>0.0012</b>
<b>Total:</b>							<b>0.171</b>



**CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

- Pre-event measures:** Arrange 60MW of load constraint to avoid cascading failure of the remaining interconnecting transformers.  
Arrange 5MW of load constraint at Haywards to avoid overloading the supply transformer
- Consequence:** Wellington regional load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	60	8760	10,000	N/A	N/A	0.10	525.6
Constrained load– Haywards	5	8760	10,000	N/A	N/A	0.19	83.22
<b>TOTAL</b>							<b>608.82</b>

***ECE Approach : Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)***

- Pre-2012:** Trip the average of 220 MW for HVDC South transfer post event
- Pre-event measures:** Arrange 60MW post-event load shedding  
Arrange 5MW of post-event load shedding at Haywards
- Consequence:** Wellington regional load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	60	7.5	10,000	4.5	0.021	0.1	0.009
Load shedding - Haywards	5	7.5	10,000	0.375	0.021	0.19	0.001
HVDC trip	220		1250.00	0.275	0.021	0.2	0.0012
<b>TOTAL</b>							<b>0.011</b>

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (post-2012)***

- Post-2012:** Arrange to constrain 75MW HVDC post event. Average HVDC transfer above the constraint of 280 MW is 355MW for 1% of the time
- Pre-event measures:** Arrange 60MW post-event load shedding  
Arrange 5MW of post-event load shedding at Haywards
- Consequence:** Wellington regional load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	60	7.5	10,000	4.5	0.021	0.1	0.009
Load shedding - Haywards	5	7.5	10,000	0.375	0.021	0.19	0.001
HVDC constraint	75		1250.00	0.094	0.021	0.01	0.00002
<b>TOTAL</b>							<b>0.010</b>

**Event:** Loss of Haywards 110kV busbar sections A1 and A2      **Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW

HVDC Pole 1 out of service

No Wind Generation

Wellington load excluding Linton and Wilton is 648MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:** Loss of two of the three interconnecting transformers

Loss of reactive support

Loss of one 110kV Haywards – Takapu Road circuit

Loss of one 110kV Haywards – Melling circuit

Loss of one 110kV Haywards – Greyfield circuit

Loss of one 110kV Haywards – Upper Hutt circuit

Loss of one Haywards supply transformer

**Consequence:** Overloading/Tripping of the remaining interconnecting transformer at Haywards and subsequent loss of the Wellington regional load

Loss of Hayward load

**Constraint:** Load constraint limit of 242MW for Wellington region to avoid overloading of the remaining interconnecting transformer above its 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 81% of the time.

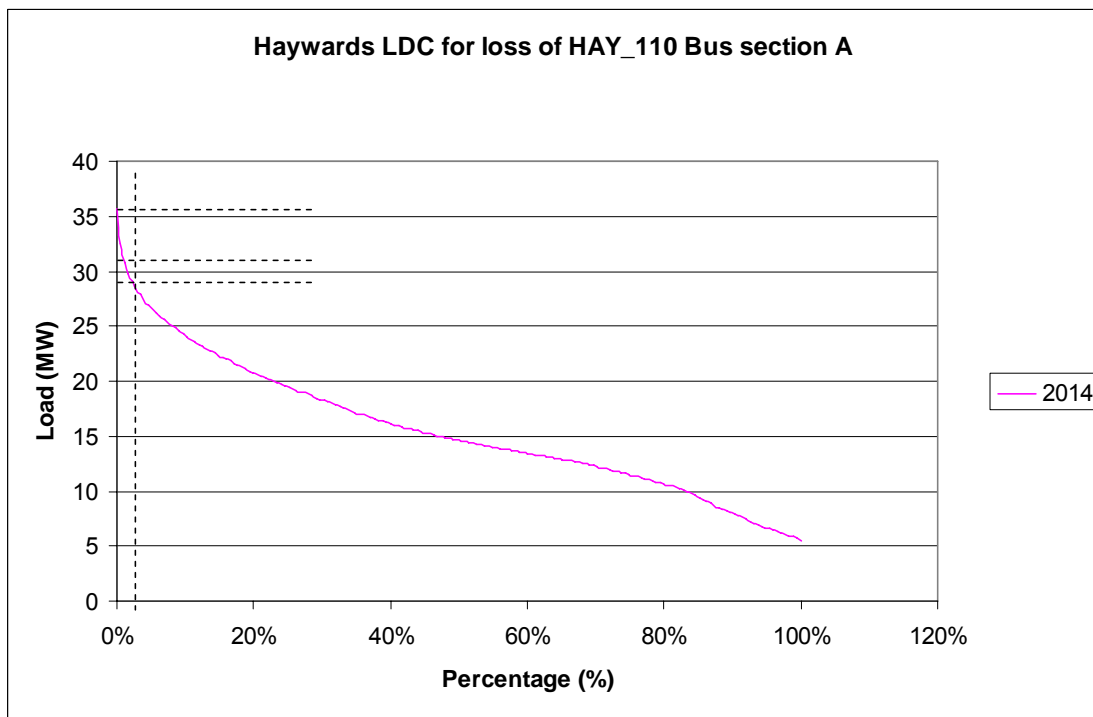
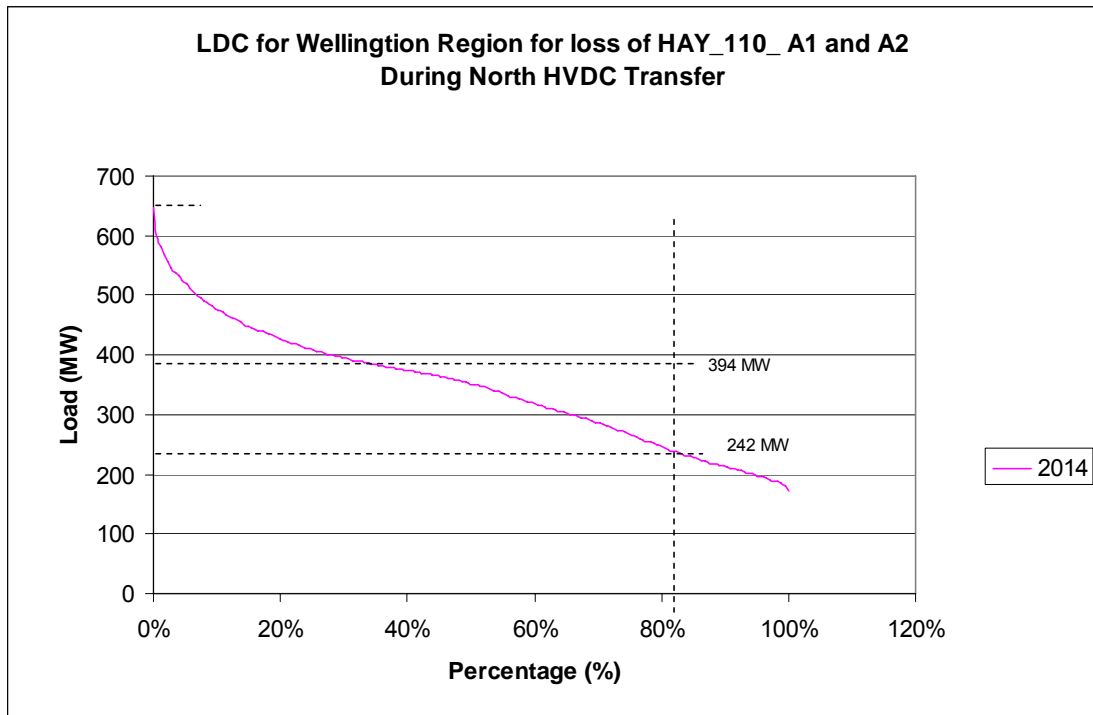
From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 242MW is 394MW.

Load constraint limit of 28MW for the Haywards load to avoid overloading of the remaining supply transformer.

For 2014, constraint is exceeded for 3% of the time.

From the LDC, the average value above the constraint limit of 28MW is 33MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	394	7.5	20,000	59.1	0.021	0.81	1.005



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 152MW of load constraint to avoid cascading failure of the remaining interconnecting transformer.

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Constrained load – regional	152	8760	10,000	N/A	N/A	0.81	10785.3
Constrained load- Haywards	5	8760	10,000	N/A	N/A	0.03	13.14
<b>TOTAL</b>							<b>10798.4</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 152MW of automatic post-event load shedding

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Load shedding – regional	152	7.5	10,000	11.4	0.021	0.81	0.194
Load shedding - Haywards	5	7.5	10,000	0.375	0.021	0.03	0.0002
<b>TOTAL</b>							<b>0.194</b>

**Event:** Loss of Haywards 110kV busbar sections A1 and A2      **Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Pre-event measures:** None

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW

HVDC Pole 1 out of service

Te Apiti Generation of 90MW to avoid overload of the 110kV Bunnythorpe – Woodville circuits

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:** Loss of two of the three interconnecting transformers

Loss of reactive support

Loss of one 110kV Haywards – Takapu Road circuit

Loss of one 110kV Haywards – Melling circuit

Loss of one 110kV Haywards – Greyfield circuit

Loss of one 110kV Haywards – Upper Hutt circuit

Loss of one Haywards supply transformer

**Consequence:** Overloading/Tripping of the remaining interconnecting transformer at Haywards and subsequent loss of the Wellington regional load, loss of Hayward load and loss of HVDC

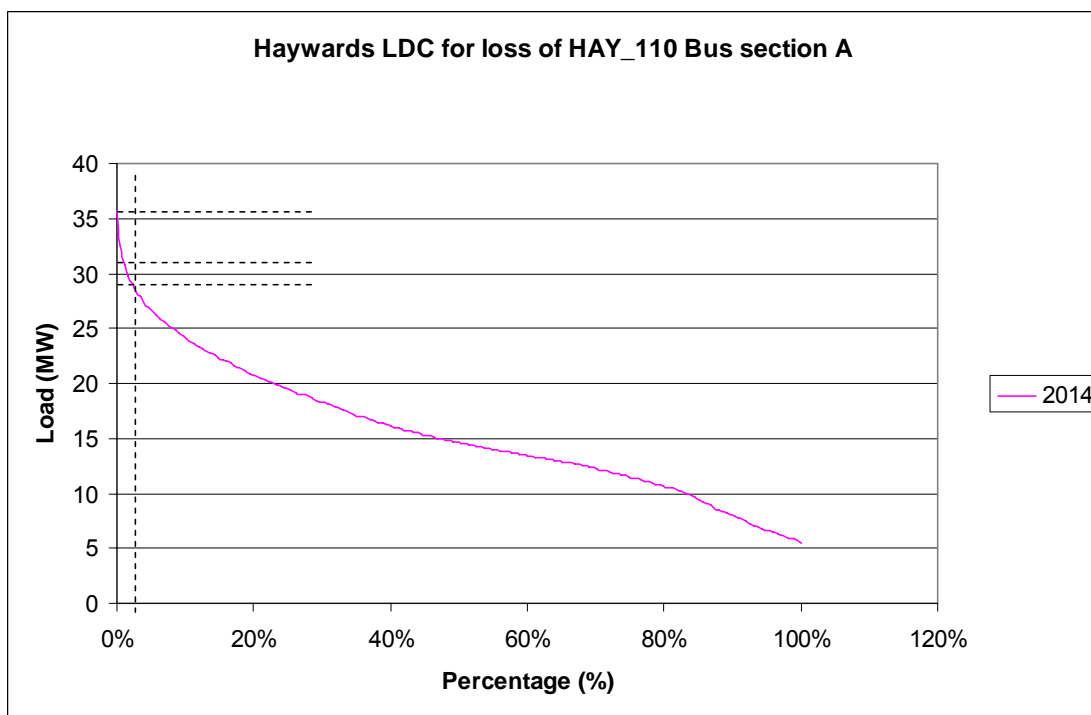
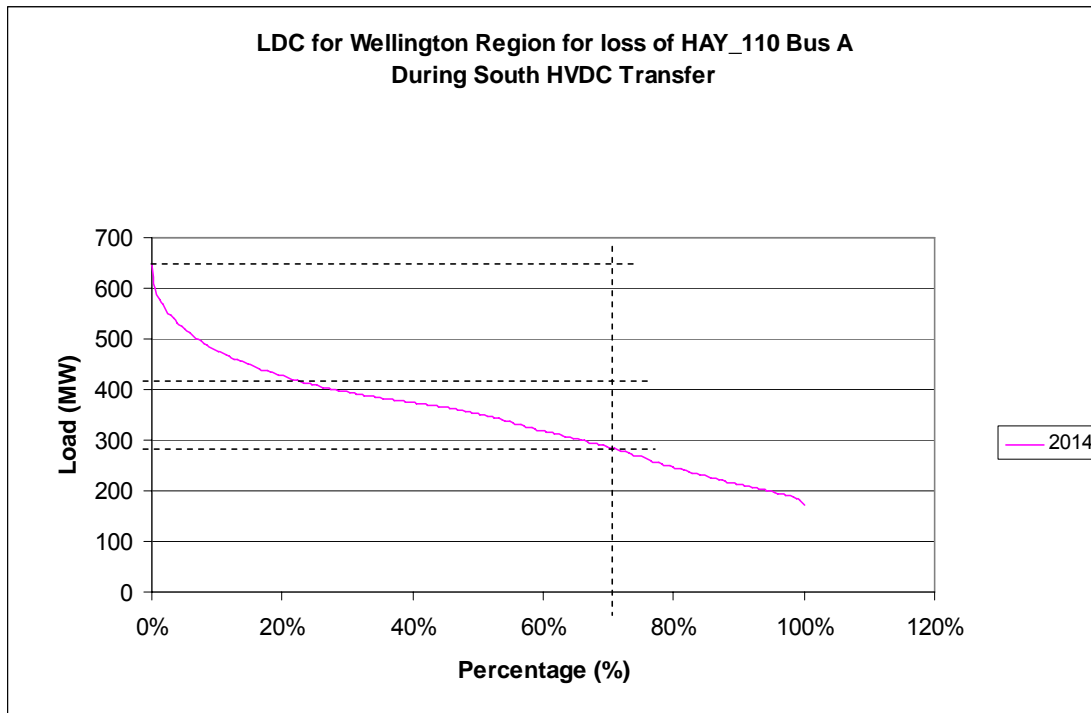
**Constraint:** Load constraint limit of 286MW for Wellington region to avoid overloading of the remaining interconnecting transformer above its 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 70% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 286MW is 412MW.

Load constraint limit of 28MW for the Haywards load to avoid overloading of the remaining supply transformer.

For 2014, constraint is exceeded for 3% of the time. From the LDC, the average value above the constraint limit of 28MW is 33MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	412	7.5	20,000	61.8	0.021	0.70	<b>0.908</b>
HVDC trip	220		1250.00	0.275	0.021	0.20	<b>0.0012</b>
<b>Total:</b>							<b>0.91</b>



**CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

**Pre-event measures:** Arrange 126MW of Wellington load constraint to avoid cascading failure of the remaining interconnecting transformer.

Arrange 5MW of load constraint at Haywards to avoid overloading the supply transformer

**Consequence:** Wellington regional load is secured for this event

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)***

**Pre-2012:** Trip the average of 220MW for HVDC South transfer post event

**Pre-event measures:** Arrange 126MW post-event load shedding

Arrange 5MW of post-event load shedding at Haywards

**Consequence:** Wellington regional load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	126	7.5	10,000	9.45	0.021	0.70	0.139
Load shedding - Haywards	5	7.5	10,000	0.375	0.021	0.03	0.0002
HVDC trip	220		1250.00	0.275	0.021	0.2	0.0012
<b>TOTAL</b>							<b>0.14</b>

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (post-2012)***

**Post-2012:** Arrange to constrain 75MW HVDC post event. Average HVDC transfer above the constraint of 280MW is 355MW for 1% of the time

**Pre-event measures:** Arrange 126MW post-event load shedding

Arrange 5MW of post-event load shedding at Haywards

**Consequence:** Wellington regional load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	126	7.5	10,000	9.45	0.021	0.70	0.139
Load shedding - Haywards	5	7.5	10,000	0.375	0.021	0.03	0.0002
HVDC constraint	75		1250.00	0.094	0.021	0.01	0.00002
<b>TOTAL</b>							<b>0.14</b>

**Event:** Loss of Haywards 110kV busbar section B

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

***SE Approach: Post-event unplanned load shedding***

**Pre-event measures:** None

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW

HVDC Pole 1 out of service

No Wind Generation

Wellington load excluding Linton is 648MW

Under these conditions, the Wilt on interconnector is overloading. For this study, the Wilton T8 is switched off.

**Post event:**

Loss of one of the three interconnecting transformers

Loss of reactive support

Loss of one 110kV Haywards – Takapu Road circuit

Loss of one 110kV Haywards – Melling circuit

Loss of one 110kV Haywards – Upper Hutt circuit

Loss of one 110kV Haywards – Greyfield circuit

Loss of one Haywards supply transformer

**Consequence:**

The remaining two interconnecting transformers at Haywards will overload and trip, losing a II Wellington region load. Low voltages in the Wellington region

**Constraint:**

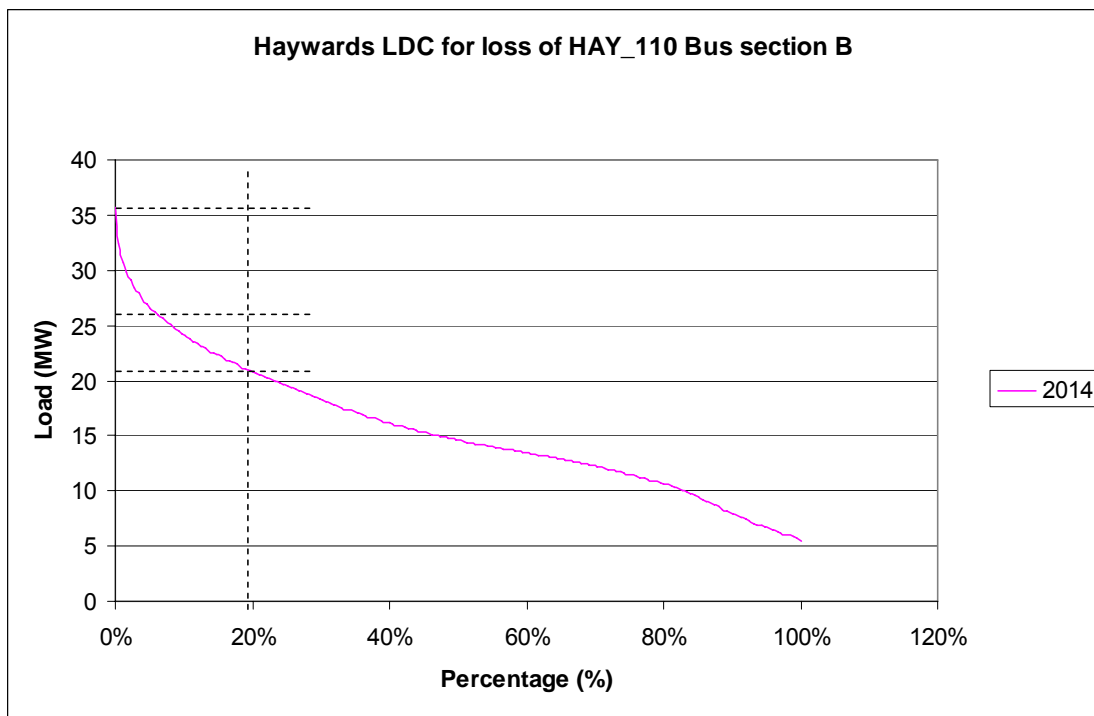
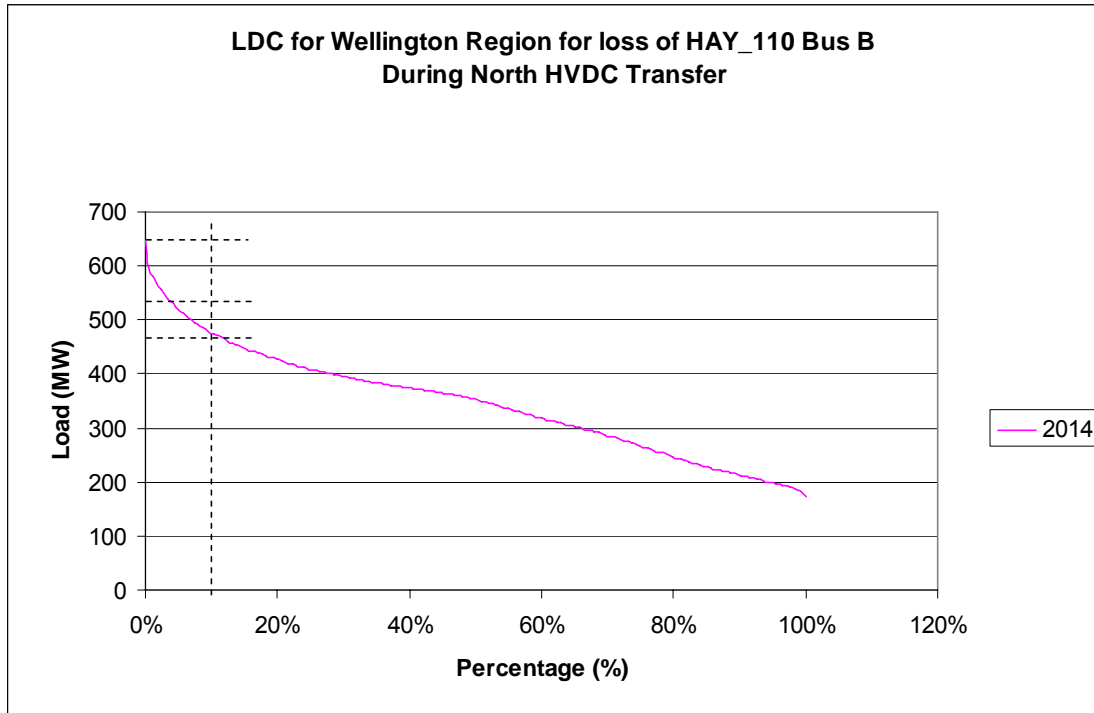
Load constraint of 473MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 10% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 473MW is 540MW.

Load constraint limit of 21MW for the Haywards load to avoid overloading of the remaining supply transformer.

For 2014, constraint is exceeded for 19% of the time. From the LDC, the average value above the constraint limit of 21MW is 26MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	540	7.5	20,000	81.00	0.021	0.10	<b>0.170</b>



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 67MW of load constraint

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Constrained load- regional	67	8760	10,000	N/A	N/A	0.10	586.92
Constrained load- Haywards	5	8760	10,000	N/A	N/A	0.19	83.22
<b>TOTAL</b>							<b>670.14</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 67MW of post-event load shedding

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Load shedding – regional	67	7.5	10,000	5.03	0.021	0.10	0.0106
Load shedding- Haywards	5	7.5	10,000	0.375	0.021	0.19	0.0015
<b>TOTAL</b>							<b>0.012</b>

**Event:** Loss of Haywards 220kV busbar section A

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW. HVDC Pole 1 out of service, No Wind Generation. Wellington load excluding Linton is 648MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

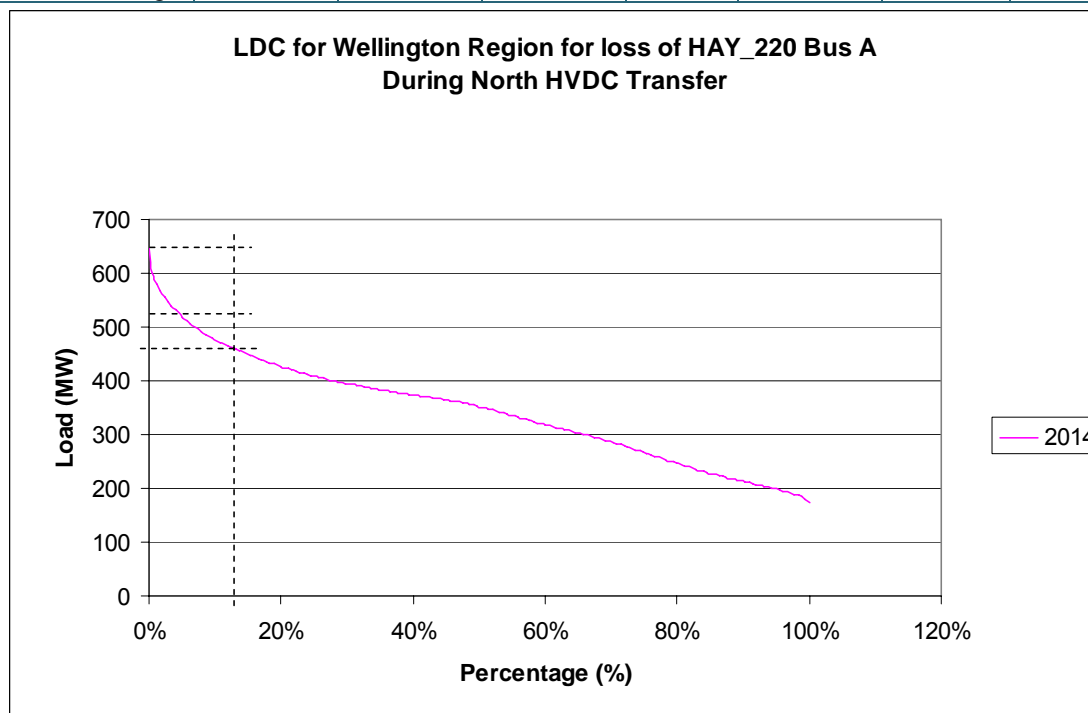
**Post event:** Loss of one interconnecting transformer. Loss of reactive support. and the 220kV Haywards-Wilton circuit

**Consequence:** Overloading/Tripping of the remaining two interconnecting transformers at Haywards. Loss of the Wellington regional load. Low voltages in the Wellington region

**Constraint:** Load constraint limit of 460MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 13% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 460MW is 525MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	525	7.5	20,000	78.75	0.021	0.13	<b>0.215</b>



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 65MW of load constraint to avoid cascading failure of the remaining two interconnecting transformers.

**Consequence:** Wellington region is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	65	8760	10,000	N/A	N/A	0.13	<b>740.2</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 78MW of post-event load shedding

**Consequence:** Wellington region is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	65	7.5	10,000	4.87	0.021	0.13	<b>0.013</b>

**Event:** Loss of Haywards 220kV bus section A

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:**

HVDC South Transfer on Pole 2 of 430MW

HVDC

Pole 1 out of service

No wind generation

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:**

Loss of one of the three interconnecting transformers

Loss of reactive support

Loss of the 220kV Haywards – Wilton circuit

**Consequence:**

Overloading/Tripping of the remaining two interconnecting transformers at Haywards

Loss of the Wellington regional load

Low voltages in the Wellington region

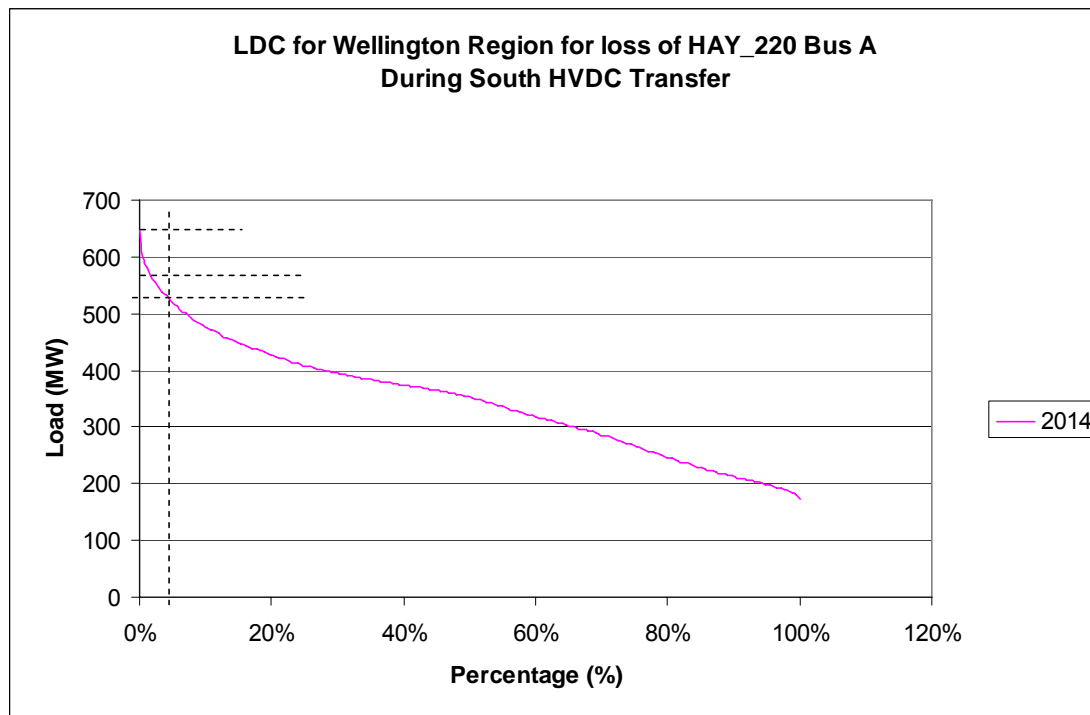
Voltage instability at the 220kV busbar causing the HVDC to trip

**Constraint:**

Load constraint limit of 525MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 5% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 525MW is 567MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	567	7.5	20,000	85.05	0.021	0.05	0.089
HVDC drop	220	N/A	1250.00	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>0.090</b>



**CE Approach : Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

**Pre-event measures:** Arrange 42MW of Wellington load constraint to avoid cascading failure of the remaining two interconnecting transformers.

**Consequence:** Wellington regional load secured for this event

**ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)**

**Pre-2012:** Trip the average of 220MW for HVDC South transfer post event

**Pre-event measures:** Arrange 42MW post-event load shedding

**Consequence:** Wellington regional load secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	42	7.5	10,000	3.15	0.021	0.05	0.003
Pre-2012 HVDC	220		1250.00	0.275	0.021	0.2	0.0012
<b>Total:</b>							<b>0.004</b>

***ECE Approach: Pre-arranged post event load shedding & Constrain back HVDC South transfer (post-2012)***

**Post-2012:** Arrange to constrain 75MW HVDC post event. Average HVDC transfer above the constraint of 280MW is 355MW for 1% of the time

**Pre-event measures:** Arrange 42MW post-event load shedding

**Consequence:** Wellington regional load secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	42	7.5	10,000	3.15	0.021	0.05	0.003
Post-2012 HVDC	75		1250	0.281	0.021	0.01	0.00002
<b>Total:</b>							<b>0.003</b>

**Event:** Loss of Haywards 220kV busbar section B

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW. HVDC Pole 1 out of service, No Wind Generation. Wellington load excluding Linton is 648 MW. Under these conditions, the Wilton interconnector is overloading. For this study, the Wilton T8 is switched off.

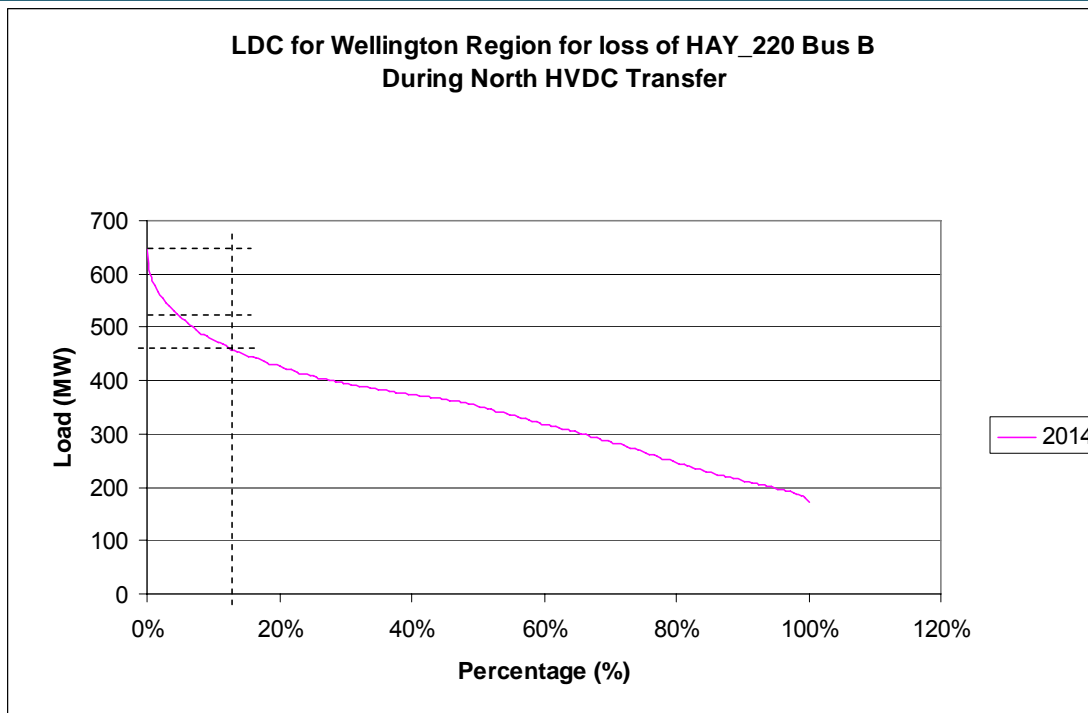
**Post event:** Loss of one interconnecting transformer. Loss of reactive support. Loss of both 220kV Bunnythorpe – Haywards circuits.

**Consequence:** The remaining two interconnecting transformers at Haywards will overload and trip, losing a 1/2 Wellington region load. Low voltages in the Wellington region

**Constraint:** Load constraint limit of 460MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 13% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 460MW is 525MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	525	7.5	20,000	89.7	0.021	0.13	<b>0.215</b>



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 65MW of load constraint

**Consequence:** Wellington region is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	65	8760	10,000	N/A	N/A	0.13	<b>740.2</b>

***ECE Approach: Pre-arranged post event load shedding***

**Pre-event measures:** Arrange 65MW of post-event load shedding

**Consequence:** Wellington regional load is secured

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	65	7.5	10,000	4.87	0.021	0.13	<b>0.013</b>

**Event:** Loss of Haywards 220kV busbar section B

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

***SE Approach: Post-event unplanned load shedding***

**Assumptions:**

HVDC

HVDC South Transfer on Pole 2 of 430MW

Pole 1 out of service

No wind Generation

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilton interconnector is overloading. For this study, the Wilton T8 is switched off.

**Post event:**

Loss of one of the three interconnecting transformers

Loss of reactive support

Loss of both 220kV Bunnythorpe – Haywards circuits

**Consequence:**

The remaining two interconnecting transformers at HAY will overload and trip, losing all Wellington region load.

Low voltages in the Wellington region

The 110kV Woodville – Mangamaire – Masterton circuit reaches its winter capability of 113MVA

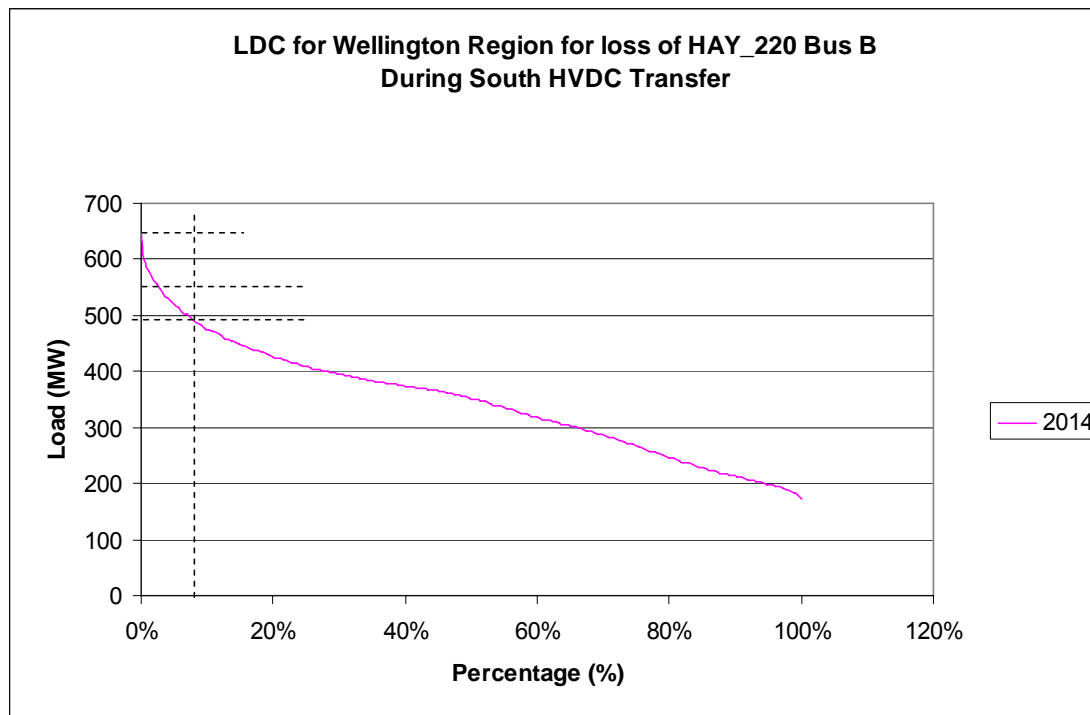
Voltage instability at the 220kV busbar causing the HVDC to trip

**Constraint:**

Load constraint limit of 494MW for Wellington region to avoid overloading of the 110kV Woodville – Mangamaire – Masterton circuit. The remaining two interconnecting transformers at Haywards are operating at their thermal capability

For 2014, the constraint is exceeded for 7% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 494MW is 556MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Post-event current costs	556	7.5	20,000	83.4	0.021	0.07	0.123
HVDC drop	220	N/A	1250.00	0.275	0.021	0.2	0.0012
<b>TOTAL</b>							<b>0.124</b>



**CE Approach : Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option

**Pre-event measures:** Arrange 62MW of Wellington load constraint

**Consequence:** Wellington regional load is secured

**ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)**

**Pre-2012:** Trip the average of 220 MW for HVDC South transfer post event.

**Pre-event measures:** Arrange 62MW of post-event load shedding

**Consequence:** Wellington regional load is secured

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	62	7.5	10,000	4.65	0.021	0.07	0.007
Pre-2012 HVDC	220		1250.00	0.275	0.021	0.2	0.001
<b>Total:</b>							<b>0.008</b>

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (post-2012)***

**Post-2012:** Arrange to constrain 105MW HVDC post event. Average HVDC transfer above the constraint of 220MW is 325MW for 1% of the time

**Pre-event measures:** Arrange 62MW of post-event load shedding

**Consequence:** Wellington regional load is secured

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	62	7.5	10,000	4.65	0.021	0.07	0.007
Post-2012 HVDC	105		1250.00	0.131	0.021	0.01	0.00002
<b>Total:</b>							<b>0.007</b>

**Event:** Loss of Haywards 220kV busbar section C

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW. HVDC Pole 1 out of service, No Wind Generation. Wellington load excluding Linton is 648 MW. Under these conditions, the Wilton interconnector is overloading. For this study, the Wilton T8 is switched off.

**Post event:** Loss of 660MW generation. Loss of one interconnecting transformer. Loss of reactive support. Loss of the 220 kV Haywards-Linton circuit.

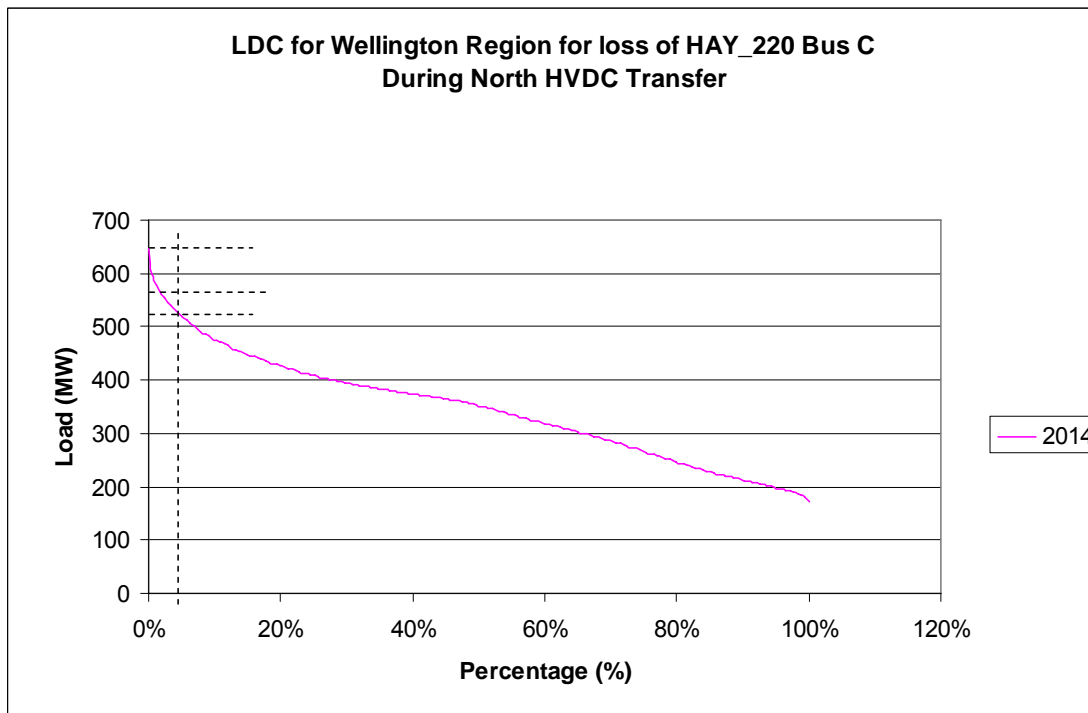
**Consequence:** Under frequency /Cascading failure

**Constraint:** Load constraint of 518MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 5% of the time.

From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 518MW is 567MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	567	7.5	20,000	85.05	0.021	0.05	<b>0.089</b>



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 49MW of load constraint

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-event load constraint	49	8760	10,000	N/A	N/A	0.05	<b>214.6</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 49MW of post-event load shedding

**Consequence:** Wellington load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	49	7.5	10,000	N/A	0.021	0.05	<b>0.004</b>

**Event:** Loss of Haywards 220kV busbar section C

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW. HVDC Pole 1 out of service. No wind Generation. Wellington load excluding Linton and Wilton is 583MW. Under these conditions, the Wilton interconnector is overloading. For this study, the Wilton T8 is switched off.

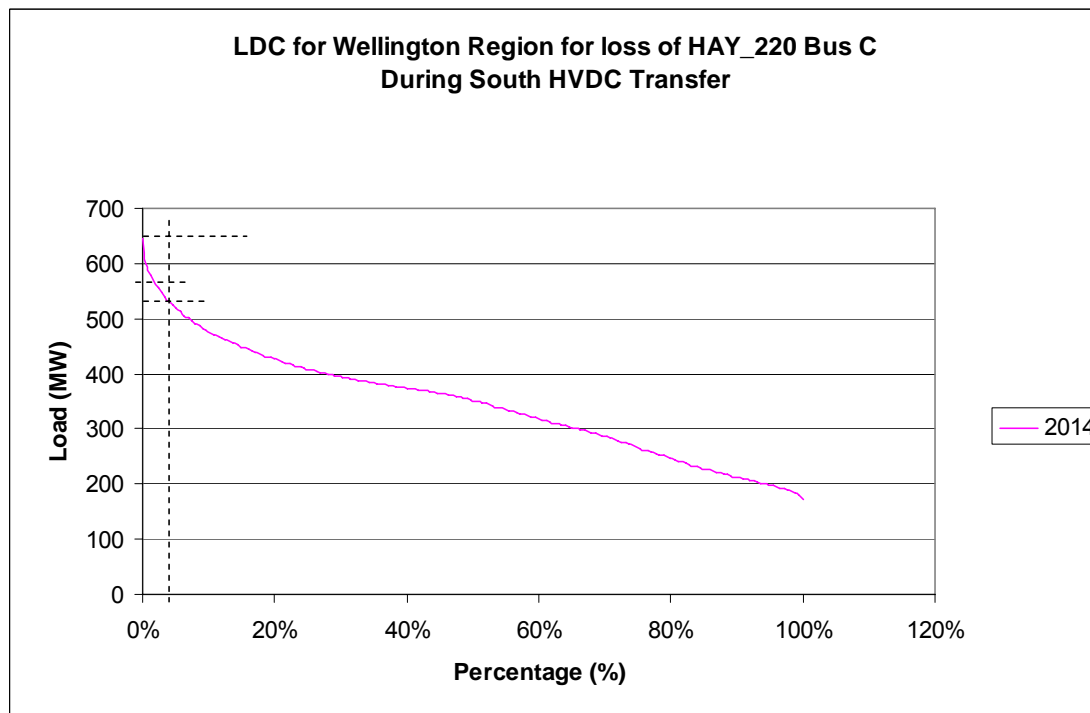
**Post event:** Loss of 430MW HVDC load. Loss of one interconnecting transformer. Loss of reactive support and Loss of the 220kV Haywards-Linton circuit

**Consequence:** Over frequency event

**Constraint:** Load constraint limit of 525MW for Wellington region to avoid overloading of the remaining two interconnecting transformers above their 24h post-contingency winter rating of 221MVA.

For 2014, the constraint is exceeded for 5% of the time. From the LDC for the Wellington region for 2014, the average value of the load above the constrained limit of 525MW is 567MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	567	7.5	20,000	85.05	0.021	0.05	0.089
HVDC drop	220	N/A	1250.00	0.275	0.021	0.20	0.0012
<b>TOTAL</b>							<b>0.090</b>



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 42MW of load constraint

**Consequence:** Wellington region is secured for this event

***ECE Approach: Pre-arranged post event load shedding***

**Pre-event measures:** Arrange 42MW of post-event load shedding

**Consequence:** Wellington region is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Planned load shedding	42	7.5	10,000	N/A	0.021	0.05	<b>0.003</b>

**Event:** Loss of Takapu Road 110kV busbar section 1 or 2 **Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC North Transfer on Pole 2 of 660MW. HVDC Pole 1 out of service. No Wind Generation. Wellington load excluding Linton is 648 MW. Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:** Loss of one 110kV Haywards-Takapu Road circuit. Loss of one 110kV Takapu Road-Wilton circuit. Loss of one 110kV Takapu Road-Pautahanui circuit. Loss of a supply transformer at Takapu Road.

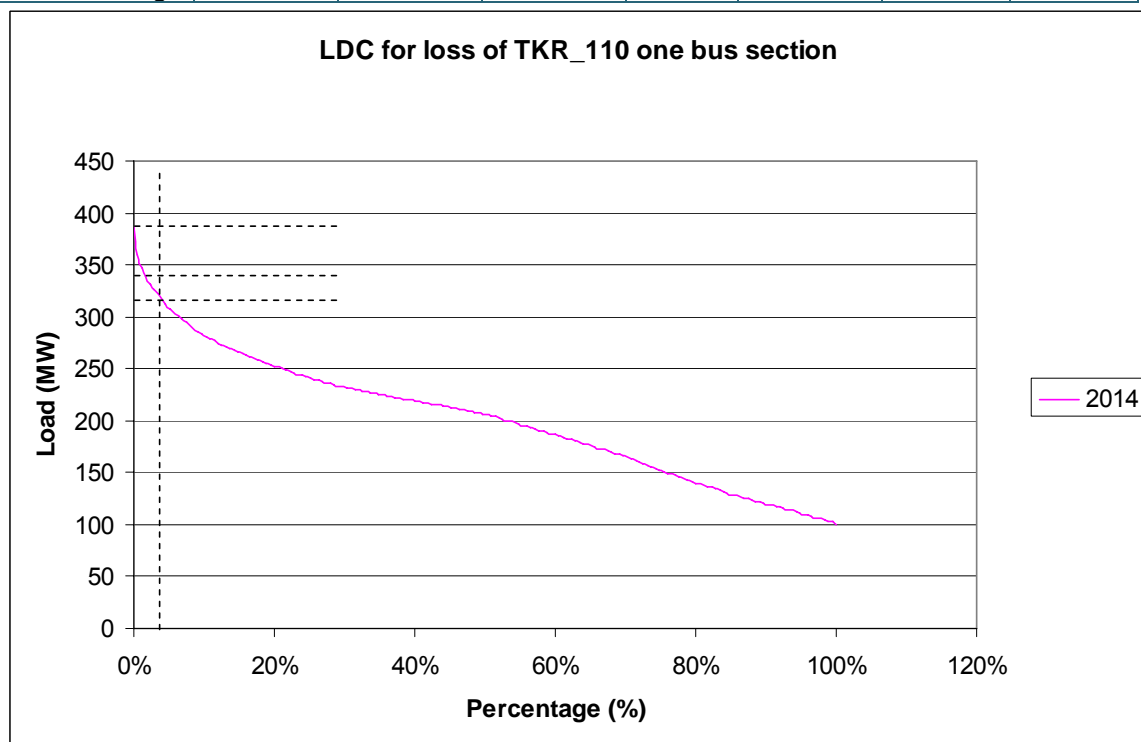
**Consequence:** Low voltages in the Wellington region

**Constraint:** Constrain the combined load of Central Park, Kaiwharawhara, Pauatahanui, Paraparaumu and Takapu Road to 309MW to avoid voltage collapse and/or low voltages at the respective GXPs.

For 2014, the constraint is exceeded for 5% of the time.

From the LDC for these GXPs for 2014, the average value of the load above the constrained limit of 309MW is 339MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	339	7.5	20,000	50.85	0.021	0.05	<b>0.053</b>



**CE Approach: Pre-event security constraints**

**Pre-event measures:** Arrange 30MW of load constraint to avoid low voltages in the region and/or voltage collapse

**Consequence:** Local load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Constrained load	30	8760	10,000	N/A	N/A	0.05	<b>131.4</b>

**ECE Approach: Pre-arranged post event load shedding**

**Pre-event measures:** Arrange 30MW post-event load shedding

**Consequence:** Local load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Load shedding	30	7.5	10,000	2.25	0.021	0.05	<b>0.002</b>

**Event:** Loss of Takapu Road 110kV busbar section 1 or 2 **Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach:** *Post-event unplanned load shedding*

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW. HVDC Pole 1 out of service. Te Api ti Generation of 90MW to avoid overload of the 110kV Bunnythorpe-Woodville circuit. Wellington load excluding Linton is 583MW. Under these conditions, the Wilton interconnect or T8 is overloading and is switched off.

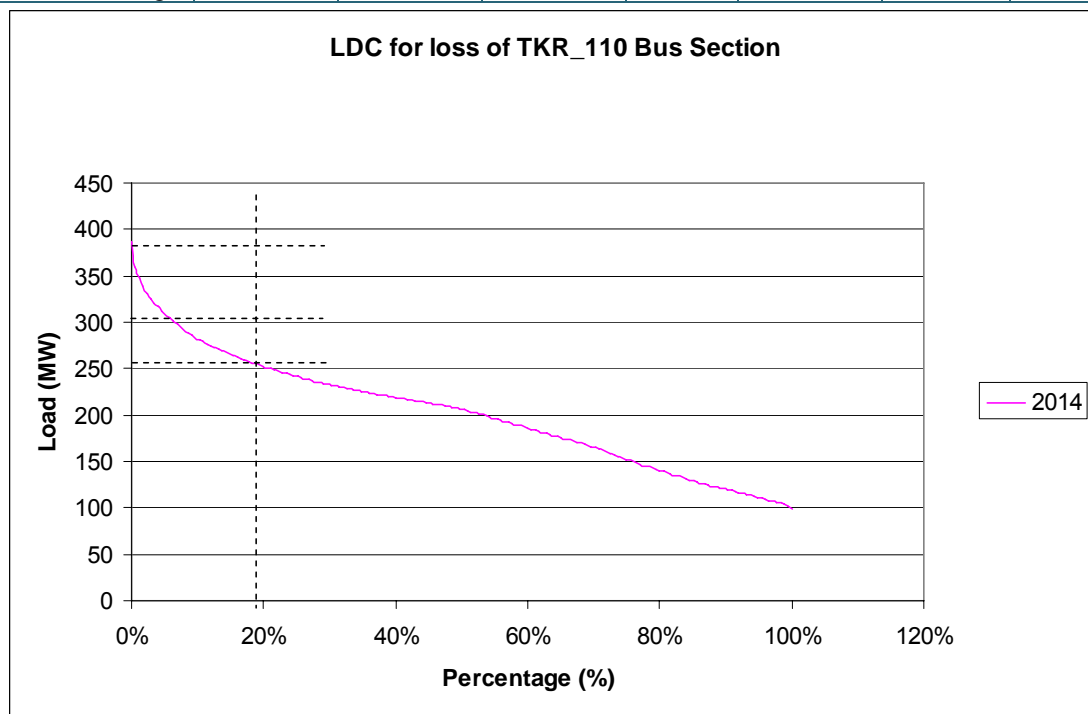
**Post event:** Loss of one 110kV Haywards-Takapu Road circuit. Loss of one 110kV Takapu Road-Wilton circuit. Loss of one 110kV Takapu Road-Pautahanui circuit. Loss of a supply transformer at Takapu Road.

**Consequence:** Low voltages in the Wellington region

**Constraint:** Constrain the combined load of Central Park, Kaiwharawhara, Pauatahanui, Paraparaumu and Takapu Road to 255MW to avoid voltage collapse and/or low voltages at the respective GXPs.

For 2014, the constraint is exceeded for 19 % of the time. From the LDC for these GXPs for 2014, the average value of the load above the constrained limit of 255MW is 301MW.

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Unplanned load shedding	301	7.5	20,000	45.15	0.021	0.19	<b>0.180</b>



***CE Approach: Pre-event security constraints***

**Pre-event measures:** Arrange 46MW of load constraint to avoid low voltages in the region and/or voltage collapse

**Consequence:** Local load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Constrained load	46	8760	10,000	N/A	N/A	0.19	<b>756.6</b>

***ECE Approach: Pre-arranged post event load shedding***

**Pre-event measures:** Arrange 46MW of post-event load shedding

**Consequence:** Local load is secured for this event

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Load shedding	46	7.5	10,000	3.45	0.021	0.19	<b>0.014</b>

**Event:** Loss of Wilton 220kV busbar section A

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

***SE Approach: Post-event unplanned load shedding***

**Pre-event measures:** None

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW

HVDC Pole 1 out of service

Te Apiti generation of 90MW to avoid overloading the Bunnythorpe – Woodville – 110 circuits

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:** Loss of the 220kV Bunnythorpe – Wilton circuit

Loss of a supply transformer

**Consequence:** Voltage instability at the 220kV busbar causing the HVDC to trip

**Constraint:** Trip HVDC or reduce the South transfer by 100MW to avoid voltage instability

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC drop	220	N/A	1250.00	0.275	0.021	0.2	<b>0.0012</b>

***CE Approach : Pre-event security constraints***

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)***

**Pre-2012:** Trip the average of 220MW for HVDC South transfer post event

**Consequence:** Voltage levels on the 220kV network are stable

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-2012 HVDC	220		1250.00	0.275	0.021	0.2	<b>0.0012</b>

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (post-2012)***

**Post-2012:** Arrange to constrain 55MW HVDC post event. Average HVDC transfer above the constraint of 330MW is 380MW for 1% of the time

**Consequence:** Voltage levels on the 220kV network are stable

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Post-2012 HVDC	50		1250	0.063	0.021	0.01	<b>0.00001</b>

**Event:** Loss of Wilton 220kV busbar section B

**Region:** Wellington

**Event Risk Factor:** 0.021

**Average Duration:** 7.5h

**SE Approach: Post-event unplanned load shedding**

**Pre-event measures:** None

**Assumptions:** HVDC South Transfer on Pole 2 of 430MW

HVDC Pole 1 out of service

Te Apiti generation of 90MW to avoid overloading the Bunnythorpe – Woodville – 110 circuits

Wellington load excluding Linton and Wilton is 583MW

Under these conditions, the Wilton interconnector T8 is overloading and is switched off.

**Post event:** Loss of the 220kV Haywards – Wilton circuit

Loss of a supply transformer

**Consequence:** Low voltages in the 220 busbars in Wellington region

**Constraint:** Trip HVDC or reduce the South transfer by 100MW to avoid voltage instability

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
HVDC drop	220	N/A	1250.00	0.275	0.021	0.2	<b>0.0012</b>

**CE Approach: Pre-event security constraints**

The application of a pre-event security constraint on HVDC south transfer as a management measure for treatment as a Contingent Event is not considered to be an economic option.

**ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (pre-2012)**

**Pre-2012:** Trip the average of 220MW for HVDC South transfer post event

**Consequence:** Voltage levels on the 220kV network are stable

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Pre-2012 HVDC	220		1250.00	0.275	0.021	0.2	<b>0.0012</b>

***ECE Approach: Pre-arranged post event load shedding & constrain back HVDC South transfer (post-2012)***

**Post-2012:** Arrange to constrain 55MW HVDC post event. Average HVDC transfer above the constraint of 330MW is 380MW for 1% of the time

**Consequence:** Voltage levels on the 220kV network are stable

Event Measure	Average Load (MW)	Duration (h)	Unit Cost (\$/MWh)	Event Cost (\$m)	Event Risk Factor	Load Risk Factor	Annual Cost (\$m)
Post-2012 HVDC	50		1250	0.063	0.021	0.01	<b>0.00001</b>