Transient Rotor Angle Stability – Additional Studies

System Security Forecast 2025

Version: 1.2

Date: August 2025

IMPORTANT

Disclaimer

Copyright

Contact Details

Address:	Transpower New Zealand Ltd Waikoukou 22 Boulcott Street PO Box 1021 Wellington New Zealand
Telephone:	+64 4 495 7000
Email:	system.operator@transpower.co.nz
Website:	www.transpower.co.nz

Contents

1 Executive Summary

As System Operator, we have a crucial role in identifying and managing new system risks. Part of this role involves undertaking a System Security Forecast (SSF) every two years. In our 2024 SSF we included a Transient Rotor Angle Stability (TRAS) Study which assessed system stability across both North and South Islands for the first time. This focused on assessing system stability based on the network conditions at the time and provided an initial screening to identify potential risks across the full system.

Based on the findings of this initial 2024 study, we signalled further studies and coordination were required. We also emphasised the need for accurate, validated generator dynamic models.

This report provides updates for future committed generation projects and additional studies covering a wider set of scenarios. In particular, the studies include:

- the effect of future committed generation projects on TRAS;
- the influence of increasing levels of IBRs on TRAS, particularly during periods of low system inertia.
- the impact of updated Ngāwha B (NGB) dynamic model. Following our last study, Top Energy provided updated parameters for the NGB generator model.

Key findings – North Island

Our studies show one new stability issue associated with Tauhara B and Te Huka C for one scenario when generator terminal voltages are low. These studies were conducted using pre-validation models of the two stations. We will repeat the analysis when we have fully validated models

Two stability issues identified in the December 20204 report for NGB and Te Ai O Maui (TAM) showed improvements.

Te Ahi o Māui (TAM) failed to maintain synchronism during faults on the local 110 kV circuits while connected to the Kawerau 110 kV bus in the December 2024 report. However, once TAM is relocated to the Kawerau 220 kV bus in the future, this generator remained stable.

The updated dynamic model parameters for the Ngāwha B (NGB) generator showed notable improvements in transient stability performance. However, the critical clearing time (CCT) remained lower than the design fault clearance time for some 110 kV circuit faults.

Otherwise, stability issues for smaller generators were reconfirmed, this underlines the importance of generators protecting their equipment from potential 'pole slipping'.

Key findings – South Island

The future addition of Kaiwera Downs 2 (KWE) generation increases the stability issues for Manapouri (MAN), that we reported in our December 2024 studies. The issues are influenced by generation output (both MAN and KWE), load modelling as this affects impedance, and voltage setpoints.

Conclusions and next steps

The results underline the importance of accurate dynamic models and connections studies for generators to accurately identify transient stability risks. The identification of these risks, in the event of severe disturbances, also raises the importance of pole-slip protection for synchronous generators to avoid potential damage to equipment. As System Operator, we will continue to emphasise these two points with asset owners.

Given the studies have identified potential transient stability issues, the System Operator is investigating the following mitigations:

- Operationalising real time monitoring of TRAS, focusing on where we are seeing issues.
- Investigating real time mitigations (such as managing voltage setpoints is real time and constraining generation)
- Considering adjusting existing constraints or designing new market constraints
- For Manapouri, where stability issues are dependent on load behaviour, investigate and determine an appropriate load model.

2 Introduction

As System Operator, we have a crucial role in identifying and managing new system risks. Part of this role involves undertaking a System Security Forecast (SSF) every two years. In our 2024 SSF we included a Transient Rotor Angle Stability (TRAS) Study which assessed system stability across both North and South Islands for the first time. This focused on assessing system stability based on the network conditions at the time and provided an initial screening to identify potential risks across the full system.

Based on the findings of this initial 2024 study, we signalled further studies and coordination were required. We also emphasised the need for accurate, validated generator dynamic models.

This report provides updates for future committed generation projects and additional studies covering a wider set of scenarios. In particular, the studies include:

- the effect of future committed generation projects on TRAS;
- the influence of increasing levels of IBRs on TRAS, particularly during periods of low system inertia;
- the impact of updated Ngāwha B (NGB) dynamic model. Following our last study, Top Energy provided updated parameters for the NGB generator model.

To support this analysis, we selected real operating snapshots from January 2024 to May 2025, capturing critical low-inertia periods such as summer and winter peaks, day troughs and night troughs. These scenarios help provide a more realistic understanding of evolving TRAS risks in a transitioning power system.

2.1 What is Transient Rotor Angle Stability?

Transient rotor angle stability (TRAS) is a synchronous machine's ability to remain synchronised under normal operating conditions and to regain synchronism after a disturbance. TRAS is critical for the System Operator to ensure the stable operation of the grid. Loss of synchronism–sometimes referred to as "out of step" or "pole slipping" for synchronised machines–can lead to damage to the synchronous generators. Further, it could lead to power system instability, voltage fluctuation and loss of other generators.

The key factors that impact TRAS are:

- **The severity of disturbance**: the most important factor for TRAS is usually the type and duration of a system fault, since that affects the resulting protection operation. Another important factor is the specific equipment that disconnects, as it impacts whether the synchronous generation will return to stable operation after the fault or not.
- **The power system topology, or more specifically, its impedance**: in general, the chance of TRAS issues increases the further generators are from demand or other generators. In addition, the outage of some assets often increases the system's impedance, and with that, further risks appear.
- **The loading of generators**: a generator operating close to its maximum real power output is usually more likely to fail to regain synchronism following a disturbance. In addition, the

operation of generation-absorbing reactive power (under-excited) significantly increases the risk of instability after a disturbance.

- **The local strength of the network**: strength is determined by a combination of mechanical, electrical and control factors, such as the dispatched generators' inertia and fault current contribution, transmission interconnection, load characteristics, and nearby reactive power support

2.2 Overview of Committed Generation and Grid Upgrade Projects

For these studies we have included committed generation and grid upgrades projects.

Table 2-1 and Table 2-2 outline the committed projects for the North and South Islands respectively between January 2025 and May 2027. This is the same study horizon used in the SSF N-1 thermal and voltage stability study. Similarly, Table 2-3 summarises the grid upgrade projects.

Table 2-1: Summary of committed generation projects in North Island

Generation Asset	Region	Type	Operating Capacity (MW)	Grid Injection Point	Commissioning Date
Edgecumbe Solar Far North	Edgecumbe	Solar	28.7	EDG	Sep-25
Karapiro upgrade (Capacity Increase)	Hamilton	Hydro	112	KPO	Aug-25
Pukenui Solar	Northland	Solar	23.7	KOE	Commissioned
Ruakaka BESS	Northland	BESS	100	BRB	Commissioned
Whitianga Solar	Hamilton	Solar	23.75	KPU	Oct-25
Glenbrook BESS	Auckland	BESS	100	GLN	Oct-25
Taiohi Solar	Hamilton	Solar	22.4	HLY	Sep-25
Twin Rivers Solar	Northland	Solar	24	KOE	Aug-25
Golden Stairs Solar	Northland	Solar	17.6	MTO	Sep-25
Huntly BESS	Hamilton	BESS	100	HLY	Aug-26
Tauhei Solar	Hamilton	Solar	150	WHU	Apr-26
Kawerau TOPP2	Edgecumbe	Geothermal	55	KAW	Oct-25
Kawerau Te Ahi o maui (TAM)*	Edgecumbe	Geothermal	-	KAW	Oct-25
Kaiwaikawe Wind Plant	Northland	Wind	70	KTA	Dec-26
Ngatamariki G5	Edgecumbe	Geothermal	54	NTM	Nov-25

** This project transfers the TAM generator from the Kawerau 110 kV bus to the Kawerau 220 kV bus with TOPP2.*

Table 2-2: Summary of committed generation projects in the South Island

Generation Asset	Region	Type	Operating Capacity (MW)	Grid Injection Point	Commissioning Date
KWD stage 2 (KWE)	Southland	Wind	152	KIW (Kaiwera)**	July-26

***New Grid Injection Point*

Table 2-3: Committed grid upgrade projects

Asset	Changes	Commissioning Date	Grid Zone
BRK New Supply Transformer	New Supply Transformer (TF)	Dec-27	6
HWA ODID	Improve the supply TF ratings	May-25	6
MTN ODID	Improve the supply TF ratings	Jul-26	7
KIN TF 8/ KIN-11-T5 out of Service	KIN load reduction	Jul-25	4
TMI T1 Replacement	T1 capacity increased from 30 to 80 MVA	Oct-25	4
WRD T9 Second Transformer	New Interconnecting Transformer	Sep-26	1
WRK Supply TF T29 and T30 Capacity Upgrade	Capacity increased from 50 MVA to 60 MVA	Sep-25	4
NZGP Stage 1 (CCT Upgrades)	Capacity upgrades of 220 kV circuits	By Jun-27	NA

NZGP Stage 1 will increase the current carrying capacity of a few 220 kV circuits detailed in Appendix A: Grid Configuration. This will help to manage the N-1 thermal limits during the peak conditions. None of the other projects have changed either 220 kV or 110 kV network topology significantly and hence have not been considered in this study.

3 Study Considerations

To maintain consistency and comparability, the additional studies in this report use the same stability assessment process and key assumptions as the Transient Rotor Angle Stability Study report published in December 2024. A summary is provided in the sections below.

3.1 Study Assumptions

Our study included several key baseline assumptions:

- The network was intact except during specific outage scenarios.
- We modelled faults as three-phase balanced faults with zero impedance on 110 kV and 220 kV circuits, Appendix 1.
- The fault clearance times were 120 ms for 220 kV and 200 ms for 110 kV circuits in accordance with the Electricity Industry Participation Code 2010, Part 12 Transport, Schedule 12.6, Appendix B, Table B4.
- We did not consider any auto-reclosure of faults.
- We used load models with 60% constant current and 40% constant impedance for both real and reactive power consumption.

3.2 Modelling of Power System Components

This study adhered to the following modelling principles:

- Generators were represented either by validated generator models or standard generator models with typical parameters.
- Voltage control models consisted either of validated AVR/PSS models or standard AVR/PSS models with typical parameters.
- Governor models were represented either by validated governor models or standard governor models with typical parameters.
- Class 4 wind turbines were represented by generic WECC models.
- Solar plants were represented by standard WECC models.
- Other wind and flexible AC transmission systems (FACTS) were either validated or standard models.

3.3 Study Cases

Transient stability is influenced by the operational state of the system, including demand and generation dispatch. To ensure the study captures a wide range of possible stability conditions, we selected representative system snapshots that reflected different seasonal and daily load variations.

We considered the following demand and dispatch scenarios:

- Winter peak and winter night trough load conditions

- Summer peak and summer night trough load conditions
- Summer day trough load conditions.

Of the 15 committed generation projects in the North Island, 11 are inverter-based, reflecting a significant shift in the generation mix towards non-synchronous resources. To better understand the impact of this change, we included study scenarios where these future committed projects were dispatched to higher output levels. This allowed us to specifically assess how increased IBR penetration could affect transient rotor angle stability.

In addition, with seven of these projects being solar, we included a summer day trough scenario to capture the system's response during periods of high solar generation and low demand. Since most of the future committed projects are solar-based, summer day trough conditions characterised by high solar generation and low demand could represent one of the most challenging scenarios for transient stability.

Unlike synchronous generators, IBRs do not naturally contribute to system inertia or offer the same fault response characteristics. Thus, we focused on the operational scenarios that reflected low system inertia combined with high inverter-based generation. To this end, we screened the real-time archived snapshots between January 2024 and May 2025 to select the most suitable study cases.

We obtained system inertia values for the above period from online TSAT results, calculated based on the generators online at the time of each snapshot. The inertia data showed that North Island system inertia ranged from 12,861 MW·s to 24,696 MW·s during winter, and from 9,100 MW·s to 21,117 MW·s during summer. During the period of Jan 24-May 25, wind generation contribution ranged from 0% to 80% and solar from 0% to 5%. However, with no impact from solar generation during peak and night trough conditions, only wind generation was considered during the screening process. We observed that system inertia varied widely, regardless of the level of wind generation present, thus no clear correlation was found between system inertia values and the level of wind generation. Consequently, there was no straightforward way to select study cases that simultaneously satisfied both conditions. After thoroughly reviewing the available data, we selected five study cases using two main criteria: high wind generation penetration and low overall system inertia. These conditions were considered critical for assessing the transient stability of the system. Table 3-1 outlines the selected study cases from the real-time operation scenarios and their features.

Table 3-1: Selected study cases from real-time operation scenarios

Study Case #	Study Case	Features
North Island		
1	Winter Night Trough High Wind-2024 (WNT-TRAS 2024)	Wind contribution is around 80% of NI wind capacity. HVDC South Flow is 460 MW.
2	Summer Night Trough, Low Wind-2024 (SNT-TRAS 2024)	Wind contribution is around 0.2% of NI wind capacity. HVDC South Flow is 520 MW.
3	Winter Night Peak High Wind - 2024 (WNP-TRAS 2024)	Wind contribution is around 75% of NI wind capacity. HVDC North Flow is 680 MW.
4	Winter Night Peak (WNP)	Wind contribution is around 65% and inertia of the system is 16,962 MW·s. HVDC North Flow is 80MW.
5	Summer Night Peak (SNP)	Wind contribution is around 65% and inertia of the system is 13,147 MW·s. HVDC North Flow is 670MW.

Study Case #	Study Case	Features
6	Winter Night Trough (WNT)	Wind contribution is around 60% and inertia of the system is 13,437 MW·s. HVDC North Flow is 380MW.
7	Summer Night Trough (SNT)	Wind contribution is around 72% and inertia of the system is 11,980 MW·s. HVDC South Flow is 225MW.
8	Summer Day Trough (SDT)	Wind contribution is around 67% and solar contribution is 80% (405 MW) inertia of the system is 12,558 MW·s. HVDC North Flow is 594MW.
South Island		
9	Winter Peak (TRAS 2024)	Manapouri generation-750 MW, HVDC North Flow is 620 MW.
10	Winter Night Trough (TRAS 2024)	Manapouri generation-750 MW, HVDC South Flow is 200 MW.

Study cases 1 to 3 were selected from the TRAS study report released in December 2024 to assess the impact of the updated generator parameters of Ngāwha B (NGB).

Study cases 4 to 8 were selected to assess the impact of future committed projects and the increasing penetration of inverter-based generation. These study cases were modified for analysis as outlined in the Table 3-2 below.

Study cases 9 to 10 were selected from the transient rotor angle stability study report released in December 2024 to assess the impact of the Kaiwera Downs Stage 2 wind plant on Lower South Island transient stability.

3.4 Study Case Preparation

According to Table 2-1, all committed projects will be commissioned by summer 2026, so we limited our study to winter and summer 2026. Study cases 4-10 were modified by applying the 2026 seasonal load forecast and incorporating all committed projects. Any increase in demand relative to the original cases was balanced by generation from these new committed projects.

For both winter and summer night trough and peak scenarios, we did not consider solar generation. The increased load was fully supplied by the (non-solar) committed projects in night trough scenarios. In contrast, under peak demand scenarios, generation from the committed projects excluding solar alone was insufficient to meet the higher load. To manage the shortfall, we adjusted output from already dispatched synchronous generators and modified the HVDC flow, while avoiding the dispatch of additional existing synchronous machines to prevent altering the overall inertia of the system.

The summer day trough study case is ideal for analysing the impact of high inverter-based generation composed of 400 MW from Solar and 793 MW (70%) from wind generation with the committed projects. In this case we saw excessive generation after catering for the increased load. Surplus generation could be used to replace high-cost generation. However, as no high-cost thermal generation was dispatched in this case, the existing dispatch scenario was maintained. Therefore, the remaining surplus was managed by constraining the HVDC northward flow by 202 MW.

In study cases 9 and 10, any increase in demand relative to the original cases was balanced by generation from the Kaiwera Downs Stage 2. In addition, we adjusted output from already dispatched synchronous generators during peak conditions to manage the shortfall. Table 3-2 shows the modified study cases used for transient studies.

Table 3-2: Modified study cases used for the transient studies

Study Case #	Study Case	Features
North Island		
1	Winter Night Trough High Wind-2024 (WNT-TRAS 2024)	No change
2	Summer Night Trough, Low Wind-2024 (SNT-TRAS 2024)	No change
3	Winter Night Peak High Wind - 2024 (WNP-TRAS 2024)	No change
4	Winter Night Peak (WNP)	Wind contribution is around 70% and HVDC North Flow is 344 MW.
5	Summer Night Peak (SNP)	Wind contribution is around 70% and HVDC North Flow is 614 MW.
6	Winter Night Trough (WNT)	Wind contribution is around 70% and HVDC North Flow is 493 MW.
7	Summer Night Trough (SNT)	Wind contribution is around 70% and HVDC South Flow is 200 MW.
8	Summer Day Trough (SDT)	Wind contribution is around 70% and Solar contribution is 80% (405 MW). HVDC North Flow is 392 MW.
South Island		
9	Winter Peak (TRAS 2024)	Wind contribution from Kaiwera Downs Stage 2 is 75% and HVDC North flow is 620 MW.
10	Winter Night Trough (TRAS 2024)	Wind contribution from Kaiwera Downs Stage 2 is 75% and HVDC south flow is 260 MW.

4 Additional North Island Studies

4.1 Impact of NGB Generator Model Parameter Update

The 2024 TRAS study showed that NGB was unstable for certain 110 kV contingencies when the critical clearance time (CCT) was less than 200 ms. We have selected three study cases from TRAS 2024 – winter night trough (WNT), summer night trough (SNT) and winter night peak (WNP) – to analyse the impact of updated parameters. Figure 4-1 illustrates how the CCT values improved with the updated generator parameters. See Appendix 1 for contingency numbers.

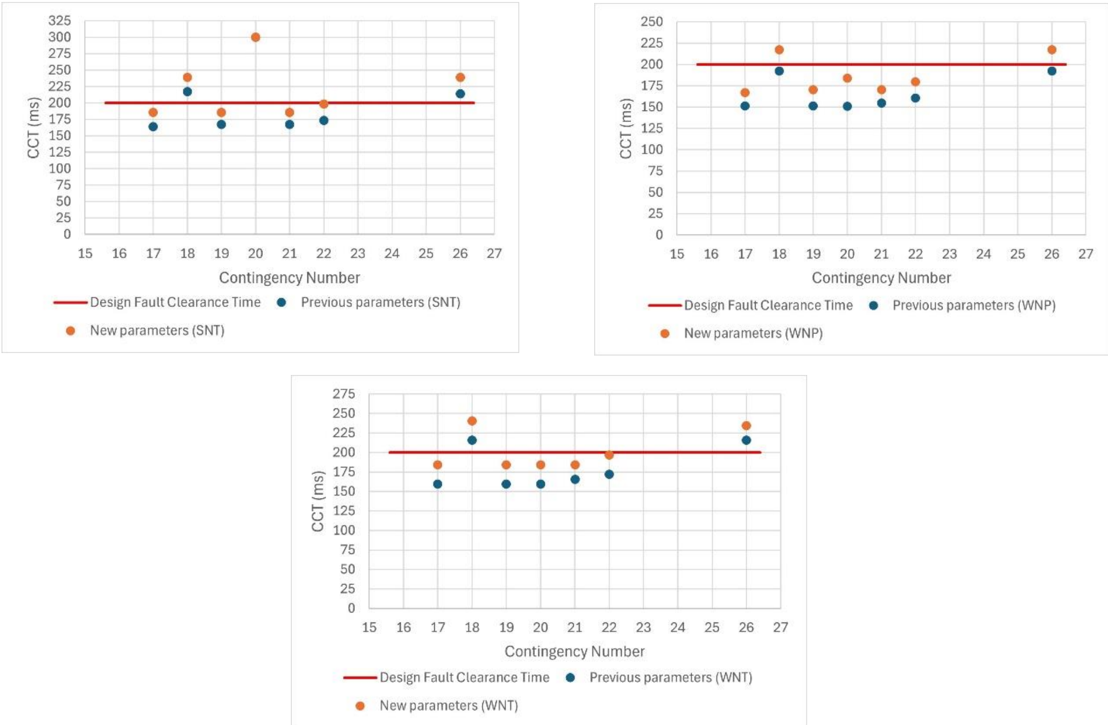

Figure 4-1: CCT values with the updated generator parameters of NGB

The NGB generator successfully maintained synchronism during faults at the MPE 110 kV bus in both the MPE-MTO and MPE-MDN 110 kV circuits under winter peak high wind scenarios with updated NGB parameters, where it was unstable previously. However, though the CCTs have improved here, they still fall short of the design fault clearance times for other contingencies. This indicates that transient stability margins continue to be constrained.

4.2 220 kV Faults

4.2.1 220 kV Circuit Faults: Intact Conditions

Figure 4-2 illustrates how the range of CCTs varied for each numbered contingency. Contingencies with minimum CCTs exceeding 300 ms were excluded from the graph to enhance clarity and focus on the more critical cases. The CCTs were evaluated between 100 ms and 300 ms.

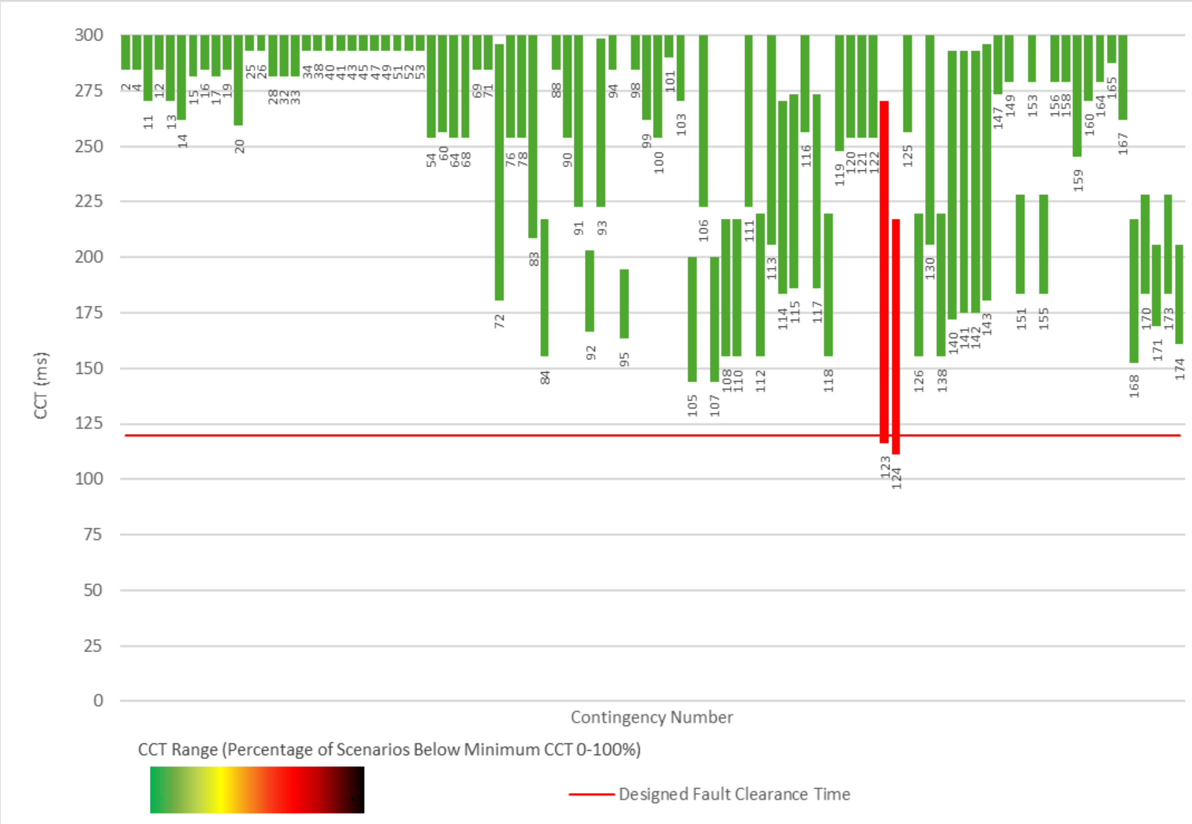

Figure 4-2: Range of CCTs for North Island 220 kV contingencies

With one exception, all generators were able to maintain synchronism during contingencies simulated on 220 kV buses under intact conditions. The CCTs for all contingencies exceeded the design fault clearance time with a sufficient margin, indicating system stability. However, Tauhara B and Te Huka 3 showed CCTs less than 120 ms for two contingencies in the summer night trough study case; we have analysed this in detail in section 4.3.1.

We observed previously that Te Ahi o Maui (TAM) was unable to maintain synchronism for faults in the EDG-KAW 110 kV circuits under intact conditions. However, we observed no instabilities with TAM under intact conditions when it was reconnected to the KAW 220 kV bus with the new generator TOPP 2.

Figure 4-3 shows the rotor angle variation of TAM during the contingencies of the EDG-KAW 220 kV and KAW-OHK 220 kV circuits under intact conditions which remains synchronised following the contingency. This confirms the stability of TAM for the nearest contingencies under intact conditions.

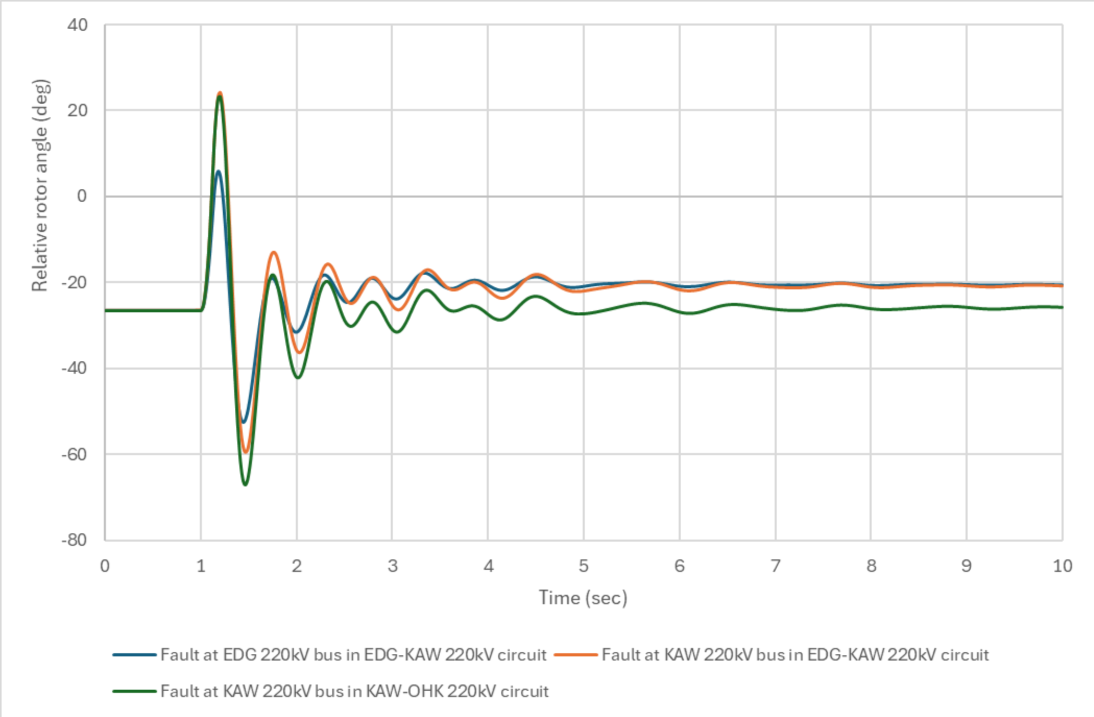

Figure 4-3: Rotor angle variation of the TAM generator with reference to TKU

4.2.2 220 kV Circuit Faults: Outage Conditions

We have studied the 220 kV circuits that showed lower CCTs under intact conditions for network outages in the Edgecumbe and Hawke's Bay region. The outages include the following 220 kV circuits: TAB-WRK, HRP-RDF, EDG-KAW, KAW-OHK, OHK-WRK, THI-WKM, WRK-RPO, RPO-WRK and SFD-HLY.

Table 4-1 outlines only the CCTs under planned outage conditions that were significantly impacted. Instances of generator islanding due to the combined effect of outages and faults during normal operating conditions were not included in the studies in Table 4-1. Additionally, generators connected to KAW 220 kV and 110 kV buses become islanded during outage-fault combinations of KAW 220 kV circuits due to the operational splits placed during outages. These cases were also excluded from the table.

All CCTs remained within an adequate margin relative to the design fault clearance time for the assessed outages.

Table 4-1: Transient stability status of the system under planned outages

Study case	Most Limiting Contingency		CCT Under Intact Condition	Outage	CCT under planned outage
	Faulted 220 kV Bus	Removed circuit			
Winter Night Trough	ATI	ATI-TRK 220 kV circuit	300	OHK-WRK 220 kV circuit	236
Summer Night Trough	KAW	KAW-OHK 220 kV circuit	300	HRP-RDF 220 kV circuit	160

Summer Night Trough	OHK	ATI-OHK 220 kV circuit	300	EDG-KAW 220 kV circuit	267
Summer Night Trough	OHK	OHK-WRK 220 kV circuit	300	EDG-KAW 220 kV circuit	250
Summer Night Trough	EDG	EDG-TRK 220 kV circuit	264	KAW-OHK 220 kV circuit	188
Summer Day trough	EDG	EDG-TRK 220 kV circuit	236	KAW-OHK 220 kV circuit	191
Winter Peak	WRK	WRK-WKM 220 kV circuit	155	THI-WKM 220 kV circuit	135

4.3 Analysis of Unstable 220 kV Contingencies

4.3.1 Tauhara B and Te Huka 3 Generators

Potential first swing instability issues appeared with the Tauhara B (TAB) and Te Huka 3 (TAC) generators for two fault scenarios in the summer night trough study case: a fault at the TAB 220 kV bus in the TAB-WRK 220 kV circuit, and a fault at the WRK 220 kV bus in the TAB-WRK 220 kV circuit.

We used the model parameters provided by the asset owner in their connection study report for TAC. For TAB, the system operator used the parameters provided in the model validation report, although we discovered some discrepancies and sent feedback to the asset owner.

The unstable base case had TAB generator's terminal voltage at 0.975 p.u. and absorbing 29 Mvar, while TAC's terminal voltage was 0.996 p.u. and injecting 9 Mvar into the system. TAB and TAC injected a total of 222 MW into the TAB 220 kV bus, contributing 172 MW and 50 MW, respectively. This highlights the risk of losing the synchronism under low terminal voltage conditions, particularly when only the HRP-TAB 220 kV circuit is available to dispatch 220 MW during an outage on the TAB-WRK 220 kV circuit.

We conducted sensitivity studies on the same study case to assess the impact of terminal voltage and generation output. Table 4-2 shows the CCTs for the limiting contingency. Note that the red font indicates changes with respect to the base case.

Table 4-2: Study scenarios for TAB and TAC stability assessment

Study case	TAB (MW/Mvar)	TAC (MW/Mvar)	TAB 220 kV (p.u.)	TAB V_t (p.u.)	TAC V_t (p.u.)	CCT (ms)	Faulted 220 kV Bus	Limiting Contingency (Removed circuit)
Base case	172 /-29	50 / 9	0.997	0.975	0.996	111	WRK	TAB-WRK 220 kV circuit
Sensitivity case **1:** TAB Vt increase	172 / 14	50 / 8.2	1.00	1.005	0.994	183	WRK	TAB-WRK 220 kV circuit
Sensitivity case **2**: TAC out of service	172 /-26	0 / 0	0.997	0.975	-	194	WRK	TAB-WRK 220 kV circuit
Sensitivity case **3**: TAB out of service	0 / 0	50 / 9	0.997	-	1.004	200	WRK	TAB-WRK 220 kV circuit
Sensitivity case **4**: Constrain TAC by 20 MW	172 /-30	30 / 5.7	0.997	0.972	0.991	158	WRK	TAB-WRK 220 kV circuit

Sensitivity case 1 shows that CCT improved well above the design fault clearance time, achieving the stability with the combined operation of TAB and TAC when the terminal voltage (V_t) of TAB was increased to 1.005 p.u. This emphasises the importance of maintaining a terminal voltage close to 1.0 p.u. when combined generation from TAC and TAB exceeds 200 MW.

Furthermore, sensitivity cases 2 and 3 show that TAB remained stable when TAC was out of service, and vice versa. Sensitivity case 4 indicates that CCT could be improved by constraining the total generation from TAB and TAC even when TAB operates at a lower terminal voltage. However, sustained rotor angle oscillations were observed, and the system exhibited a delayed damping response. These are shown in the Figure 4-4. This underscores the need to repeat the study once the system operator has reviewed the validated models of TAB and TAC.

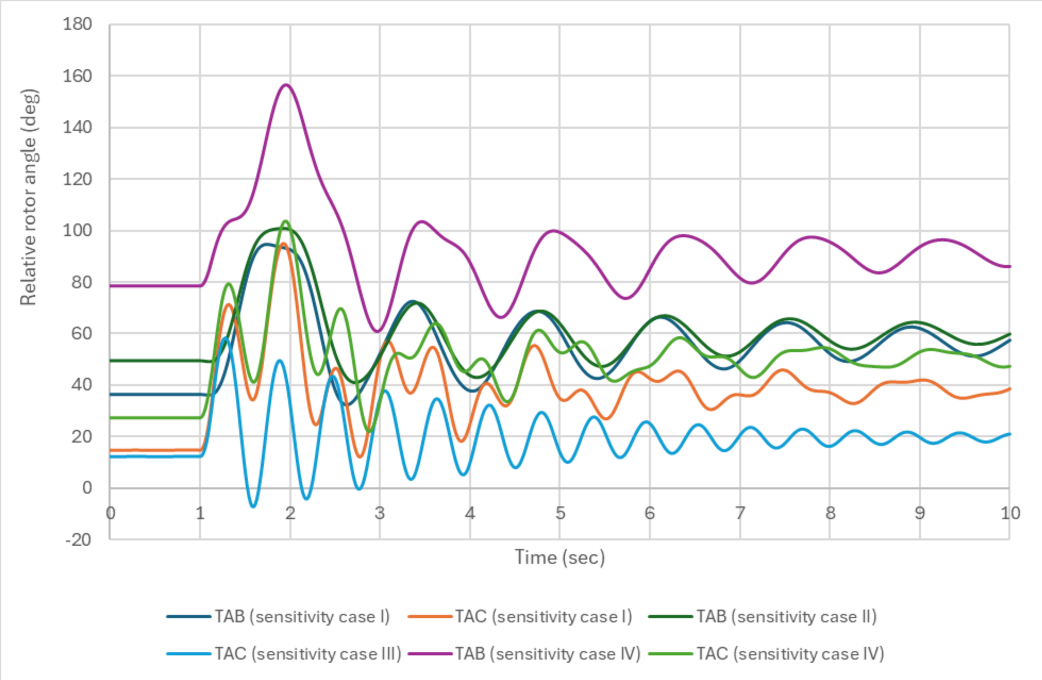

Figure 4-4: Rotor angle variation of TAB and TAC generator reference to TKU

4.4 110 kV Faults

Figure 4-5 illustrates how the range of CCTs for each 110 kV circuit contingency. Contingencies with minimum CCTs exceeding 300 ms were excluded to focus on the more critical cases. As with 220 kV circuits, the CCTs were evaluated between 100 ms and 300 ms.

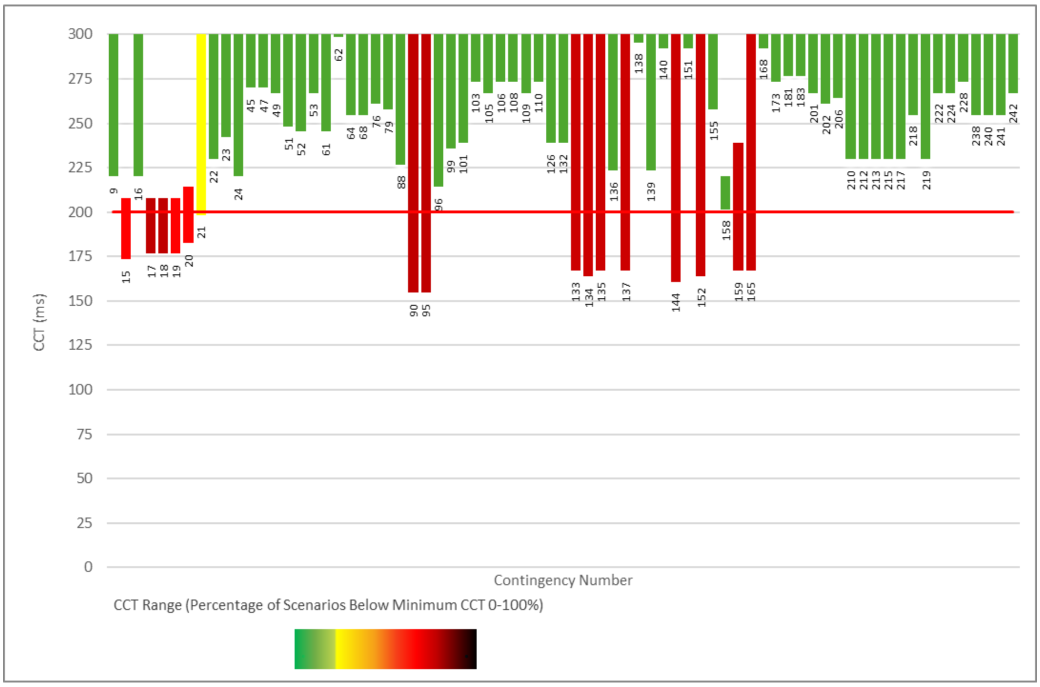

Figure 4-5: Range of CCTs for North Island 110 kV contingencies.

The TRAS study showed that most generators were able to maintain synchronism during 110 kV bus contingencies for all assessed scenarios. However, 16 contingencies' minimum CCTs were below 200 ms design fault clearance time. These are shown in Table 4-3.

Table 4-3: 110 kV faults with CCTs less than 200 ms

#	Contingency #	Contingency Location		Unstable Generators	Minimum CCT (ms)	Study Case
		Faulted 110 kV Bus	Removed circuit			
1	15	KOE	KOE-MPE 110 kV circuit	NGB	173	WNT
2	17	KOE	KOE-KTS 110 kV circuit	NGB	176	WNT
3	18	KTS	KTS-KOE 110 kV circuit	NGB	176	WNT
4	19	KOE	KOE-NGA 110 kV circuit	NGB	176	WNT
5	20	NGA	KOE-NGA 110 kV circuit	NGB	182	WNT
6	21	KOE	KOE-NGB 110 kV circuit	NGB	198	WNT
7	90	KAW	EDG-KAW 110 kV circuit	ONU TOPP1	154	WNT
8	95	KAW	KAW-MAT 110 kV circuit	ONU TOPP1	154	WNT
9	133	CST	CST-SFD 110 kV circuit	JRD	167	WNT
10	134	SFD	CST-SFD 110 kV circuit	JRD	164	WNT
11	135	CST	CST-HUI 110 kV circuit	JRD	167	WNT
12	137	CST	CST-MNI 110 kV circuit	JRD	167	WNT
13	144	SFD	SFD-HWA 110 kV circuit	JRD	160	WNT
14	152	SFD	MKT-MNI-SFD 110 kV circuit	JRD	164	WNT
15	159	SFD	SFD-KPA 110kV circuit	JRD	167	WNT
16	165	SFD	SFD-OPK 110kV circuit	JRD	167	WNT

All generators identified as unstable in the previous TRAS study were still found to be unstable under the additional scenarios. No new generators exhibited instability, even under the more challenging high wind and low system inertia conditions examined in this report's investigations. Moreover, the 2024 TRAS study showed that Te Ahi O Maui (TAM) was unstable for contingencies 90 and 95. TAM's point of connection will change from the KAW 110 kV bus to the KAW 220 kV bus via the KAW–Te Ahi

O Maui Upgrade project. With this new point of connection, we observed that the TAM generator was able to maintain synchronism under intact conditions, as noted in section 4.2.1.

4.5 Conclusion and Proposed Mitigations

The additional studies have revealed one new stability issue for the North Island 220 kV circuit faults. The concern is associated with the TAB and TAC generators, particularly when the generator terminal voltages are relatively low. We found that managing the active power output of TAB and TAC, and increasing the terminal voltage of TAB generator improves the stability. As these studies were conducted using pre-validation models, we will need to repeat the analysis once we have reviewed and validated the TAB and TAC generator models.

After these are confirmed, the system operator will consider whether to monitor the stability of these stations in real time. Given the combined size of the stations, it is prudent for the system operator to apply mitigations measures such as voltage setpoint adjustments and constraining the generation in the market scheduling if required.

We have studied the impact of selected 220 kV circuits outages that were considered onerous under specific generation scenarios. While some outages resulted in reduced CCTs, all CCTs remained above the design fault clearance time for the assessed outages.

The updated NGB generator parameters improved transient stability for faults at the MPE 110 kV bus. However, the NGB generator remains unstable for 110 kV faults at the KOE bus.

No new instability issues found under 110 kV contingencies even under high renewable energy penetration levels.

5 Additional South Island Studies

5.1 Impact of Kaiwera Downs Stage 2

We have studied the impact of the Kaiwera Downs Stage 2 (KWE) on Lower South Island (LSI) transient stability, having found stability issues associated with Manapouri generation in the region in the previous TRAS study. Kaiwera Downs Stage 2 connection is depicted in Figure 5-1.

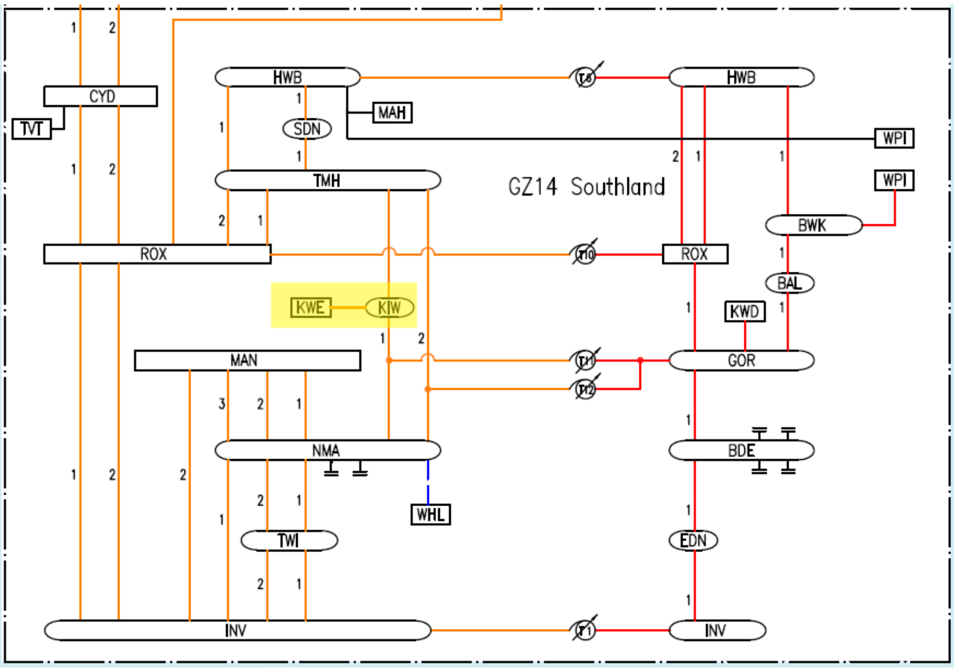

Figure 5-1: Single line diagram of the Kaiwera Downs Stage 2 (KWE) connection

The studies were done for winter peak and winter night trough scenarios. The following cases were studied for the 220 kV contingencies. The 220 kV contingencies represent the most onerous disturbances that could potentially cause stability issues in the region based on the previous studies.

- **Base case:** MAN 125 MW x 6 units and KWE 0 MW
- **KWE case 1:** KWE Station generating at 75% of rating (114 MW)

Apart from the items in Section 3.1, the cases for the LSI were set up with these assumptions:

- Only one North Makarewa capacitor was dispatched, giving 54 Mvar.
- Tiwai operated at full load: 570 MW/160 Mvar.
- Grid Zone 14 load excluding Tiwai was 355 MW and 182 MW during winter peak and winter night trough respectively.
- Manapouri dispatch was 125 MW x 6 units.
- Manapouri 220 kV voltage was at 1.02 p.u.
- Wind generation from KWD and WHL was 90 MW during winter peak and winter night trough respectively.

5.1.1 Study Results

Table 5-1 outlines the lowest CCTs for LSI contingencies during winter peak and winter night trough study cases.

We observed new stability issues in Manapouri generation with KWE generation in both study cases. Generally, the CCTs reduced by approximately 6% with KWE generation. Red fonts indicate the CCT values less than design fault clearance time.

During the winter peak, the CCTs fell below 120 ms for a fault at the MAN 220 kV bus for any of the 220 kV circuit contingencies out of Manapouri. This is like the study case 11-2 in the previous report where it was unstable with Manapouri running at 125 MW each, but the Grid Zone 14 load was low (182 MW). For ease of comparison, the Grid Zone 14 net load of KWE generation excluding Tiwai here was 241 MW.

For the winter night trough, the CCTs of the faults on the 220 kV circuits out of Manapouri were already below 120 ms. With KWE generation, the CCTs were further reduced. The circuits close to instability with the KWE generation are the faults at INV-ROX and NMA-GOT-TMH 220 kV circuits.

Table 5-1: Critical clearance times for LSI contingencies

Contingency location		Critical Clearance Time (ms)			
Faulted 220 kV Bus	Removed 220 kV circuit	Winter Peak		Winter Night Trough	
		Base case	KWE case 1	Base case	KWE case 1
MAN	INV-MAN	121	114	107	92[1]
MAN	MAN-NMA	124	114	107	92
NMA	MAN-NMA	155	144	119	111
INV	INV-MAN	158	147	119	114
INV	INV-ROX	166	155	130	121
NMA	NMA-GOT-TMH	166	161	130	124
NMA	NMA-GOT- KWI	166	152	130	130
NMA	INV-NMA	172	161	136	127
NMA	NMA-TWI	175	164	138	130
INV	INV-NMA	178	166	141	133

[1] CCT scanning were normally evaluated between 100 ms and 300 ms but lowered for this case to find the exact value.

5.1.2 Sensitivity Studies with Load Modelling

All the above studies were conducted considering the 60% constant current and 40% constant impedance load model for both active and reactive power due to limited data availability. However, the load model can significantly influence the system's dynamic response, particularly under transient stability conditions. Given the observed reduction in stability margins with increased KWE generation, it was important to assess the impact of KWE on LSI transient stability under a different load modelling assumption. Therefore, we performed sensitivity studies with the 100% constant impedance load model for both active and reactive power. This model represents a more conservative system behaviour during voltage dips. Moreover, we added sensitivity case with KWE full load (152 MW).

The following features apply to the cases in Table 5-2:

- **KWE case 2:** KWE 114 MW and a load model with 100% constant impedance for both active and reactive power
- **KWE case 3**: KWE 152 MW and a load model with 100% constant impedance for both active and reactive power

Table 5-2: Critical clearance times for sensitivity studies

Fault location		Critical Clearance Time (ms)					
Faulted 220 kV Bus	Removed 220 kV circuit	Winter Peak			Winter Night Trough		
		KWE Case 1	KWE case 2	KWE case 3	KWE case 1	KWE case 2	KWE case 3
MAN	INV-MAN	114	130	127	92	119	111
MAN	MAN-NMA	114	133	130	92	121	114
NMA	MAN-NMA	144	161	155	111	144	136
INV	INV-MAN	147	164	158	114	147	138
INV	INV-ROX	155	169	164	121	152	144
NMA	NMA-GOT-TMH	161	175	172	124	152	144
NMA	NMA-GOT- KWI	152	169	164	130	158	150
NMA	INV-NMA	161	175	169	127	158	150
NMA	NMA-TWI	164	178	172	130	161	152
INV	INV-NMA	166	181	178	133	164	152

These results show that the CCTs improve significantly when a constant impedance load model is used. This highlights that the selection of load model can have a substantial impact on system stability margins. Given that Tiwai is the largest load in the region, applying an appropriate load model for Tiwai is critical, as it can significantly influence the transient stability of the Manapouri generators. Additionally, KWE case 3 shows that CCT decreases as expected with KWE generation increasing to its rated output.

5.2 Conclusion and Proposed Mitigation

The previous Transient Rotor Angle Stability (TRAS) Study (section 3.1.3) found that managing active power output of Manapouri station enhances stability. We also found that keeping the Manapouri terminal voltage high while maintaining adequate reactive power margins to support the voltage control also supports stability. Tiwai load also directly impacts on Manapouri's stability.

Additional studies have shown that Kaiwera Downs Stage 2 project has worsened the stability issues as observed with the lower CCTs. With these dynamic factors that affect the stability of the Manapouri station, it is prudent for the system operator to operationalise real-time stability monitoring and apply mitigation measures such as voltage setpoint adjustments and constraining generation in the lower South Island in the market scheduling if required.

Finally, it is also important for the system operator to adopt the most suitable load model to assess stability margins. This will require a separate investigation to determine the appropriate load model.

Appendix 1 CONTINGENCY LIST

1.1 NORTH ISLAND 220 KV CONTINGENCIES

Contingency Number	Description
1	Fault at ALB 220kV bus in ALB-HEN 220kV circuit
2	Fault at HEN 220kV bus in HEN-ALB 220kV circuit
3	Fault at ALB 220kV bus in ALB-HPI 220kV circuit
4	Fault at HPI 220kV bus in HPI-ALB 220kV circuit
5	Fault at ALB 220kV bus in ALB-SVL 220kV circuit
6	Fault at SVL 220kV bus in SVL-ALB 220kV circuit
7	Fault at ALB 220kV bus in ALB-SVL 220kV circuit
8	Fault at SVL 220kV bus in SVL-ALB 220kV circuit
9	Fault at ALB 220kV bus in ALB-WRD 220kV circuit
10	Fault at WRD 220kV bus in WRD-ALB 220kV circuit
11	Fault at BRB 220kV bus in BRB-HPI 220kV circuit
12	Fault at HPI 220kV bus in HPI-BRB 220kV circuit
13	Fault at BRB 220kV bus in BRB-MDN 220kV circuit
14	Fault at MDN 220kV bus in MDN-BRB 220kV circuit
15	Fault at HEN 220kV bus in HEN-HPI 220kV circuit
16	Fault at HPI 220kV bus in HPI-HEN 220kV circuit
17	Fault at HEN 220kV bus in HEN-SWN 220kV circuit
18	Fault at SWN 220kV bus in SWN-HEN 220kV circuit
19	Fault at HPI 220kV bus in HPI-MDN 220kV circuit
20	Fault at MDN 220kV bus in MDN-HPI 220kV circuit
21	Fault at DRY 220kV bus in DRY-GLN 220kV circuit
22	Fault at GLN 220kV bus in GLN-DRY 220kV circuit
23	Fault at DRY 220kV bus in DRY-TAK-OTA 220kV circuit 1
24	Fault at TAK 220kV bus in DRY-TAK-OTA 220kV circuit 1
25	Fault at OTA 220kV bus in DRY-TAK-OTA 220kV circuit 1
26	Fault at OTA 220kV bus in DRY-BOB-HLY-DRY-TAK-OTA 220kV circuit2
27	Fault at TAK 220kV bus in DRY-BOB-HLY-DRY-TAK-OTA 220kV circuit2
28	Fault at HLY 220kV bus in HLY-BOB-DRY 220kV circuit 2
29	Fault at BOB 220kV bus in HLY-BOB-DRY 220kV circuit 2
30	Fault at DRY 220kV bus in HLY-BOB-DRY 220kV circuit 1
31	Fault at BOT 220kV bus in HLY-BOB-DRY 220kV circuit 1
32	Fault at HLY 220kV bus in HLY-BOB-DRY 220kV circuit 1
33	Fault at HEN 220kV bus in HEN-OTA 220kV circuit
34	Fault at OTA 220kV bus in OTA-HEN 220kV circuit
35	Fault at HOB 220kV bus in HOB-PEN 220kV circuit
36	Fault at PEN 220kV bus in PEN-HOB 220kV circuit
37	Fault at OHW 220kV bus in OHW-OTA 220kV circuit
38	Fault at OTA 220kV bus in OTA-OHW 220kV circuit
39	Fault at OHW 220kV bus in OHW-OTA 220kV circuit
40	Fault at OTA 220kV bus in OTA-OHW 220kV circuit
41	Fault at OTA 220kV bus in OTA-PAK 220kV circuit

Contingency Number	Description
42	Fault at PAK 220kV bus in PAK-OTA 220kV circuit
43	Fault at OTA 220kV bus in OTA-PAK 220kV circuit
44	Fault at PAK 220kV bus in PAK-OTA 220kV circuit
45	Fault at OTA 220kV bus in OTA-PEN 220kV circuit
46	Fault at PEN 220kV bus in PEN-OTA 220kV circuit
47	Fault at OTA 220kV bus in OTA-PEN 220kV circuit
48	Fault at PEN 220kV bus in PEN-OTA 220kV circuit
49	Fault at OTA 220kV bus in OTA-SWN 220kV circuit
50	Fault at SWN 220kV bus in SWN-OTA 220kV circuit
51	Fault at OTA 220kV bus in OTA-OTA 220kV circuit
52	Fault at OTA 220kV bus in OTA-OTA 220kV circuit
53	Fault at OTA 220kV bus in OTA-WKM 220kV circuit
54	Fault at WKM 220kV bus in WKM-OTA 220kV circuit
55	Fault at PAK 220kV bus in PAK-PEN 220kV circuit
56	Fault at PEN 220kV bus in PEN-PAK 220kV circuit
57	Fault at BHL 220kV bus in BHL-PAK 220kV circuit
58	Fault at PAK 220kV bus in PAK-BHL 220kV circuit
59	Fault at BHL 220kV bus in BHL-WKM 220kV circuit
60	Fault at WKM 220kV bus in WKM-BHL 220kV circuit
61	Fault at BHL 220kV bus in BHL-PAK 220kV circuit
62	Fault at PAK 220kV bus in PAK-BHL 220kV circuit
63	Fault at BHL 220kV bus in BHL-WKM 220kV circuit
64	Fault at WKM 220kV bus in WKM-BHL 220kV circuit
65	Fault at HAM 220kV bus in HAM-OHW 220kV circuit
66	Fault at OHW 220kV bus in OHW-HAM 220kV circuit
67	Fault at HAM 220kV bus in HAM-WKM 220kV circuit
68	Fault at WKM 220kV bus in WKM-HAM 220kV circuit
69	Fault at HLY 220kV bus in HLY-OHW 220kV circuit
70	Fault at OHW 220kV bus in OHW-HLY 220kV circuit
71	Fault at HLY 220kV bus in HLY-SFD 220kV circuit
72	Fault at SFD 220kV bus in SFD-HLY 220kV circuit
73	Fault at HLY 220kV bus in HLY-TWH 220kV circuit
74	Fault at TWH 220kV bus in TWH-HLY 220kV circuit
75	Fault at OHW 220kV bus in OHW-WKM 220kV circuit
76	Fault at WKM 220kV bus in WKM-OHW 220kV circuit
77	Fault at OHW 220kV bus in OHW-WKM 220kV circuit
78	Fault at WKM 220kV bus in WKM-OHW 220kV circuit
79	Fault at TMN 220kV bus in TMN-TWH 220kV circuit
80	Fault at TWH 220kV bus in TWH-TMN 220kV circuit
81	Fault at ATI 220kV bus in ATI-ATI 220kV circuit
82	Fault at ATI 220kV bus in ATI-ATI 220kV circuit
83	Fault at ARA 220kV bus in ARA-WRK 220kV circuit
84	Fault at WRK 220kV bus in WRK-ARA 220kV circuit
85	Fault at ATI 220kV bus in ATI-OHK 220kV circuit
86	Fault at OHK 220kV bus in OHK-ATI 220kV circuit
87	Fault at ATI 220kV bus in ATI-TRK 220kV circuit
88	Fault at TRK 220kV bus in TRK-ATI 220kV circuit

Contingency Number	Description
89	Fault at ATI 220kV bus in ATI-WKM 220kV circuit
90	Fault at WKM 220kV bus in WKM-ATI 220kV circuit
91	Fault at EDG 220kV bus in EDG-KAW 220kV circuit
92	Fault at KAW 220kV bus in KAW-EDG 220kV circuit
93	Fault at EDG 220kV bus in EDG-TRK 220kV circuit
94	Fault at TRK 220kV bus in TRK-EDG 220kV circuit
95	Fault at KAW 220kV bus in KAW-OHK 220kV circuit
96	Fault at OHK 220kV bus in OHK-KAW 220kV circuit
97	Fault at KMO 220kV bus in KMO-TRK 220kV circuit
98	Fault at TRK 220kV bus in TRK-KMO 220kV circuit
99	Fault at MTI 220kV bus in MTI-WKM 220kV circuit
100	Fault at WKM 220kV bus in WKM-MTI 220kV circuit
101	Fault at MTI 220kV bus in MTI-WPA 220kV circuit
102	Fault at WPA 220kV bus in WPA-MTI 220kV circuit
103	Fault at NAP 220kV bus in NAP-NTM 220kV circuit
104	Fault at NTM 220kV bus in NTM-NAP 220kV circuit
105	Fault at NAP 220kV bus in NAP-OKI 220kV circuit
106	Fault at OKI 220kV bus in OKI-NAP 220kV circuit
107	Fault at NAP 220kV bus in NAP-WRK 220kV circuit
108	Fault at WRK 220kV bus in WRK-NAP 220kV circuit
109	Fault at OHK 220kV bus in OHK-WRK 220kV circuit
110	Fault at WRK 220kV bus in WRK-OHK 220kV circuit
111	Fault at OKI 220kV bus in OKI-WRK 220kV circuit
112	Fault at WRK 220kV bus in WRK-OKI 220kV circuit
113	Fault at PPI 220kV bus in PPI-THI 220kV circuit
114	Fault at THI 220kV bus in THI-PPI 220kV circuit
115	Fault at THI 220kV bus in THI-WKM 220kV circuit
116	Fault at WKM 220kV bus in WKM-THI 220kV circuit
117	Fault at THI 220kV bus in THI-WRK 220kV circuit
118	Fault at WRK 220kV bus in WRK-THI 220kV circuit
119	Fault at TKU 220kV bus in TKU-WKM 220kV circuit
120	Fault at WKM 220kV bus in WKM-TKU 220kV circuit
121	Fault at WKM 220kV bus in WKM-WKM 220kV circuit
122	Fault at WKM 220kV bus in WKM-WKM 220kV circuit
123	Fault at TAB 220kV bus in TAB-WRK 220kV circuit
124	Fault at WRK 220kV bus in WRK-TAB 220kV circuit
125	Fault at WKM 220kV bus in WKM-WRK 220kV circuit
126	Fault at WRK 220kV bus in WRK-WKM 220kV circuit
127	Fault at HRP 220kV bus in HRP-RDF 220kV circuit
128	Fault at RDF 220kV bus in RDF-HRP 220kV circuit
129	Fault at HRP 220kV bus in HRP-TAB 220kV circuit
130	Fault at TAB 220kV bus in TAB-HRP 220kV circuit
131	Fault at RDF 220kV bus in RDF-WHI 220kV circuit
132	Fault at WHI 220kV bus in WHI-RDF 220kV circuit
133	Fault at RDF 220kV bus in RDF-WTU 220kV circuit
134	Fault at WTU 220kV bus in WTU-RDF 220kV circuit
135	Fault at RDF 220kV bus in RDF-WTU 220kV circuit

Contingency Number	Description
136	Fault at WTU 220kV bus in WTU-RDF 220kV circuit
137	Fault at WHI 220kV bus in WHI-WRK 220kV circuit
138	Fault at WRK 220kV bus in WRK-WHI 220kV circuit
139	Fault at BRK 220kV bus in BRK-SFD 220kV circuit
140	Fault at SFD 220kV bus in SFD-BRK 220kV circuit
141	Fault at SFD 220kV bus in SFD-SPL 220kV circuit
142	Fault at SPL 220kV bus in SPL-SFD 220kV circuit
143	Fault at SFD 220kV bus in SFD-TMN 220kV circuit
144	Fault at TMN 220kV bus in TMN-SFD 220kV circuit
145	Fault at LTN 220kV bus in LTN-TUR 220kV circuit
146	Fault at TUR 220kV bus in TUR-LTN 220kV circuit
147	Fault at BPE 220kV bus in BPE-BRK 220kV circuit
148	Fault at BRK 220kV bus in BRK-BPE 220kV circuit
149	Fault at BPE 220kV bus in BPE-LTN 220kV circuit
150	Fault at LTN 220kV bus in LTN-BPE 220kV circuit
151	Fault at HAY 220kV bus in HAY-PRM-BPE 220kV circuit 1
152	Fault at PRM 220kV bus in HAY-PRM-BPE 220kV circuit 1
153	Fault at BPE 220kV bus in HAY-PRM-BPE 220kV circuit 1
154	Fault at PRM 220kV bus in HAY-PRM-BPE 220kV circuit 2
155	Fault at HAY 220kV bus in HAY-PRM-BPE 220kV circuit 2
156	Fault at BPE 220kV bus in HAY-PRM-BPE 220kV circuit 2
157	Fault at PRT 220kV bus in PRT-BPE 220kV circuit
158	Fault at BPE 220kV bus in BPE-TKU 220kV circuit
159	Fault at TKU 220kV bus in TKU-BPE 220kV circuit
160	Fault at BPE 220kV bus in BPE-TNG 220kV circuit
161	Fault at TNG 220kV bus in TNG-BPE 220kV circuit
162	Fault at LTN 220kV bus in LTN-TWC-BPE 220kV circuit
163	Fault at TWC 220kV bus in LTN-TWC-BPE 220kV circuit
164	Fault at BPE 220kV bus in LTN-TWC-BPE 220kV circuit
165	Fault at RPO 220kV bus in RPO-TNG 220kV circuit
166	Fault at TNG 220kV bus in TNG-RPO 220kV circuit
167	Fault at RPO 220kV bus in RPO-WRK 220kV circuit
168	Fault at WRK 220kV bus in WRK-RPO 220kV circuit
169	Fault at LTN 220kV bus in HAY-WIL-LTN 220kV circuit 1
170	Fault at HAY 220kV bus in HAY-WIL-LTN 220kV circuit 1
171	Fault at WIL 220kV bus in HAY-WIL-LTN 220kV circuit 1
172	Fault at LTN 220kV bus in HAY-WIL-LTN 220kV circuit 2
173	Fault at HAY 220kV bus in HAY-WIL-LTN 220kV circuit 2
174	Fault at WIL 220kV bus in HAY-WIL-LTN 220kV circuit 2

1.2 NORTH ISLAND 110 KV CONTINGENCIES

Contingency Number	Description
1	Fault at ALB 110kV bus in ALB-WRD 110kV circuit
2	Fault at WRD 110kV bus in WRD-ALB 110kV circuit
3	Fault at ALB 110kV bus in ALB-WRD 110kV circuit
4	Fault at WRD 110kV bus in WRD-ALB 110kV circuit
5	Fault at ALB 110kV bus in ALB-WRD 110kV circuit
6	Fault at WRD 110kV bus in WRD-ALB 110kV circuit
7	Fault at HEN 110kV bus in HEN-HEP 110kV circuit
8	Fault at HEP 110kV bus in HEP-HEN 110kV circuit
9	Fault at MPE 110kV bus in HEN-WEL-MTO-MPE 110kV circuit
10	Fault at MTO 110kV bus in HEN-WEL-MTO-MPE 110kV circuit
11	Fault at HEN 110kV bus in HEN-WEL-MTO-MPE 110kV circuit
12	Fault at WEL 110kV bus in HEN-WEL-MTO-MPE 110kV circuit
13	Fault at HEP 110kV bus in HEP-ROS 110kV circuit
14	Fault at ROS 110kV bus in ROS-HEP 110kV circuit
15	Fault at KOE 110kV bus in KOE-MPE 110kV circuit
16	Fault at MPE 110kV bus in MPE-KOE 110kV circuit
17	Fault at KOE 110kV bus in KOE-KTS 110kV circuit
18	Fault at KTS 110kV bus in KTS-KOE 110kV circuit
19	Fault at KOE 110kV bus in KOE-NGA 110kV circuit
20	Fault at NGA 110kV bus in NGA-KOE 110kV circuit
21	Fault at KOE 110kV bus in KOE-NGB 110kV circuit
22	Fault at NGB 110kV bus in NGB-KOE 110kV circuit
23	Fault at MDN 110kV bus in MDN-MPE 110kV circuit
24	Fault at MPE 110kV bus in MPE-MDN 110kV circuit
25	Fault at OTA 110kV bus in OTA-WIR 110kV circuit
26	Fault at WIR 110kV bus in WIR-OTA 110kV circuit
27	Fault at OTA 110kV bus in OTA-WIR 110kV circuit
28	Fault at WIR 110kV bus in WIR-OTA 110kV circuit
29	Fault at HOB 110kV bus in HOB-LST 110kV circuit
30	Fault at LST 110kV bus in LST-HOB 110kV circuit
31	Fault at LST 110kV bus in LST-PEN 110kV circuit
32	Fault at PEN 110kV bus in PEN-LST 110kV circuit
33	Fault at LST 110kV bus in LST-QST 110kV circuit
34	Fault at QST 110kV bus in QST-LST 110kV circuit
35	Fault at LST 110kV bus in LST-ROS 110kV circuit
36	Fault at ROS 110kV bus in ROS-LST 110kV circuit
37	Fault at MNG 110kV bus in MNG-OTA 110kV circuit
38	Fault at OTA 110kV bus in OTA-MNG 110kV circuit
39	Fault at MNG 110kV bus in MNG-ROS 110kV circuit
40	Fault at ROS 110kV bus in ROS-MNG 110kV circuit
41	Fault at OTA 110kV bus in OTA-PEN 110kV circuit
42	Fault at PEN 110kV bus in PEN-OTA 110kV circuit
43	Fault at OTA 110kV bus in OTA-ROS 110kV circuit
44	Fault at ROS 110kV bus in ROS-OTA 110kV circuit
45	Fault at ARI 110kV bus in ARI-BOB 110kV circuit

Contingency Number	Description
46	Fault at BOB 110kV bus in BOB-ARI 110kV circuit
47	Fault at ARI 110kV bus in ARI-HAM 110kV circuit
48	Fault at HAM 110kV bus in HAM-ARI 110kV circuit
49	Fault at ARI 110kV bus in ARI-HTI 110kV circuit
50	Fault at HTI 110kV bus in HTI-ARI 110kV circuit
51	Fault at ARI 110kV bus in ARI-KIN 110kV circuit
52	Fault at KIN 110kV bus in KIN-ARI 110kV circuit
53	Fault at ARI 110kV bus in ARI-RTO 110kV circuit
54	Fault at RTO 110kV bus in RTO-ARI 110kV circuit
55	Fault at ONG 110kV bus in ONG-RTO 110kV circuit
56	Fault at RTO 110kV bus in RTO-ONG 110kV circuit
57	Fault at HTI 110kV bus in HTI-RTO 110kV circuit
58	Fault at RTO 110kV bus in RTO-HTI 110kV circuit
59	Fault at BOB 110kV bus in BOB-HAM 110kV circuit
60	Fault at HAM 110kV bus in HAM-BOB 110kV circuit
61	Fault at CBG 110kV bus in CBG-HAM 110kV circuit
62	Fault at HAM 110kV bus in HAM-CBG 110kV circuit
63	Fault at CBG 110kV bus in CBG-KPO 110kV circuit
64	Fault at KPO 110kV bus in KPO-CBG 110kV circuit
65	Fault at CBG 110kV bus in CBG-HAM 110kV circuit
66	Fault at HAM 110kV bus in HAM-CBG 110kV circuit
67	Fault at CBG 110kV bus in CBG-KPO 110kV circuit
68	Fault at KPO 110kV bus in KPO-CBG 110kV circuit
69	Fault at HAM 110kV bus in HAM-PAO-WHU 110kV circuit 1
70	Fault at WHU 110kV bus in HAM-PAO-WHU 110kV circuit 1
71	Fault at PAO 110kV bus in HAM-PAO-WHU 110kV circuit
72	Fault at PAO 110kV bus in HAM-PAO-WHU 110kV circuit 2
73	Fault at WHU 110kV bus in HAM-PAO-WHU 110kV circuit 2
74	Fault at HAM 110kV bus in HAM-PAO-WHU 110kV circuit 2
75	Fault at HIN 110kV bus in HIN-KPO 110kV circuit
76	Fault at KPO 110kV bus in KPO-HIN 110kV circuit
77	Fault at HTI 110kV bus in HTI-TMU 110kV circuit
78	Fault at TMU 110kV bus in TMU-HTI 110kV circuit
79	Fault at KPO 110kV bus in KPO-TMU 110kV circuit
80	Fault at TMU 110kV bus in TMU-KPO 110kV circuit
81	Fault at KPU 110kV bus in KPU-WKO 110kV circuit
82	Fault at WKO 110kV bus in WKO-KPU 110kV circuit
83	Fault at KPU 110kV bus in KPU-WKO 110kV circuit
84	Fault at WKO 110kV bus in WKO-KPU 110kV circuit
85	Fault at WHU 110kV bus in WHU-WKO 110kV circuit
86	Fault at WKO 110kV bus in WKO-WHU 110kV circuit
87	Fault at ANI 110kV bus in ANI-MAT 110kV circuit
88	Fault at MAT 110kV bus in MAT-ANI 110kV circuit
89	Fault at EDG 110kV bus in EDG-KAW 110kV circuit
90	Fault at KAW 110kV bus in KAW-EDG 110kV circuit
91	Fault at EDG 110kV bus in EDG-OWH 110kV circuit
92	Fault at OWH 110kV bus in OWH-EDG 110kV circuit

Contingency Number	Description
93	Fault at EDG 110kV bus in EDG-WAI 110kV circuit
94	Fault at WAI 110kV bus in WAI-EDG 110kV circuit
95	Fault at KAW 110kV bus in KAW-MAT 110kV circuit
96	Fault at MAT 110kV bus in MAT-KAW 110kV circuit
97	Fault at LFD 110kV bus in KIN-LFD-TRK 110kV circuit 1
98	Fault at TRK 110kV bus in KIN-LFD-TRK 110kV circuit 1
99	Fault at KIN 110kV bus in KIN-LFD-TRK 110kV circuit 1
100	Fault at TRK 110kV bus in KIN-LFD-TRK 110kV circuit 2
101	Fault at KIN 110kV bus in KIN-LFD-TRK 110kV circuit 2
102	Fault at LFD 110kV bus in KIN-LFD-TRK 110kV circuit 2
103	Fault at KMO 110kV bus in KMO-TGA-MTM 110kV circuit
104	Fault at MTM 110kV bus in KMO-TGA-MTM 110kV circuit
105	Fault at TGA 110kV bus in KMO-TGA-MTM 110kV circuit
106	Fault at KMO 110kV bus in KMO-MTM 110kV circuit
107	Fault at MTM 110kV bus in MTM-KMO 110kV circuit
108	Fault at KMO 110kV bus in KMO-TGA 110kV circuit
109	Fault at TGA 110kV bus in TGA-KMO 110kV circuit
110	Fault at KMO 110kV bus in KMO-TMI 110kV circuit
111	Fault at TMI 110kV bus in TMI-KMO 110kV circuit
112	Fault at MOK 110kV bus in MOK-WKM 110kV circuit
113	Fault at WKM 110kV bus in WKM-MOK 110kV circuit
114	Fault at OWH 110kV bus in TIM-OKE-OWH-TRK 110kV circuit
115	Fault at TMI 110kV bus in TIM-OKE-OWH-TRK 110kV circuit
116	Fault at TRK 110kV bus in TIM-OKE-OWH-TRK 110kV circuit
117	Fault at ROT 110kV bus in ROT-TRK 110kV circuit
118	Fault at TRK 110kV bus in TRK-ROT 110kV circuit
119	Fault at ROT 110kV bus in ROT-TRK 110kV circuit
120	Fault at TRK 110kV bus in TRK-ROT 110kV circuit
121	Fault at ROT 110kV bus in ROT-WHE 110kV circuit
122	Fault at WHE 110kV bus in WHE-ROT 110kV circuit
123	Fault at FHL 110kV bus in FHL-RDF 110kV circuit
124	Fault at RDF 110kV bus in RDF-FHL 110kV circuit
125	Fault at FHL 110kV bus in FHL-TUI 110kV circuit
126	Fault at TUI 110kV bus in TUI-FHL 110kV circuit
127	Fault at FHL 110kV bus in FHL-WPW 110kV circuit
128	Fault at WPW 110kV bus in WPW-FHL 110kV circuit
129	Fault at FHL 110kV bus in FHL-WPW 110kV circuit
130	Fault at WPW 110kV bus in WPW-FHL 110kV circuit
131	Fault at RDF 110kV bus in RDF-TUI 110kV circuit
132	Fault at TUI 110kV bus in TUI-RDF 110kV circuit
133	Fault at CST 110kV bus in CST-SFD 110kV circuit
134	Fault at SFD 110kV bus in SFD-CST 110kV circuit
135	Fault at CST 110kV bus in CST-HUI 110kV circuit
136	Fault at HUI 110kV bus in HUI-CST 110kV circuit
137	Fault at CST 110kV bus in CST-MNI 110kV circuit
138	Fault at MNI 110kV bus in MNI-CST 110kV circuit
139	Fault at HUI 110kV bus in HUI-MNI 110kV circuit

Contingency Number	Description
140	Fault at MNI 110kV bus in MNI-HUI 110kV circuit
141	Fault at HWA 110kV bus in HWA-PTA 110kV circuit
142	Fault at PTA 110kV bus in PTA-HWA 110kV circuit
143	Fault at HWA 110kV bus in HWA-SFD 110kV circuit
144	Fault at SFD 110kV bus in SFD-HWA 110kV circuit
145	Fault at HWA 110kV bus in HWA-WAA 110kV circuit
146	Fault at WAA 110kV bus in WAA-HWA 110kV circuit
147	Fault at HWA 110kV bus in HWA-WVY 110kV circuit
148	Fault at WVY 110kV bus in WVY-HWA 110kV circuit
149	Fault at WPP 110kV bus in WPP-WVY 110kV circuit
150	Fault at WVY 110kV bus in WVY-WPP 110kV circuit
151	Fault at MNI 110kV bus in MKT-MNI-SFD 110kV circuit
152	Fault at SFD 110kV bus in MKT-MNI-SFD 110kV circuit
153	Fault at MKE 110kV bus in MKT-MNI-SFD 110kV circuit
154	Fault at CST 110kV bus in CST-JRD-SFD 110kV circuit
155	Fault at SFD 110kV bus in CST-JRD-SFD 110kV circuit
156	Fault at JRD 110kV bus in CST-JRD-SFD 110kV circuit
157	Fault at JRT 110kV bus in JRT-JRD 110kV circuit
158	Fault at KPA 110kV bus in KPA-SFD 110kV circuit
159	Fault at SFD 110kV bus in SFD-KPA 110kV circuit
160	Fault at KPA 110kV bus in KPA-KPI 110kV circuit
161	Fault at KPI 110kV bus in KPI-KPA 110kV circuit
162	Fault at KPA 110kV bus in KPA-OPK 110kV circuit
163	Fault at OPK 110kV bus in OPK-KPA 110kV circuit
164	Fault at OPK 110kV bus in OPK-SFD 110kV circuit
165	Fault at SFD 110kV bus in SFD-OPK 110kV circuit
166	Fault at MTR 110kV bus in MTR-MTR 110kV circuit
167	Fault at MTR 110kV bus in MTR-MTR 110kV circuit
168	Fault at BPE 110kV bus in BPE-MHO 110kV circuit
169	Fault at MHO 110kV bus in MHO-BPE 110kV circuit
170	Fault at BPE 110kV bus in BPE-MTR 110kV circuit
171	Fault at MTR 110kV bus in MTR-BPE 110kV circuit
172	Fault at BPE 110kV bus in BPE-WDV 110kV circuit
173	Fault at WDV 110kV bus in WDV-BPE 110kV circuit
174	Fault at MTN 110kV bus in BPE-MTN-WGN 110kV circuit 1
175	Fault at WGN 110kV bus in BPE-MTN-WGN 110kV circuit 1
176	Fault at BPE 110kV bus in BPE-MTN-WGN 110kV circuit 1
177	Fault at MTN 110kV bus in BPE-MTN-WGN 110kV circuit 2
178	Fault at MTN 110kV bus in BPE-MTN-WGN 110kV circuit 2
179	Fault at WGN 110kV bus in BPE-MTN-WGN 110kV circuit 2
180	Fault at DVK 110kV bus in DVK-WDV 110kV circuit
181	Fault at WDV 110kV bus in WDV-DVK 110kV circuit
182	Fault at DVK 110kV bus in DVK-WDV 110kV circuit
183	Fault at WDV 110kV bus in WDV-DVK 110kV circuit
184	Fault at DVK 110kV bus in DVK-WPW 110kV circuit
185	Fault at WPW 110kV bus in WPW-DVK 110kV circuit
186	Fault at DVK 110kV bus in DVK-WPW 110kV circuit

Contingency Number	Description
187	Fault at WPW 110kV bus in WPW-DVK 110kV circuit
188	Fault at MTR 110kV bus in MTR-OKN 110kV circuit
189	Fault at OKN 110kV bus in OKN-MTR 110kV circuit
190	Fault at OKN 110kV bus in OKN-RTR 110kV circuit
191	Fault at RTR 110kV bus in RTR-OKN 110kV circuit
192	Fault at NPK 110kV bus in NPK-RTR 110kV circuit
193	Fault at RTR 110kV bus in RTR-NPK 110kV circuit
194	Fault at ONG 110kV bus in ONG-RTR 110kV circuit
195	Fault at RTR 110kV bus in RTR-ONG 110kV circuit
196	Fault at TAP 110kV bus in TAP-WDV 110kV circuit
197	Fault at WDV 110kV bus in WDV-TAP 110kV circuit
198	Fault at WGN 110kV bus in WGN-WVY 110kV circuit
199	Fault at WVY 110kV bus in WVY-WGN 110kV circuit
200	Fault at CPK 110kV bus in CPK-WIL 110kV circuit
201	Fault at WIL 110kV bus in WIL-CPK 110kV circuit
202	Fault at WIL 110kV bus in CPK-WIL-WWD 110kV circuit 2
203	Fault at WWD 110kV bus in CPK-WIL-WWD 110kV circuit 2
204	Fault at CPK 110kV bus in CPK-WIL-WWD 110kV circuit 2
205	Fault at MHT 110kV bus in CPK-WIL-WWD 110kV circuit 3
206	Fault at WIL 110kV bus in CPK-WIL-WWD 110kV circuit 3
207	Fault at CPK 110kV bus in CPK-WIL-WWD 110kV circuit 3
208	Fault at MHT 110kV bus in MHT-CPK 110kV circuit
209	Fault at GFD 110kV bus in GFD-HAY 110kV circuit
210	Fault at HAY 110kV bus in HAY-GFD 110kV circuit
211	Fault at GFD 110kV bus in GFD-HAY 110kV circuit
212	Fault at HAY 110kV bus in HAY-GFD 110kV circuit
213	Fault at HAY 110kV bus in HAY-MLG 110kV circuit
214	Fault at MLG 110kV bus in MLG-HAY 110kV circuit
215	Fault at HAY 110kV bus in HAY-MLG 110kV circuit
216	Fault at MLG 110kV bus in MLG-HAY 110kV circuit
217	Fault at HAY 110kV bus in HAY-TKR 110kV circuit
218	Fault at TKR 110kV bus in TKR-HAY 110kV circuit
219	Fault at HAY 110kV bus in HAY-UHT 110kV circuit
220	Fault at UHT 110kV bus in UHT-HAY 110kV circuit
221	Fault at KWA 110kV bus in KWA-WIL 110kV circuit
222	Fault at WIL 110kV bus in WIL-KWA 110kV circuit
223	Fault at KWA 110kV bus in KWA-WIL 110kV circuit
224	Fault at WIL 110kV bus in WIL-KWA 110kV circuit
225	Fault at MGM 110kV bus in MGM-MST 110kV circuit
226	Fault at MST 110kV bus in MST-MGM 110kV circuit
227	Fault at MGM 110kV bus in MGM-WDV 110kV circuit
228	Fault at WDV 110kV bus in WDV-MGM 110kV circuit
229	Fault at GYT 110kV bus in GYT-UHT 110kV circuit
230	Fault at UHT 110kV bus in UHT-GYT 110kV circuit
231	Fault at GYT 110kV bus in GYT-MST 110kV circuit
232	Fault at MST 110kV bus in MST-GYT 110kV circuit
233	Fault at GYT 110kV bus in GYT-UHT 110kV circuit

Contingency Number	Description
234	Fault at UHT 110kV bus in UHT-GYT 110kV circuit
235	Fault at GYT 110kV bus in GYT-MST 110kV circuit
236	Fault at MST 110kV bus in MST-GYT 110kV circuit
237	Fault at PNI 110kV bus in PNI-TKR 110kV circuit
238	Fault at TKR 110kV bus in TKR-PNI 110kV circuit
239	Fault at PNI 110kV bus in PNI-TKR 110kV circuit
240	Fault at TKR 110kV bus in TKR-PNI 110kV circuit
241	Fault at TKR 110kV bus in TKR-WIL 110kV circuit
242	Fault at WIL 110kV bus in WIL-TKR 110kV circuit

1.3 SOUTH ISLAND 220 KV CONTINGENCIES

Contingency Number	Description
1	Fault at KIK 220 kV bus in KIK-STK 220 kV circuit
2	Fault at STK 220 kV bus in STK-KIK 220 kV circuit
3	Fault at ISL 220 kV bus in ISL-KIK 220 kV circuit
4	Fault at KIK 220 kV bus in KIK-ISL 220 kV circuit
5	Fault at ISL 220 kV bus in ISL-WPR 220 kV circuit
6	Fault at WPR 220 kV bus in WPR-ISL 220 kV circuit
7	Fault at KIK 220 kV bus in KIK-CUL 220 kV circuit
8	Fault at ISL 220 kV bus in ISL-WPR 220 kV circuit
9	Fault at WPR 220 kV bus in WPR-ISL 220 kV circuit
10	Fault at KIK 220 kV bus in KIK-CUL 220 kV circuit
11	Fault at ISL 220 kV bus in ISL-NWD 220 kV circuit
12	Fault at NWD 220 kV bus in NWD-ISL 220 kV circuit
13	Fault at ISL 220 kV bus in ISL-TKB 220 kV circuit
14	Fault at TKB 220 kV bus in TKB-ISL 220 kV circuit
15	Fault at ASB 220 kV bus in ASB-BRY 220 kV circuit
16	Fault at BRY 220 kV bus in BRY-ASB 220 kV circuit
17	Fault at ASB 220 kV bus in ASB-ISL 220 kV circuit
18	Fault at ISL 220 kV bus in ISL-ASB 220 kV circuit
19	Fault at TIM 220 kV bus in TIM-OPI 220 kV circuit
20	Fault at TWZ 220 kV bus in TWZ-OPI 220 kV circuit
21	Fault at ASB 220 kV bus in ASB-OPI 220 kV circuit
22	Fault at TWZ 220 kV bus in TWZ-OPI 220 kV circuit
23	Fault at ASB 220 kV bus in ASB-OPI 220 kV circuit
24	Fault at TIM 220 kV bus in TIM-OPI 220 kV circuit
25	Fault at BRY 220 kV bus in BRY-ISL 220 kV circuit
26	Fault at ISL 220 kV bus in ISL-BRY 220 kV circuit
27	Fault at LIV 220 kV bus in LIV-NWD 220 kV circuit
28	Fault at NWD 220 kV bus in NWD-LIV 220 kV circuit
29	Fault at AVI 220 kV bus in AVI-BEN 220 kV circuit
30	Fault at BEN 220 kV bus in BEN-AVI 220 kV circuit
31	Fault at AVI 220 kV bus in AVI-WTK 220 kV circuit
32	Fault at WTK 220 kV bus in WTK-AVI 220 kV circuit
33	Fault at BEN 220 kV bus in BEN-OHB 220 kV circuit
34	Fault at OHB 220 kV bus in OHB-BEN 220 kV circuit
35	Fault at BEN 220 kV bus in BEN-OHC 220 kV circuit
36	Fault at OHC 220 kV bus in OHC-BEN 220 kV circuit
37	Fault at BEN 220 kV bus in BEN-TWZ 220 kV circuit
38	Fault at TWZ 220 kV bus in TWZ-BEN 220 kV circuit
39	Fault at CML 220 kV bus in CML-TWZ 220 kV circuit
40	Fault at TWZ 220 kV bus in TWZ-CML 220 kV circuit
41	Fault at CML 220 kV bus in CML-CYD 220 kV circuit
42	Fault at CYD 220 kV bus in CYD-CML 220 kV circuit
43	Fault at CML 220 kV bus in CML-TWZ 220 kV circuit
44	Fault at TWZ 220 kV bus in TWZ-CML 220 kV circuit
45	Fault at CML 220 kV bus in CML-CYD 220 kV circuit

Contingency Number	Description
46	Fault at CYD 220 kV bus in CYD-CML 220 kV circuit
47	Fault at LIV 220 kV bus in LIV-NSY 220 kV circuit
48	Fault at NSY 220 kV bus in NSY-LIV 220 kV circuit
49	Fault at LIV 220 kV bus in LIV-WTK 220 kV circuit
50	Fault at WTK 220 kV bus in WTK-LIV 220 kV circuit
51	Fault at NSY 220 kV bus in NSY-ROX 220 kV circuit
52	Fault at ROX 220 kV bus in ROX-NSY 220 kV circuit
53	Fault at OHA 220 kV bus in OHA-TWZ 220 kV circuit
54	Fault at TWZ 220 kV bus in TWZ-OHA 220 kV circuit
55	Fault at OHB 220 kV bus in OHB-TWZ 220 kV circuit
56	Fault at TWZ 220 kV bus in TWZ-OHB 220 kV circuit
57	Fault at OHC 220 kV bus in OHC-TWZ 220 kV circuit
58	Fault at TWZ 220 kV bus in TWZ-OHC 220 kV circuit
59	Fault at TKB 220 kV bus in TKB-TWZ 220 kV circuit
60	Fault at TWZ 220 kV bus in TWZ-TKB 220 kV circuit
61	Fault at GOT 220 kV bus in GOT-NMA 220 kV circuit
62	Fault at NMA 220 kV bus in NMA-GOT 220 kV circuit
63	Fault at GOT 220 kV bus in GOT-TMH 220 kV circuit
64	Fault at TMH 220 kV bus in TMH-GOT 220 kV circuit
65	Fault at GOR 220 kV bus in GOR-GOT 220 kV circuit
66	Fault at GOT 220 kV bus in GOT-GOR 220 kV circuit
67	Fault at GOT 220 kV bus in GOT-NMA 220 kV circuit
68	Fault at NMA 220 kV bus in NMA-GOT 220 kV circuit[2]
69	Fault at GOT 220 kV bus in GOT-TMH 220 kV circuit[3]
70	Fault at TMH 220 kV bus in TMH-GOT 220 kV circuit[4]
71	Fault at GOR 220 kV bus in GOR-GOT 220 kV circuit[5]
72	Fault at GOT 220 kV bus in GOT-GOR 220 kV circuit[6]
73	Fault at CYD 220 kV bus in CYD-ROX 220 kV circuit
74	Fault at ROX 220 kV bus in ROX-CYD 220 kV circuit
75	Fault at HWB 220 kV bus in HWB-SDN 220 kV circuit
76	Fault at SDN 220 kV bus in SDN-HWB 220 kV circuit
77	Fault at HWB 220 kV bus in HWB-TMH 220 kV circuit
78	Fault at TMH 220 kV bus in TMH-HWB 220 kV circuit
79	Fault at INV 220 kV bus in INV-MAN 220 kV circuit
80	Fault at MAN 220 kV bus in MAN-INV 220 kV circuit
81	Fault at INV 220 kV bus in INV-NMA 220 kV circuit
82	Fault at NMA 220 kV bus in NMA-INV 220 kV circuit
83	Fault at INV 220 kV bus in INV-ROX 220 kV circuit
84	Fault at ROX 220 kV bus in ROX-INV 220 kV circuit
85	Fault at INV 220 kV bus in INV-TWI 220 kV circuit
86	Fault at TWI 220 kV bus in TWI-INV 220 kV circuit

[2] *This contingency is replaced with Fault at NMA 220 kV bus in NMA-GOT-KIW 220 kV circuit for KWE connection*
[3] *This contingency is replaced with Fault at TMH 220 kV bus in TMH-KIW 220 kV circuit for KWE connection*
[4] *This contingency is replaced with Fault at KIW 220 kV bus in NMA-GOT-KIW 220 kV circuit for KWE connection*
[5] *This contingency is replaced with Fault at GOR 220 kV bus in NMA-GOT-KIW 220 kV circuit for KWE connection*
[6] *This contingency is replaced with Fault at KIW 220 kV bus in TMH-KIW 220 kV circuit for KWE connection*

Contingency Number	Description
87	Fault at MAN 220 kV bus in MAN-NMA 220 kV circuit
88	Fault at NMA 220 kV bus in NMA-MAN 220 kV circuit
89	Fault at NMA 220 kV bus in NMA-TWI 220 kV circuit
90	Fault at TWI 220 kV bus in TWI-NMA 220 kV circuit
91	Fault at ROX 220 kV bus in ROX-TMH 220 kV circuit
92	Fault at TMH 220 kV bus in TMH-ROX 220 kV circuit
93	Fault at SDN 220 kV bus in SDN-TMH 220 kV circuit
94	Fault at TMH 220 kV bus in TMH-SDN 220 kV circuit

1.4 SOUTH ISLAND 110 KV CONTINGENCIES

Contingency Number	Description
1	Fault at ATU 110 kV bus in ATU-DOB 110 kV circuit
2	Fault at DOB 110 kV bus in DOB-ATU 110 kV circuit
3	Fault at IGH 110 kV bus in IGH-RFN 110 kV circuit
4	Fault at RFN 110 kV bus in RFN-IGH 110 kV circuit
5	Fault at ATU 110 kV bus in ATU-RFN 110 kV circuit
6	Fault at RFN 110 kV bus in RFN-ATU 110 kV circuit
7	Fault at ARG 110 kV bus in ARG-KIK 110 kV circuit
8	Fault at KIK 110 kV bus in KIK-ARG 110 kV circuit
9	Fault at ARG 110 kV bus in ARG-BLN 110 kV circuit
10	Fault at BLN 110 kV bus in BLN-ARG 110 kV circuit
11	Fault at BLN 110 kV bus in BLN-STK 110 kV circuit
12	Fault at STK 110 kV bus in STK-BLN 110 kV circuit
13	Fault at RFC 110 kV bus in RFC-RFN 110 kV circuit
14	Fault at RFN 110 kV bus in RFN-RFC 110 kV circuit
15	Fault at IGH 110 kV bus in IGH-RFC 110 kV circuit
16	Fault at RFC 110 kV bus in RFC-IGH 110 kV circuit
17	Fault at DOB 110 kV bus in DOB-RFC 110 kV circuit
18	Fault at RFC 110 kV bus in RFC-DOB 110 kV circuit
19	Fault at IGH 110 kV bus in IGH-MCH 110 kV circuit
20	Fault at MCH 110 kV bus in MCH-IGH 110 kV circuit
21	Fault at KIK 110 kV bus in KIK-MCH 110 kV circuit
22	Fault at MCH 110 kV bus in MCH-KIK 110 kV circuit
23	Fault at IGH 110 kV bus in IGH-KIK 110 kV circuit
24	Fault at KIK 110 kV bus in KIK-IGH 110 kV circuit
25	Fault at ORO 110 kV bus in ORO-ROB 110 kV circuit
26	Fault at ROB 110 kV bus in ROB-ORO 110 kV circuit
27	Fault at IGH 110 kV bus in IGH-ORO 110 kV circuit
28	Fault at ORO 110 kV bus in ORO-IGH 110 kV circuit
29	Fault at IGH 110 kV bus in IGH-ORO 110 kV circuit
30	Fault at ORO 110 kV bus in ORO-IGH 110 kV circuit
31	Fault at ORO 110 kV bus in ORO-ROB 110 kV circuit
32	Fault at ROB 110 kV bus in ROB-ORO 110 kV circuit
33	Fault at KIK 110 kV bus in KIK-STK 110 kV circuit

Contingency Number	Description
34	Fault at STK 110 kV bus in STK-KIK 110 kV circuit
35	Fault at STU 110 kV bus in STU-TIM 110 kV circuit
36	Fault at TIM 110 kV bus in TIM-STU 110 kV circuit
37	Fault at ABY 110 kV bus in ABY-TIM 110 kV circuit
38	Fault at TIM 110 kV bus in TIM-ABY 110 kV circuit
39	Fault at ABY 110 kV bus in ABY-TKA 110 kV circuit
40	Fault at TKA 110 kV bus in TKA-ABY 110 kV circuit
41	Fault at TIM 110 kV bus in TIM-TMK 110 kV circuit
42	Fault at TMK 110 kV bus in TMK-TIM 110 kV circuit
43	Fault at CML 110 kV bus in CML-FKN 110 kV circuit
44	Fault at FKN 110 kV bus in FKN-CML 110 kV circuit
45	Fault at CML 110 kV bus in CML-FKN 110 kV circuit
46	Fault at FKN 110 kV bus in FKN-CML 110 kV circuit
47	Fault at BPC 110 kV bus in BPC-BPT 110 kV circuit
48	Fault at BPT 110 kV bus in BPT-BPC 110 kV circuit
49	Fault at BPC 110 kV bus in BPC-WTK 110 kV circuit
50	Fault at WTK 110 kV bus in WTK-BPC 110 kV circuit
51	Fault at BPC 110 kV bus in BPC-OAM 110 kV circuit
52	Fault at OAM 110 kV bus in OAM-BPC 110 kV circuit
53	Fault at BPD 110 kV bus in BPD-WTK 110 kV circuit
54	Fault at WTK 110 kV bus in WTK-BPD 110 kV circuit
55	Fault at BPD 110 kV bus in BPD-GNY 110 kV circuit
56	Fault at GNY 110 kV bus in GNY-BPD 110 kV circuit
57	Fault at GNY 110 kV bus in GNY-STU 110 kV circuit
58	Fault at STU 110 kV bus in STU-GNY 110 kV circuit
59	Fault at GNY 110 kV bus in GNY-OAM 110 kV circuit
60	Fault at OAM 110 kV bus in OAM-GNY 110 kV circuit
61	Fault at BAL 110 kV bus in BAL-GOR 110 kV circuit
62	Fault at GOR 110 kV bus in GOR-BAL 110 kV circuit
63	Fault at BWK 110 kV bus in BWK-HWB 110 kV circuit
64	Fault at HWB 110 kV bus in HWB-BWK 110 kV circuit
65	Fault at BAL 110 kV bus in BAL-BWK 110 kV circuit
66	Fault at BWK 110 kV bus in BWK-BAL 110 kV circuit
67	Fault at BDE 110 kV bus in BDE-EDN 110 kV circuit
68	Fault at EDN 110 kV bus in EDN-BDE 110 kV circuit
69	Fault at BDE 110 kV bus in BDE-GOR 110 kV circuit
70	Fault at GOR 110 kV bus in GOR-BDE 110 kV circuit
71	Fault at EDN 110 kV bus in EDN-INV 110 kV circuit
72	Fault at INV 110 kV bus in INV-EDN 110 kV circuit
73	Fault at GOR 110 kV bus in GOR-ROX 110 kV circuit
74	Fault at ROX 110 kV bus in ROX-GOR 110 kV circuit
75	Fault at HWB 110 kV bus in HWB-ROX 110 kV circuit
76	Fault at ROX 110 kV bus in ROX-HWB 110 kV circuit