TRANSPOWER

Fault Ride Through Study Assumptions

Additional Information for the Auckland Region

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IMPORTANT

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1 Introduction

Fault Ride-Through (FRT) is the ability of a generating unit to stay connected to the electrical grid during and following a fault disturbance, and then to provide active power at least proportional to the grid voltage. This document provides additional information and system assumptions relevant to the Auckland Region (Grid Zone 2) for the technical studies required to demonstrate compliance with the FRT requirements stipulated in EIPC Clause 8.25A(3).

The Auckland region includes: Pakuranga, Otahuhu, Penrose, Hobson Street, Glenbrook, Drury, Takanini, Bombay, Mr.Roskill, Wiri, Mangere and Liverpool street . For a list of site code abbreviations relevant to this region, see the appendix. The contents of this document apply to any asset that will be connected within the Auckland region, which is shown geographically and as a single line diagram in Figure 1-1 and Figure 1-2.

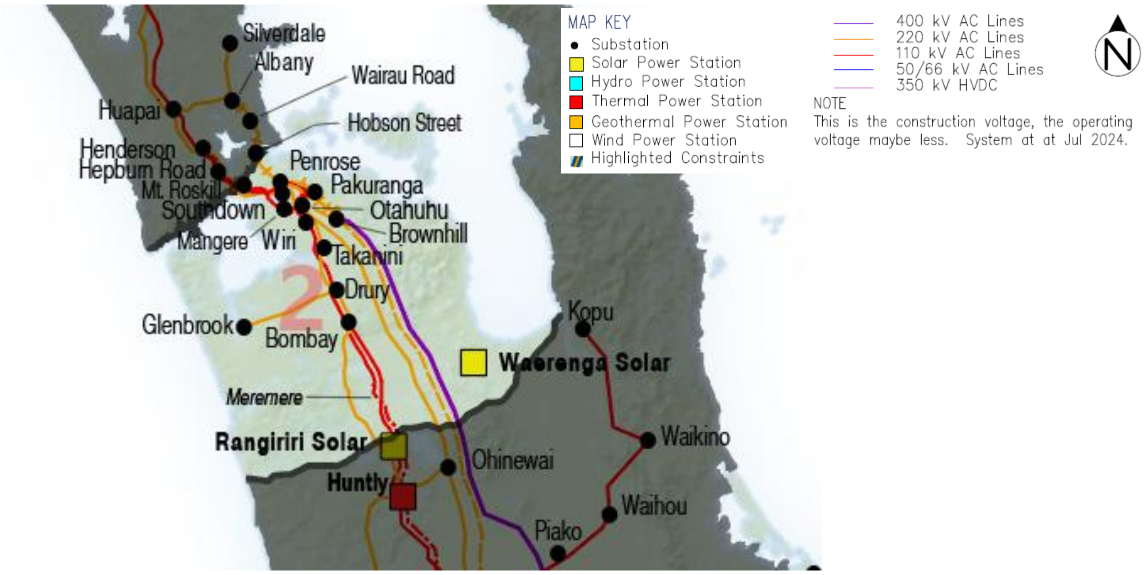

Figure 1-1 (above): Geographic representation of Auckland Region (Grid Zone 2)

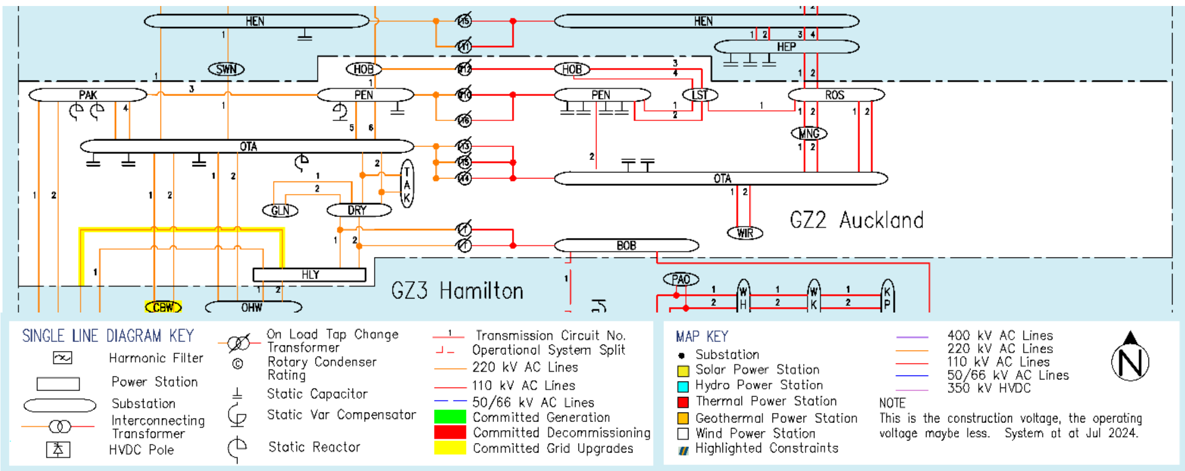

Figure 1-2: Single line diagram of Auckland Region (Grid Zone 2)

This document includes region-specific information and historical voltage trends to support you to complete your studies with accurate region-specific system conditions. You will also find an appropriate set of planned outages and corresponding generation dispatches, as well as information on any changing system conditions in the region, including the commissioning or de-commissioning of both transmission and generation assets.

Note that planned outages (section 3.5) and fault locations (section 7.3) to be studied will depend on the point of common coupling (PCC) groups. These have been introduced based on the location of the stations, with each station within the region assigned to a specific PCC group. You can find these outlined in section 3.4.

If your asset has not started commissioning one year after the System Operator has received and accepted a technical study, you may need to repeat it to reflect further changes to the power system that could affect the asset's fault ride through capability.

1.1 Additional documents

Transpower's GL-EA-953 document outlines the general requirements for a new generating station's connection studies, including the FRT study. The System Operator expects the Asset Owner to be familiar with that document as it outlines relevant information such as steps for model and study case preparation, as well as study scope and assessment criteria.

The following Transpower documents are also relevant to this assessment:

- 2024 System Security forecast
- Transpower EA EMI DIgSILENT NIPS case
- PSCAD Electromagnetic Transients (EMT) network model[1]
- Special protection schemes

[1] PSCAD network model will be provided by the SO upon request

2 FRT Study Purpose

The System Operator expects an FRT study to have the following outcomes:

- The generating units meet all the assessment criteria whilst riding through post-fault voltage excursions within the envelopes prescribed by the Code.
- The fault ride through strategies are detailed.
- Any non-compliant, or potentially non-compliant, behaviours are identified and explained.
- There is confirmation that no protection or control settings at the generating station would result in a breach of the fault ride through requirements. If there is any shortfall of asset capability to meet the Code requirements, you shall discuss it with the System Operator.

3 System Conditions

3.1 System model

You should perform the FRT assessment based on the latest available design parameters of your asset.

- If you modify any controller parameter after submitting the FRT report, i.e. during or after the EIPC Compliance tests, then you must also provide the System Operator with updated parameters.
- If there is a material change in the settings that would significantly alter the FRT performance, you may need to update and resubmit the study to the System Operator.

3.1.1 Minimum and maximum short circuit level conditions

It is acceptable to use the winter/summer peak and light load summer scenarios provided in the Electricity Market Information (EMI) dataset to prepare the maximum and minimum short circuit level study scenarios. The LoadSeason triggers 'At regional night trough S EXP' and 'At regional night trough W EXP' (for summer and winter respectively) may also be used in the absence of a light load summer scenario for the study year in question. As a minimum, the studies should be carried out for the planned commissioning year. Your study should also include any significant future local changes if the EMI case contains that relevant data.

3.2 Network model

The network model used for the connecting assets in the FRT study should include an accurate representation of:

- all generation units
- generator transformers
- the internal collector network
- the grid-connected transformer
- all controllers for Inverter Based Resources, including the Plant controller, and Inverter controller. These models should include representation of any Phase Lock Loop (PLL) controls and all current controls, and
- any associated controls or equipment to be installed in the facility.
- Any control strategies that are designed to assist in riding through system fault used in IBRs

This model must align with the available single-line diagram submitted in the Asset Capability Statement (ACS). An aggregated generating station model is acceptable for wind, solar and battery generating stations that shall include a collector system equivalent network model, as long as the model accurately reflects the performance expected of the station (see section 4.2).

Calculate the Effective Short Circuit Ratio (ESCR) at the PCC under the lowest short circuit system conditions using the latest EMI study case, the lowest short circuit system conditions are likely to be during an outage.

For synchronous generators you will need to undertake fault ride through studies with PowerFactory RMS simulations.

For Inverter Based Resources (IBR) you will need to undertake fault ride through studies with PowerFactory RMS simulations as an initial screening to cover all generation scenarios, fault types and asset operation conditions agreed with System Operator. You must then undertake a PSCAD EMT study to assess a selection of study cases identified in the screening process as agreed with System Operator.

3.3 System voltages

Figure 3-1 demonstrates the grid voltage profiles over the period January to December 2024 in the Auckland Region.

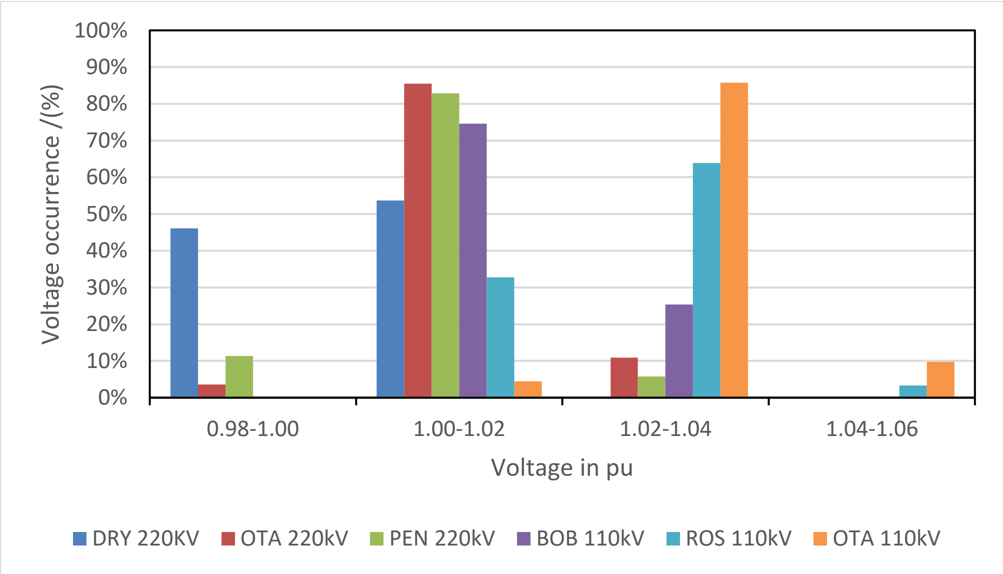

Figure 3-1: Voltage profile of DRY 220kV, OTA 220kV, PEN 220kV, BOB 110kV, ROS 110kV and OTA 110kV from Jan to Dec 2024

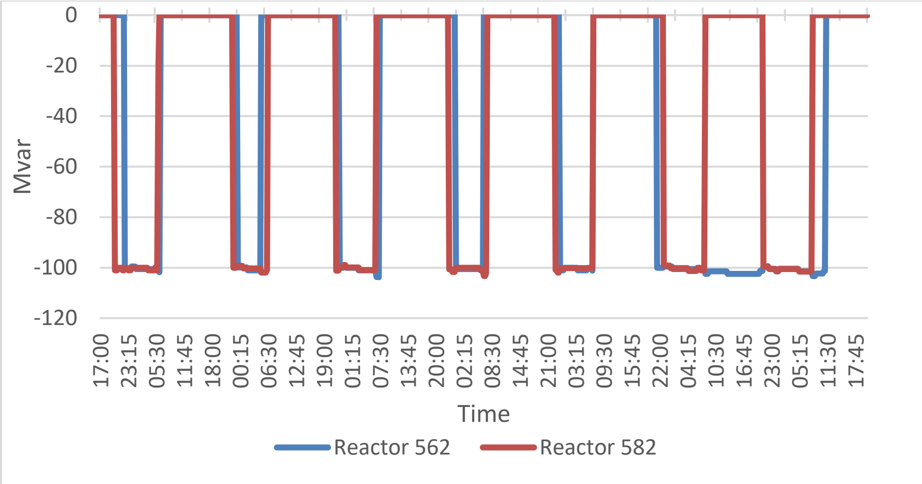

Figure 3-2: Operation of the Pakuranga Reactor over one week period in February 2025

The above graph indicates that 220kV voltage in Aukland region was mostly between 0.98-1.04pu. Further, this shows that the regions 110kV buses operated above 1.0pu throughout the year. It is to be noted that this region is well equipped with reactive power compensation devices to regulate the voltage. PAK reactor is switched In during the trough load conditions as shown in Figure 3-2. Thus, PAK reactor should be in service for studies with trough load conditions. Otahuhu has recently had a new STATCOM commissioned (OTA STC 15) and as such this should be in service during the studies. Asset Owners should perform fault ride through studies with voltage targets for the region within these ranges, highlighting any impact the new connection may have on the local voltage.

3.4 PCC groups classification

The System Operator has grouped 220kV and 110kV stations within the region as follows. This should help streamline the outages and fault locations to be studied based on the PCC. Accordingly, an asset connecting to any voltage level at these stations will belong to a particular PCC group.

PCC Group A (220kV): DRY, GLN, TAK

PCC Group B (220kV): OTA, PAK

PCC Group C (220kV): PEN, HOB

PCC Group D (110kV): PEN, HOB, LST

PCC Group E (110kV): OTA, WIR, MNG, ROS

PCC Group F (110kV): BOB

Any asset connecting to either 66kV, 33kV or lower voltage belongs to 220kV PCC group and 110kV PCC group mentioned above if particular 66kV or 33kV bus is fed directly via 220kV or 110kV bus respectively.

3.5 Transmission circuit outages

Planned outages are regular occurrences on the grid and the fault ride through study must include assessment of performance during outages. The System Operator expects outages to result in reduced system strength at the point of connection, which can make the fault ride though more difficult to achieve. We will endeavour to maintain N-1 security during planned or forced outages, and this may require special protection schemes (SPS) or pre-contingent constraints. The generation dispatch used in the outage studies should not result in unacceptable overloading of any circuit for a further contingency. If you need advice on any relevant special protection schemes (SPS), operational measures or on specific circuit overload capabilities, contact the System Operator.

You should consider the outages in Table 3-1 and Table 3-2 below during the FRT assessment. Table 3-1 outlines the outages to be considered during the studies based on 220kV PCC groups A, B and C, while * Only during trough load conditions

Table 3-2 outlines the outages to be considered during the studies based on 110kV PCC groups D, E and F as defined in section 3.4.

For 110kV PCC connections, you must also include the outage group associated with the nearest 220kV bus.

If the point of conenction to the grid is at 66kV, 33kV or a lower voltage level, the outage of at least one supply transformer feeding the PCC must also be studied in additionto the below outages**.**

Table 3-1: Outages under 220kV PCC groups A, B and C

PCC Group A	PCC Group B	PCC Group C
BOB-DRY- HLY circuit 1	OHW-OTA circuit 1	OTA-PEN circuit 5
HLY-OHW circuit 1	OTA-WKM circuit 1	PEN-PAK circuit 3
HLY-TWH circuit 1	OTA-PAK circuit 3	PEN-HOB circuit 1
DRY-GLN circuit 1	PAK-BHL-WKM circuit 1	HOB-WRD circuit 1
DRY-OTA-TAK circuit 1	OTA-SWN circuit 1	PAK-WKM circuit 1
OTA-PEN circuit 5	OTA-PEN circuit 5	OTA-WKM circuit 1
BOB T4	PEN-PAK circuit 3	PEN T10

PEN STC	HEN-OTA circuit 1	HOB T12
PAK Reactor*	PEN-HOB circuit 1	PEN STC1
OTA Capacitor (220kV)	OTA Capacitor (220kV side)	PEN Capacitor (220kV side)
	PAK Reactor*	PAK Reactor*
	PEN STC1	

* Only during trough load conditions

Table 3-2: Outages under 110kV PCC groups D, E and F

PCC Group D	PCC Group E	PCC Group F
HOB-LST circuit 3	OTA-PEN circuit 2	BOB T4
LST-PEN circuit 1	OTA-WIR circuit 2	ARI-BOB circuit 1
OTA-PEN circuit 2	MNG-OTA circuit 2	BOB-DRY- HLY circuit 1 (220kV circuit)
LST-ROS circuit 1	MNG-ROS circuit 2	PAK Reactor*
PEN T10	LST-ROS circuit 1	PEN STC1
HOB T12	HEP-ROS circuit 2	
PEN STC1	HEN-HEP circuit 2	
PEN Capacitor (110kV side)	OTA-ROS circuit 1	
PAK Reactor*	OTA Capacitor (110kV side)	
	PEN STC1	
	PAK Reactor*	

*Only during trough load conditions

The outages detailed above are expected to identify any problematic network configurations up to the post-fault N-1-1 condition. However, the Asset Owner remains responsible for identifying any onerous outage scenarios that result in an inability to ride through a system fault. To this end, you may choose to carry out a wider range of outage studies.

3.5.1 EMT studies

EMT studies should be conducted for a range of outages, with a focus on the most critical scenarios, typically the most onerous will be outages that result in the lowest short circuit ratios at the PCC. Outages in Table 3-1 and * Only during trough load conditions

Table 3-2 can be used for screening through the SCR, in some cases not all the outages will need to be studied in the EMT case. If the point of connection to the grid is at 66 kV, 33 kV, or a lower voltage level, the outage of at least one supply transformer feeding the PCC must also be studied in addition to the above outages.

4 Local Conditions

4.1 Local network model

The network topology for Transpower assets is depicted in the EMI study case. Where there is a complex local network that can affect the study results, Asset Owners should acquire this data from the network owner and add this to the study. An equivalent representation of a local network may be sufficient.

A significant local network would, for example, be a network connected between the nearest Transpower asset and the generation site, or a network that could provide a parallel or alternative export path during any potential operation of the generation. A local network with generation that also feeds into a common connection at a Transpower asset may also need to be included.

It is to be noted BOB-HLY-DRY-2 220kV circuit directly connects with the DRY-OTA-TAK -2 220kV circuit bypassing the Drury GXP. CB472 and CB492 cannot be closed to Drury 220kV busbars and this is modelled in the EMI case.

The Otahuhu-Penrose 110kV circuit 02 is available but normally open from Otahuhu end. The Penrose 220kV series reactor is normally bypassed[2]. However, this reactor can be put into service to reduce the loading of Penrose-Hobson street 220kV cable during the following outages.

HEN-OTA-1, HEN-SWN-1, OTA-SWN-1, HEN-HPI-1, ALB-HEN-3, OTA-PEN-5, OTA-PEN-6, PAK-PEN-3

Penrose 220kV is supplied by three circuits; OTA-PEN-5, OTA-PEN-6, PAK-PEN-3. When one of these is out of service, the tripping of another circuit may overload the remaining circuit. To prevent the need for a pre-contingency measures when one of these circuits is out of service a circuit overload protection scheme (COPS) is implemented[3]. This changes the

[2] Microsoft Word - PEN Reactor Bypass Scheme (v2.0) Overview v1.0
[3] Microsoft Word - PEN COPS Scheme (v5.4) Overview v1.0

network configuration, including disconecting the Penrose interconnecting transformers, and Penrose to Hobson street circuit.

Penrose 220/33 kV supply transformers have a transformer overload protection scheme (TOPS)[4]. The 110 kV Hepburn Road – Mt Roskill circuits have a COPS implemented to disconnect the lines and prevent overloading post contingency[5]. This is required to meet peak demand at the substations whilst ensuring the lines don't become overloaded when either HEN-OTA-1, HEN-SWN-1, OTA-SWN-1 are out of service.

OTA STATCOM was commissioned in April 2025, however at the time of writing the validated models have not been incorperated into the EMI case. You may consult SO to check for the availability of STATCOM dynamic model at the time of the study.

The load model in the 2024 EMI case is set with constant impedance modelling in the transient studies, this is an optimistic assumption for the load behaviour. It is prudent to perform fault ride through studies with less optimistic load modelling (such as modelling the real power load component as constant current, or modelling both real and reactive load components as 50% constant current, 50% constant impedance) as a sensitivity.

4.2 Generator model

The high-level details for modelling the generation facility are available in the GL-EA-953 guideline. If you use an aggregated model instead of modelling individual units, you must demonstrate that the aggregated model accurately represents the characteristics of the entire facility at the connection point. To this end, you must provide any relevant underlying assumptions.

4.2.1 Active power output of the generating unit/ station

The Asset Owner should conduct an FRT study at both 80%, and 100% of the maximum continuous output (MCO) of the generation. Inverter based generation is also expected to be studied at 20% of its MCO with all inverters are in service. When EMT studdies are also required, the Asset Owner can limit the EMT studies to the two most onerous generation outputs.

The System Operator expects you to identify and study any power output conditions below maximum generation that may be onerous for FRT studies. A simple example of this would be a site with more than one connection to the grid, where, during an outage, the output through one or more of those connections may surpass its output under intact conditions, despite the total station output being lower.

[4] Microsoft Word - PEN TOPS Scheme (v1.0) Overview v1.0

[5] Microsoft Word - HEP-ROS COPS Scheme (v1.0) Overview v1.0

If a facility has more than one operating mode, then you must study the FRT performance of the facility in all its configurations. For example, battery or hybrid connections must include import, export and idling modes.

4.2.2 Reactive power output of the generating unit/station

You must identify the asset's reactive power capability at the point of connection given the expected grid voltage range. To demonstrate successful fault ride through, studies should include the expected operation as well as identify the most onerous pre-fault reactive power dispatch conditions for both lagging and leading power factors.

Further, for a synchronous generating station, you should carry out sensitivity studies to assess the performance of generating units when operating near their under-excitation and over-excitation limits.

All nearby generating stations should be dispatched to manage their respective target bus voltages within an acceptable operating range, typically between 0.98- 1.05pu. Bus voltage profiles provided in Figure 3-1 (see section 3.3 above) serve as a starting point to configure the study cases. Fault ride through studies should include a voltage of 1.00p.u. at the point of connection. You should also perform sensitivity studies at the most common voltage levels expected at the PCC to reflect the existing operating voltage range as shown in Figure 3-1, allowing for any impact of the new connection.

5 Other Generation

Huntly is the most significant plant to be considered during the studies in the connections of this region. The EMI case light load study case doesn't include any Huntly generation. However, Summer peak study cases typically include HLY unit 5, and Winter peak study cases include Huntly unit 5 and one or more Rankine units. Outages of Huntly unit 5 (or a Rankine unit if running) should be considered in these study cases.

100MW BESS will be connected to GLN 33kV bus by mid 2026. It should be noted that dynamic models are not included for any IBR generation in this region. You may consult SO to check for the availability of these models at the time of the study.

The hydro units connected closely to Wairakei or Whakamaru (e.g. at Aratiati, Atiamuri, Whakamaru, Maraetai and Rangipo) are highly dispatchable and can be scaled as needed. If additional adjustments are required, wind generation outside the study area or DC flow can also be scaled.

6 Relevant External Conditions

The System Operator requires Asset Owners to ensure that permanent splits are enabled during the studies, particularly those relevant to the Auckland region. These are outlined in the Appendix A: grid configuration - SSF 2024.

7 Fault Conditions

The studies to be documented are not simply be the product of all various faults, outages and system conditions identified below. FRT study should identify and focus on the most difficult fault ride through conditions.

7.1 Fault types

The study can demonstrate fault ride through capability with three-phase balanced faults to ground and single-phase to ground faults with zero impedance. Further, it is necessary to study the line-line-ground fault for inverter based resources. To clear the fault, remove faulted circuits from the system after the designated fault clearance time mentioned in the next section (7.2).

FRT studies should also include failed auto-reclose scenarios. Auto-reclose is enabled by default on 220kV transmission lines and will re-close onto 3 phase faults. Default reclose times of 1 second should be applied.

Further, the System Operator suggests to detail the fault duration and retained voltage at the PCC as stipulated in section 4.6.4 in GL-EA-953 to demonstrate fault ride through performance in compliance with Code clause 8.25A, .

7.2 Fault clearance times

For the specific faults specified in

Table 7-1 below, use the following durations:

- **220kV faults**: 120ms; while the close in end to a circuit fault is likely to clear earlier than 120ms, this is the currently designed guaranteed clearance time and should be applied at both ends.
- **110kV faults**: although target clearance time is 120ms for Zone 1, the EIPC Benchmark Agreement design fault clearance time allows 200ms for 110kV circuits. Therefore, we recommend you use 200ms for the 110kV circuit faults.
- **33 kV faults:** fault clearance times can be assumed as up to 1000ms.

7.3 Fault locations

We have listed the faults to be studied under each 220kV and 110kV PCC groups in Table 7-1 and Table 7-2 respectively. Asset Owner remains responsible for identifying the onerous fault locations that result in an inability to ride through a system fault under each PCC group.

For 110kV or lower voltage connections within PCC groups D, E or F, you should also include the faults associated with the nearest 220kV bus (PCC group). For example, if a new connection (GLN-BESS) belongs to PCC group A, you should study faults under PCC group A in Table 7-1. However, for a new connection at OTA 110kV, you should study the faults under the PCC group A in Table 7-1 in addition to faults under PCC group E in Table 7-2.

Table 7-1: Fault cases to be studied under each 220kV PCC groups; A, B and C

PCC Group A	PCC Group B	PCC Group C
BOB-DRY- HLY circuit 2	OHW-OTA circuit 2	OTA-PEN circuit 6
HLY-TWH circuit 1	OTA-WKM circuit 2	PEN-PAK circuit 3
DRY-GLN circuit 2	OTA-PAK circuit 4	PEN-HOB circuit 1
DRY-OTA-TAK circuit 2	PAK-BHL-WKM circuit 2	HOB-WRD circuit 1
OTA-PEN circuit 1	OTA-SWN circuit 1	PAK-BHL-WKM circuit 2
	OTA-PEN circuit 6	DRY-OTA-TAK circuit 2
	PEN-PAK circuit 3	
	HEN-OTA circuit 1	
	PEN-HOB circuit 1	
	ALB-HEN circuit 3	

Table 7-2: Fault cases to be studied under each 110kV PCC groups; D, E and F

PCC Group D	PCC Group E	PCC Group F
HOB-LST circuit 4	OTA-PEN circuit 2	BOB T5
LST-PEN circuit 2	OTA-WIR circuit 1	ARI-BOB circuit 1
OTA-PEN circuit 2	MNG-OTA circuit 1	BOB-DRY- HLY circuit 1 (220kV circuit)

LST-ROS circuit 1	MNG-ROS circuit 1	ARI-HAM circuit 1
HEP-ROS circuit 1	LST-ROS circuit 1	
PEN 110kV Capacitor	HEP-ROS circuit 1	
	HEN-HEP circuit 1	
	MPE-MTO-WEL-HEN circuit 1	
	OTA 110kV Capacitor	

For all PCC groups, a trip of the HVDC bipole should be tested such that the results demonstrate the asset's compliance to Electricity Industry Participation Code 2010, Part 8, Clause 8.25A(2).

The assessment should also simulate faults with the outages defined in section 3.4 to confirm the FRT performance during outage conditions.

The fault location is to be simulated at both ends of the circuit, not at an intermediate point.

FRT studies should also include failed auto-reclose scenarios. Auto-reclose is enabled by default on 220kV transmission lines and will re-close onto 3 phase faults. Default reclose times of 1 second should be applied.

The System Operator expects you to specify islanding protection separately; no islanding analysis is expected in these studies.

7.3.1 EMT studies

EMT studies should be a subset of the RMS studies carried out. The selection of fault cases should include the most onerous cases identified in the RMS studies and be sufficiently comprehensive to demonstrate the expected FRT capability. A minimum of three distinct fault types must be studied to ensure a robust assessment of system performance.

If EMT results show significant differences to RMT results, the scope of EMT studies should be expanded to provide sufficient evidence that the required FRT performance will be achieved.

7.4 Over-voltage simulations

Over-voltage situations are now relatively unusual for the Auckland region since the commissioning of the PAK reactors. These are typically associated with the unexpected loss of significant load. Therefore, you could study over-voltage ride through by simulating load shedding or simulating a energizig of ficticious capacitor within the Auckland region (without a frequency event). We recommend that you simulate an over-voltage scenario using a summer trough case.

Appendix: Site Codes

Abbreviation	Full Name
BOB	Bombay
DRY	Drury
GLN	Glenbrook
HOB	Hobston Street
LST	Liverpool Street
MNG	Mangere
ROS	Mt. Roskill
OTA	Otahuhu
PAK	Pakuranga
PEN	Penrose
TAK	Takanini
WIR	Wiri

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